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Selected, compiled, and edited by

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**1A11**

**Subthalamic Nucleus Deep Brain Stimulation Effect in Elderly Patients with Parkinson's Disease**

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*Objective:* We compare clinical, cognitive and quality of life outcomes in 2 patient populations following subthalamic nucleus deep brain stimulation (DBS) for Parkinson's disease (PD). Group I consisted of patients older than 66 years at time of surgery, Group II of patients younger than 66 years.

*Background:* Bilateral DBS provides major benefit to patients with advanced PD. Age is one of the factors that needs to be considered when determining surgical candidacy. It has been suggested that elderly PD patients may benefit less from surgery and may have a higher risk of post operative complications.

*Methods:* We studied 16 older (69+2 years, range: 67–73) (Group I) and 31 younger (54+7 years, range: 40–66) (Group II) PD patients. Motor function (UPDRS) neuropsychological tests and quality of life (PDQ-39) were assessed before surgery and at 3 and 6 month follow-up. After surgery, motor disability score (UPDRS part III) were evaluated after stimulation had been switched on in two different situations: OFF medication (after at least 12 hours of dopaminergic treatment discontinuation) and ON medication (after suprathreshold levodopa dose). The mean changes (or each parameter from pre-operative to 3 and 6 months post-operative) were compared between the 2 groups of patients.

*Results:* Before surgery, UPDRS part III while off medication was significantly higher in younger PD patients compared to older ones ( $p=0.04$ ). There was no significant difference in other parameters between the 2 groups. After surgery, mean change of UPDRS part IV was significantly greater in older patients than in younger ( $-10+3$  versus  $6+4$  at 3 months,  $p=0.01$ ). Mean changes in other components of UPDRS were similar between the 2 groups. There was no significant mean change of neuropsychological tests but older PD patients tended to have slower executive function. Despite a lack of statistical significance, mean changes in PDQ-39 were greater in older than younger PD patients. Only older patients experienced surgical complications (2 intracranial haemorrhages, and 1 death). Transient post opera-

tive confusion, apathy and depression were more frequent in elderly patients.

*Conclusion:* Even if elderly PD patients experienced more adverse events after DBS, they reported more marked improvement in motor fluctuations and a trend toward better quality of life outcomes when compared to younger patients.

*Keywords:* Parkinson's disease; STN-stimulation.

**1A12**

**Improved Motor Responding, but Central Slowing, Following Bilateral Subthalamic Nucleus Stimulation in Patients with Advanced Parkinson Disease**

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*Introduction:* Subthalamic nucleus (STN) hyperactivity is the pathophysiological hallmark of Parkinson disease (PD). Modulating its activity by high frequency stimulation (HFS) has proven to alleviate motor symptoms. However, the effect of STN HFS on cognitive performance remains to be elucidated. Reaction time (RT) performance is often used in PD to evaluate motor and cognitive functions.

*Objectives:* The aim of the present study was to assess the effect of bilateral STN stimulation on simple RT (SRT) and complex RT (CRT) performance.

*Materials and methods:* Seventeen patients suffering from advanced PD were operated on. Pre-operative and post-operative assessments of motor function, functional performance and neuropsychological parameters were conducted. SRT and CRT (go/no go task) were evaluated during four post-operative conditions with stimulation (stim) and medication (med) on and off: stim on-med on, stim on-med off, stim off-med off and stim off-med on.

*Results:* STN stimulation improved motor disability, functional performance and the depression score, but a significant slowing of mental speed occurred as reflected in the corrected CRT (CCRT) score. The latter was independent of dopaminergic medication.

*Conclusion:* These data suggest that treatment of STN hyperactivity by HFS improves motor function, confirming earlier

reports, but negatively influences the speed of cognitive processing most probably due to interference with the activity of the basal ganglia-thalamocortical pathway. It remains unclear which specific phase of the response cycle is affected. This needs further clarification in future studies. Care-givers should be aware of this negative effect as STN HFS is widely applied nowadays.

*Keywords:* Parkinson's disease; microelectrode recording; cognition.

## 1A13

### **A Consistent Pattern of Activation in Deep Brain Structures during DBS of the STN in Patients with PD Revealed by Functional MRI**

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*Objective:* To study the pattern of activation produced by deep brain stimulation (DBS) in the subthalamic nucleus (STN) using functional magnetic resonance imaging (fMRI).

*Methods:* After extensive *ex vivo* safety evaluations, the present study was carried out to examine the pattern of activation produced by DBS electrode stimulation in the STN using fMRI. Four patients with percutaneously-extended bilateral DBS electrodes in the STN were studied using a 3 T Siemens Allegra MRI. The leads were extended to a pulse generator in the MRI control room. Stimulation parameters were selected based on clinical evaluation of symptom alleviation prior to MRI. BOLD images were acquired using prospective motion correction and examinations were performed using a block style paradigm. All data were spatially filtered with a Hamming filter that increased BOLD contrast to noise. The MRI time series at each pixel was fit using least squares to a boxcar reference function plus a slope and intercept.

*Results:* All four patients were able to complete the study. Activation was demonstrated from 6 of the 7 electrodes stimulated. In all cases, activation was demonstrated in the anterior thalamus and posterior portions of the pallidum and putamen. Four of the electrode stimulations demonstrated additional activation in the STN/substantia nigra region adjacent to the electrode tip. In two cases, activation was seen in the contralateral superior cerebellum.

*Conclusions:* In vivo evaluation of DBS using fMRI may allow for a better understanding of its mechanism and lead to improved therapeutic benefit. These preliminary results suggest that effective DBS therapy in the STN of PD patients is associated with consistent areas of brain activation. Areas of activation previously noted by Jech *et al.* (2001) in the dorsal lateral prefrontal cortex, superior colliculus, and contralateral caudate nucleus were not seen. Importantly, the present study demonstrates activation only ipsilateral to stimulating electrode suggesting that artifact secondary to susceptibility effects is unlikely to explain the activation results.

*Keywords:* Parkinson's disease; magnetic resonance imaging; functional; deep brain stimulation.

## 1A14

### **Somatotopic Organization of the Subthalamic Nucleus**

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*Object:* The functional organization of the subthalamic nucleus (STN) was investigated using microelectrode recording in the

setting of stereotactic implantation of STN deep brain stimulation (DBS) leads.

*Methods:* Ventriculography and intra-operative x-rays were used to assess the position of the microelectrodes and to localize STN neurons activated by limb movements in reference to the AC-PC line. Tridimensional coordinates of the movement-related neurons were analyzed statistically to determine whether there was topographic segregation between upper and lower extremity-related neurons.

*Results:* 379 microelectrode tracks were passed during 71 procedures. Somatosensory driving was found in 288 tracks (76%). 1213 movement-related cells were analyzed, including 29 orofacial cells (2.4%), 480 arm-related cells (39.6%), 558 leg-related cells (46%), and 146 cells responsive to both arm and leg movements (12%).

In reference to the AC-PC midpoint, the average position of 480 arm cells was 13.3 mm lateral, 1.6 mm posterior, and 1.6 mm inferior, while the average position of 558 leg cells was 11.9 mm lateral, 1.5 mm posterior, and 2.0 mm inferior. The average arm position, therefore, was 1.4 mm lateral, 0.1 mm posterior and 0.4 mm superior to the average leg position. Strong statistical evidence for a segregation of arm and leg cells on the lateral plane was found ( $P < 0.0001$ ).

*Conclusion:* The functional organization of the sensorimotor STN is based on a body map characterized by mediolaterally segregated leg and arm domains. Evidence of somatotopic organization in the human STN of PD patients supports the current theory of highly segregated loops integrating cortico-basal ganglia connections.

*Keywords:* Parkinson's disease; microelectrode recording; somatotopy; STN.

## 1A15

### **Computerized Gait Analysis at 3 Months and 1 Year Postoperatively Demonstrates Synergistic Effect of Chronic Bilateral Subthalamic Nucleus Stimulation and Medication in Advanced Parkinson's Disease**

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*Objective:* To study prospectively the long-term effects of chronic bilateral subthalamic nucleus (STN) stimulation on gait in patients with advanced idiopathic Parkinson's disease and to compare its effect to medication with levodopa using computerized gait analysis.

*Methods:* Eight patients with advanced Parkinson's disease (3 women, 5 men, mean age 68.5 ys) underwent bilateral STN-stimulation. The preoperative and postoperative (3 and 12 months after surgery) spatial and temporal gait parameters were analyzed in off-drug and on drug conditions. Instrumental gait analysis was performed using a computer-assisted gait analyzing system (Ultraflex, Infotronic, The Netherlands).

*Results:* In the medication-off condition, objective gait scores were improved with bilateral STN-stimulation both at 3-month and 12-month follow-up. Preoperative gait measurements during best medication-on states were also improved with bilateral STN-stimulation as demonstrated in the follow-up assessments. Net medication effects at 3 and 12 months postoperatively were equivalent to net stimulation effects.

*Conclusions:* Bilateral STN-stimulation resulted in a substantial improvement of gait parameters in our cohort of elderly patients with advanced Parkinson's disease. Net medication effects were equivalent to net stimulation effects, but the combination of both led to further improvement.

*Keywords:* Parkinson's disease; computerized gait analysis; DBS; STN.

**1A16****Deep Brain Stimulation of the Subthalamic Nucleus and Tremor Reduction in Parkinson's Disease: A Quantitative Computerized 3D Ultrasound-Based System Analysis**

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*Objective:* Deep brain stimulation (DBS) of the subthalamic nucleus (STN) has been shown to be effective in improving the cardinal symptoms of Parkinson's disease (PD) including tremor. Recently, the STN has been suggested as the target of choice even in patients with dominant tremor. Thus far, however, clinical rating scales were used to assess tremor severity and no quantitative data are available.

*Material/methods:* We included six patients with advanced Parkinson's disease in this prospective study (mean age 66.5/–SD 3.5 years). Evaluations were performed preoperatively, in medication On and Off states (M-On/M-Off), and postoperatively, combined with stimulation On and Off states (S-On/S-Off) at a mean of 13.5/–SD 1.3 weeks after initiation of bilateral STN DBS. Amplitude and frequency of tremor of the more affected arm were measured with a computerized 3D ultrasound-based system.

*Results:* Preoperatively, tremor was mildly improved by medication, reducing the amplitude by 28.2%/–SE 20.3% in M-On as compared to M-Off. Postoperative reduction of tremor amplitude during DBS (M-On/S-On) as compared to preoperative M-Off was significantly greater (83.1%/–SE 8.4%,  $p < 0.05$ ). In fact, in 3 of 6 patients tremor could no longer be detected. Tremor reduction by DBS was similar in the M-On and M-Off conditions (87.7%/–SE 7.1,  $p < 0.01$  and 81.4%/–SE 5.9%,  $p < 0.01$ ). An effect of medication was still present at follow-up in both, the S-On and the S-Off states: M-On/S-On vs. M-Off/S-On resulted in a reduction of tremor amplitude by 49.1%/–SE 13.5%,  $p = 0.091$ , M-On/S-Off vs. M-Off/S-Off by 21.0%/–SE 8.9%,  $p = 0.144$ .

*Conclusion:* Measurements of tremor in PD using a computerized 3D ultrasound system yield quantitative and more objective data of tremor severity. Such measurements underline the efficacy of STN DBS for treatment of tremor but they also show the continued effect of medical treatment during chronic DBS.

*Keywords:* Parkinson's disease; tremor.

**1B11****Preoperative Investigations for Non Lesional Frontal Lobe Epilepsies**

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*Objectives:* Surgery in Frontal Lobe Epilepsies is wellknown to represent a challenge specially when no clear lesion is associated. Our goal is here to investigate the role and efficacy of deep electrode recording and specially SEEG in this specific difficult group.

*Material and method:* Between Sept 2000 and Sept 2003 26 patients supposed to suffer frontal lobe epilepsy have enter the invasive monitoring program of Timone University Hospital in

Marseille. Two young patients with a lesion in the central region have been investigated with grids. Among the 24 investigated with SEEG 15 have a follow up superior to 24 months after the cricectomy. Among these 12 were presenting with no clear lesion on the MRI. Based on the analysis of the patient history, the electroclinical semiology of the seizures observed during the videoEEG recording and nonstructural imaging data at first topological hypothesis was drawn allowing the shaping of the SEEG implantation.

*Results:* The epileptogenic zone (ZE) was involving the precentral region and SMA (Area 6&8) in 5 patients, the frontal operculum in 2, the prefrontal region in 2, the anterior cingulum (area 32) in 3, the orbital cortex in 4, frontopolar in 3, the temporal pole in 2. Four time the ZE was considered as neocorticolimbic. Statistical analysis of the morphology of the frontal cortex sulci have turn out to be specially valuable in this group of patients, specially in patients with dorsomesial epilepsies. Further MRI orientated by the context (2Pts) and slightly abnormal gyration pattern research (4Pts) have suggested structural abnormalities. In 8 patients the histopathological studies have demonstrated the presence of a lesion which was 6 time a small Taylor type dysplasia one time a tuber and 1 time a non specific lesion. Height patients are seizure free (67%), in 3 patients seizures have reduced dramatically in frequency and 1 patient have a complete failure.

*Conclusion:* These results need further follow up due to possibility of delayed recurrences in frontal lobe epilepsies. However, a high rate of seizure cessation can be obtained in this difficult group of patient relying on the electroanatomical methodology of the SEEG.

*Keywords:* Epilepsy; neuronavigation; deep recording.

**1B12****Stereo-EEG in the Presurgical Investigation of Children with Drug-Resistant Focal Epilepsy: Indications, Results and Safety**

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*Objective:* To elucidate the role, results and safety of stereo-electro-encephalo-graphy (SEEG) in the presurgical evaluation of children with drug-resistant focal epilepsy (DRFE).

*Methods:* Thirty-four out of 94 children operated on for DRFE underwent evaluation with stereotactically implanted intracerebral electrodes before resective surgery. Two children operated on twice required two explorations, for a total of 36 SEEGs. There were 23 males and 11 females. Age at seizure onset:  $2.0 \pm 2.2$  years (range: birth-9); age at surgery:  $8.6 \pm 3.8$  years (2–15); illness duration:  $6.6 \pm 3.5$  years (1–14); seizure frequency:  $138/\text{month} \pm 203$  (4–1000). MRI showed an anatomical lesion in 31/34 patients (91%). SEEG was indicated when non-invasive investigations failed to localize the Epileptogenic Zone (EZ). The strictly individualized strategies of implantation were based on formerly collected anatomical, EEG and clinical findings, aiming to both identify the EZ and map eloquent cortex in functionally critical areas. A total of 385 electrodes were implanted ( $10.7 \pm 3.2$  electrodes/procedure; range: 4–16). The monitoring period lasted 2 to 17 days.

*Results:* The whole procedure was well tolerated even in younger children. The only complication was represented by rupture of an electrode under the cranial vault during an agitated

seizure in a 14-year-old boy, requiring surgical removal. Basing on SEEG findings, resective surgery was unilobar in 17 children (frontal 14, temporal 2, central 1) and multilobar in 17. Histological examinations of surgical specimens showed: 26 neuronal migration disorders, 7 low-grade tumours, 1 scar. Outcome on seizures (Engel's classification) in the 28 children with a follow-up >1 year: Class I 16 cases (57.1%); class II 2 cases (7.1%); class III 1 case (3.6%); class IV 9 cases (32.2%).

**Conclusion:** SEEG is a safe and useful tool in the presurgical evaluation of children with DRFE, which allows to offer a potentially curative surgical option to patients who would have been otherwise excluded from further treatment of medically refractory epilepsy.

**Keywords:** Epilepsy; stereo-electro-encephalo-graphy.

### 1B13

#### **Epileptogenic Low-Grade Tumours in Childhood: Outcome after Lesionectomy**

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**Objectives:** Epilepsy is the most common clinical symptom in low-grade cerebral tumours of the paediatric age. Surgical resection of the lesion (lesionectomy) is often able to yield the suppression or marked reduction of seizure frequency.

**Methods:** A series of 16 consecutive patients (11 males and 5 females), aged from 4 to 17 years (mean: 10.9), operated on from January 1999 to December 2002 is reported. In all patients epilepsy was the presenting and only symptom of the brain lesion. Seizure frequency was sporadic in 3, monthly in 5, weekly or daily in 8, and became resistant to antiepileptic drugs in six. Epilepsy history before surgery lasted from 6 months to 7 years (mean: 2.4). All patients had electro-clinical evaluation: seizures were recorded in 8 cases. Invasive pre-surgical investigations were not used. Tumour location was temporal in 8, frontal in 4 and intraventricular in the last 4 cases.

**Results:** Complete removal of the lesion was achieved in 13 patients, subtotal in the last 3. Histological diagnosis was of glioma in 9 (4 oligodendrogliomas, 2 pilocytic astrocytomas, 1 fibrillary astrocytomas, 1 astroblastoma, 1 subependymal giant cell astrocytoma), of glioneuronal tumours in 6 (3 gangliogliomas, 1 gangliocytoma, 1 amartoma, 1 DNT) and teratoma with glioneuronal ectodermal differentiation in 1. No major post-operative complications occurred. Epilepsy outcome was evaluated according to Engel's classification, with a follow up ranging from 1 to 4 years (mean: 2.9). Fourteen patients are completely seizure free (Class IA), a marked reduction of seizure frequency (Class IB) and rare disabling seizures (Class II) was observed in the remaining two cases (one diffuse fibrillary astrocytoma subtotally removed and one subependymal astrocytoma in tuberous sclerosis, respectively). Antiepileptic drug regimen remained unchanged in 8, reduced in 5 and discontinued in 3 cases.

**Conclusions:** Our data, even though referred to a small series with a relatively short follow up, seem to confirm that early removal of the lesion in children harbouring low-grade cerebral tumours has a favourable impact on the concomitant epilepsy. In this cases lesionectomy can allow either seizure suppression or better seizure control by medication.

**Keywords:** Epilepsy; childhood; lesionectomy; brain tumours.

### 1B14

#### **Anterior Temporal Lobectomy and Amygdalo-Hippocampectomy: Long-Term Outcome**

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**Objectives:** Complex partial seizures of temporal lobe origin remain the most important subtype of seizures because their focal onset allows for the most successful outcome via surgical extirpation. Anterior temporal lobectomy (ATL) with ipsilateral amygdalo-hippocampectomy has been the most widely performed procedure in the surgical treatment of medically refractory epilepsy. The long-term outcome of this procedure varies significantly among different institutions. In our current communication we report the long-term outcome of our surgical series.

**Materials and methods:** At our institution, 159 patients (66 male and 93 female) underwent ATL and ipsilateral amygdalo-hippocampectomy for medically refractory epilepsy over a period of 10 years (1991–2001). Their age ranged between 17 and 58 years, median age 38.9 +/−0.2. All the patients underwent preoperative evaluation including MRI, ictal and interictal surface EEG, continuous video EEG monitoring and detailed neuropsychological evaluation including WADA test. In selected cases, further preoperative evaluation was performed by using SISCOM, MEG, and invasive monitoring with depth and/or subdural electrodes. Intraoperative monitoring consisted of electrocorticography, language and sensorimotor mapping was employed in the majority of our cases. All of our patients underwent fronto-temporal craniotomy and subpial dissection/aspiration and en block resection techniques were used.

**Results:** The modified 4-tier Engel's classification system was used for outcome classification purposes. 101 patients (63.5%) were seizure free at 3 years post-operatively. 30 patients (19%) had rare seizures, while 16 patients (10%) had more than 90% decrease in their seizure frequency. Finally, 12 patients (7.5%) had a less than 90% decrease in their seizures. The most commonly occurred early postoperative complication in this series was quadranopsia. Other early postoperative and long-term procedure related complications will be discussed. Factors predicting surgical outcome will also be identified and analyzed.

**Conclusion:** Even though ATL with ipsilateral amygdalo-hippocampectomy is the most widely performed surgical procedure in the treatment of medically refractory epilepsy, significant variation in long term outcome among different clinical series makes the identification of prognostic factors mandatory.

**Keywords:** Epilepsy; temporal lobectomy; outcome.

### 2A11

#### **Deep Brain Stimulation in Elderly Patients**

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**Objectives:** There is an ongoing discussion regarding age limits in Deep Brain Stimulation (DBS). Current indications are tremor-dominant disorders, Parkinson's disease and dystonia. By means of analgesation DBS surgery is more comfortable, especially for elderly patients. However, the value of DBS regarding the benefit-risk ratio in this patient population is still uncertain.

**Methods:** Bilateral electrode implantation in the STN was performed in a total of 86 patients, suffering from Parkinson's disease.

Patients were analyzed retrospectively. For this study they were separated in two groups: Group I (age < 65 y, n = 45) and group II (age > 65 y, n = 41). Examinations were performed preoperative and at 6 months follow-up. Age, UPDRS motor score (part III) on/off, Hoehn&Yahr scale, Activity of Daily Living (ADL), L-Dopa medication and complications were determined. SigmaStat (Jandel scientific) was used for statistical evaluation.

**Results:** Significant differences were found regarding the overall performance in the ADL score (group I: 48/71, group II: 41/62 points [preop/6 mo postop]) and in the rate of complications (group I: 4 intermittent psychosis, 4 infections in 8 patients, group II: 2 deaths [unrelated to surgery], 1 intracerebral hemorrhage, 7 intermittent psychosis, 3 infections, 2 pneumonia in 13 patients), ( $p < 0.05$ ). Interestingly changes in UPDRS score, Hoehn&Yahr scale, L-DOPA medication were not statistically different among the two groups.

**Conclusions:** DBS in the STN is as effective in elderly patients as it is in the younger ones. However, careful selection and follow-up is required because of the higher risk for both surgery related and unrelated complications.

**Keywords:** Parkinson's disease; microelectrode recording; deep brain stimulation.

## 2A12

### Effect of Subthalamic Nucleus Stimulation on the Functional Status of Patients with Advanced Parkinson's Disease: A Two Year Follow Up Controlled Study

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The evaluation of the functional status offers a different important tool to estimate the treatment outcome in Parkinson's disease (PD). The purpose of this study is to report the measure of functional independence, quality of life and symptom severity in parkinsonian patients subjected to subthalamic high frequency stimulation (STN-HFS), compared to the effect of medication alone. Thirty-two patients with advanced PD and eligible for STN-HFS (CAPSIT criteria) have been included in a prospective controlled study. Of these, sixteen (9 males/7 females, mean age: 58.8 year, mean disease history: 14.2 year) underwent bilateral STN-HFS. The remaining sixteen (5 males/11 females, mean age: 63.2 year, mean disease history: 10.1 year) preferred to delay surgery and represent the control group. Functional independence was evaluated according to UPDRS II for Activity Daily Living (ADL), the Brown's Disability Scale (BDS) and the Functional Independence Measure (FIM). Quality of life was assessed according to the 39-item Parkinson's Disease Questionnaire (PDQ-39) and the Beck Depression Inventory (BDI). Symptom severity was measured according to the items of the UPDRS concerning postural reflex, gait, freezing, drooling, speech, falls and dyskinesias. A multivariate analysis of variance (MANOVA) for paired (time effect), independent (treatment effect) and combined (time/treatment) variables was applied to compare data. Outcome predictors were investigated with multiple regression analysis, where the annual UPDRS II modification acted as dependent variable. A significant improvement in the ADL, FIM, PDQ-39 and emotional well-being (BDI) was observed one and two year after STN-HFS, as compared with the control group. Age at the onset of the disease and disability at surgery were independent outcome predictors at the stepwise multiple regression analysis. Our data seem to confirm that STN-HFS can offer an effective therapeutical chance to patients with advanced Parkinson's disease, where medical treatment is no more able to induce any

further improvement in terms of functional independence and quality of life. They can be also of great help for both surgeon and patient in their decision making for surgical option.

**Keywords:** Parkinson's disease; STN-stimulation.

## 2A13

### Comparison of Three Methods of Targeting the Subthalamic Nucleus for Chronic Stimulation in Parkinson Disease

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**Objective:** The success of subthalamic nucleus (STN) surgery for Parkinson's disease (PD) depends upon accuracy in target determination. The objective of this study was to determine which of the following techniques was most accurate and precise in targeting the STN: direct targeting, indirect targeting and a technique using the Red Nucleus (RN) as an internal fiducial.

**Methods:** We reviewed 14 patients with PD treated with bilateral STN deep brain stimulation (28 STN targets). Electrode implantation was based on direct and indirect targeting using 2D-MRI with refinement using microelectrode recording. Optimal settings, including the contacts used, were determined during the clinical follow-up. The position of the best contact was defined with a post-operative MRI. This location was compared with the modified direct, indirect and RN-based targets. The mean distance between the targets and the final position of the optimal contact were calculated. The accuracy and variance of each target was analyzed.

**Results:** The mean distance between the optimal contact position and the planned target was 3.19 mm (SD = 1.19) using the RN based method, 3.42 mm (SD = 1.34) using indirect targeting and 4.66 mm (SD = 1.33) using modified direct targeting. The mean distance between the optimal contact and the RN-based target was significantly smaller than the mean distance between the optimal contact and the direct target (Post Hoc with Tamhane correction,  $P < 0.001$ ). There was no significant difference in the mean distances of the optimal contact position to either the RN based target or the indirect target ( $P = 0.87$ ). Both the indirect and modified direct targets had larger variances than the RN-based target (F test,  $P < 0.001$ ), indicating greater precision with the RN-based target.

**Conclusion:** Using post-hoc analysis, use of the RN as an internal fiducial for targeting the optimal region of STN was reliable and compared positively with modified direct and indirect targeting.

**Keywords:** Parkinson's disease; microelectrode recording; red nucleus; subthalamic nucleus.

## 2A14

### Deep Brain Stimulation for Parkinson's Disease: Anatomical Location of Effective Contacts in the Sub Thalamic Area

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The location of effective contacts during deep brain stimulation (DBS) is still debated in particular in the sub thalamic area.

**Objectives:** To localise on 1.5 T MRI, the effective contacts in patients successfully treated for Parkinson's disease by bilateral DBS of the sub thalamic nucleus (STN).

**Material/methods:** Ten patients with excellent clinical outcome were analysed. The surgical procedure was based on direct targeting of the nucleus (anatomic targeting without reference to internal landmarks). The effective contacts were determined during the first 6 months following the implantation, i.e. those given the best efficacy on the clinical symptoms (mean improvement rate 82.5%, range 75.8–94.1%). The contact locations were retrospectively projected on the stereotactic 1.5 T MRI (3 sets, orthogonal plans), i.e. with a stereotactic frame. For each patient, we have distinguished the right and the left hemisphere. The location of the effective contacts was directly studied by visual comparison, between the 1.5 T images and an in-house 4.7 T MRI anatomic reference. The membership for a given structure was determined using the results for each orthogonal, independent plan.

**Results:** The effective contact were located within the STN in 4 cases, at the interface of the STN and the zona incerta (ZI) and/or the Forel's field (FF) in 12 cases, at the interface between ZI and FF in 3 cases, at the interface between the STN and the substantia nigra in one case.

**Discussion:** The dorsolateral part of the STN is usually considered as the target for DBS in Parkinson's disease. We discuss the role of adjacent structures, especially ZI and FF, in the clinical benefit. A largest study, including 56 patients is already in progress to assess and to refine these results.

**Keyword:** Parkinson's disease.

## 2A15

### Contemporary Bilateral DBS on GPi and STN Nuclei and Preliminary Results on Contemporary Bilateral DBS on GPi and CM-PF Complex in PD

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**Objectives:** deep brain stimulation (DBS) of STN and the pars interna of globus pallidus (GPi) is used to improve parkinsonian symptoms and attenuate levodopa-induced motor complications in PD (DBS For PD Study Group, 2001). What are the physiological effect of DBS and the best anatomical structure to stimulate are still not completely definite. From this point of view, we made contemporary bilateral targeting of STN and GPi in the same patient with symptoms of PD, to reach the best results on clinical state during DBS.

**Methods:** The surgical procedures have become safer and now is possible in selected cases to target both structure in the same patient by means of stereotactic system "3P Maranello" (CLS-SRL-Italy). In this way we could evaluate the clinical effects of simultaneous stimulation of STN and GPi as well as the isolated stimulation of each target.

**Results:** The effects of DBS have been evaluated in 13 consecutive cases of PD, immediately after (30 minutes) the stimulation has turned on and during chronic stimulation (weeks or months).

**Conclusions:** Recently in 2003 in four consecutive rigid-diskinetic patients we made the contemporary implantation of GPi and Centrum Medianum-Parascicolar complex and we present the rationale of method and the preliminary results of single and contemporary activation of both targets in acute time and in the follow-up.

**Keywords:** Parkinson's disease; centrum medianum; parafascicularis complex.

## 2A16

### Selective Effect of Bilateral STN-Electrode Insertion and STN-Stimulation on Dopamine Transporter Binding and Glucose Utilisation

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Bilateral STN stimulation is a routine procedure for medically refractory Parkinson's disease now, though the biological basis of its effect is not entirely elucidated nor the basis for side effects. We have therefore studied 5 patients with functional imaging using DAT-SPECT and FDG-PET in the off state before surgery, after electrode implantation but without stimulation and after electrode implantation with the stimulation on. Patients were clinically evaluated using UPDRS.

Electrode insertion into the STN alone caused a significant reduction of DAT binding capacity in the striatum from a mean of 44.6 7.3 (ratio striatum normalised to white matter) to 21.8 10.4 ( $p < 0.1$ ). Stimulation then did not cause any further significant change in DAT binding capacity. Electrode insertion alone led to increased glucose utilisation in both frontal lobes and the SMA ( $p < 0.05$ ) which became more significant after stimulation ( $p < .01$  compared to baseline and  $p < .05$  compared to insertion).

All patients had global UPDRS improvements of more than 60% at 18 month follow-up and a correlation between the UPDRS improvement and the change in FDG-ratio could be found ( $p < 0.5$   $r = .071$ ), but no such correlation could be found between the DAT binding capacity and concomitant UPDRS improvement.

Our study shows the effect of electrode insertion alone on dopamine transporter capacity in the striatum and glucose utilisation. Significant changes were seen after electrode insertion alone but only glucose utilisation was further significantly improved after STN stimulation whereas dopamine transporter capacity was not affected by stimulation indicating that STN stimulation does not work via altered dopamine release in the striatum.

**Keyword:** Parkinson's disease.

**2A17****Correlation of Active Electrode Location with Intra-Operative Neurophysiological Localisation of Subthalamic Nucleus, Compared with Direct MR Targeting and Atlas Co-Ordinates**

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*Objective:* A number of groups have suggested that the clinically effective target for deep brain stimulation in Parkinson's disease lies above the STN. We have previously reported that the long-term active electrode in patients with STN-DBS lies above the location of the STN as derived from standard brain atlases. This work examines the correlation between the position of the long-term active electrode and the neurophysiologically defined position of the STN.

*Methods:* Microelectrode recordings typical of STN were identified in 23 cases of advanced Parkinson's disease undergoing bilateral STN-DBS. The final position of the DBS electrode in relation to the mid-commissural point was noted. The position of the long-term active contact was assessed post-operatively at 6 months. The distance between the boundary of neurophysiologically identified STN and the long term active contact was measured. In addition the positions of the long term active contact were compared to the STN derived from the Schaltenbrand atlas.

*Results:* 46 active contact positions were measured in 23 patients. 9/46 long-term active contacts were in the uppermost part of the STN but the remaining 37 lay above the STN. Overall the average position was approximately 2 mm above the neurophysiological STN. This location was also above the atlas calculated position of the STN. These patients showed a 48% reduction in UPDRS motor off scores.

*Conclusion:* In keeping with some other studies the most effective clinical target seems to be above both the neurophysiological STN and that calculated from atlases.

*Keywords:* Parkinson's disease; microelectrode recording.

**2A18****Activation Inside the Electrode Target Area during Deep Brain Stimulation of the STN in Advanced Parkinson's Disease**

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*Objectives:* To investigate the effect of STN stimulation on its neuronal target structures using positron emission tomography (PET).

*Methods:* Resting cerebral metabolic rates of glucose (rCMRGlC) were measured with [<sup>18</sup>F]fluorodeoxy-glucose (FDG)-PET in 11 patients with advanced PD (mean age: 61.8 ± 7.7 years, disease duration 14.9 ± 4.7 years) 4 months after electrode implantation during STN-DBS off- and on-condition and in 10 healthy age-matched controls (age 62.6 ± 3.6 years). Stereotactic coordinates of active electrode poles were taken from stereotactic skull x-ray and transferred to the individual treatment planning MRI. Subse-

quently, a spherical volume-of-interest (electrode-VOI, 5 mm diameter) was defined with the active electrode pole as center on MRI images (3D-Tool). Additional VOIs were STN, caudate nucleus (head), pallidum, and putamen. Quantified FDG-PET scans were exactly matched to these MRI atlases and the rCMRGlC normalized for global brain activity calculated within each VOI.

*Results:* During DBS-on conditions, the rCMRGlC increased in the electrode-VOI significantly compared with the off-DBS state (absolute 19.4 ± 3.0 vs. 16.0 ± 2.7 micromol/100 g/min and normalized 0.79 ± 0.10 vs. 0.71 ± 0.09 micromol/100 g/min, P = 0.001, paired t test). Moreover, a non-significant activation was seen within the STN under stimulation (absolute 19.7 ± 3.0 vs. 16.8 ± 3.3 micromol/100 g/min and normalized 0.81 ± 0.11 vs. 0.75 ± 0.11 micromol/100 g/min, P = 0.088, paired t test). Compared with controls, PD patients had significantly higher normalized rCMRGlC within the putamen in both DBS-conditions (p < 0.01, unpaired t test).

*Conclusions:* The observed metabolic activation in the DBS target region suggests rather activating than inhibitory stimulation effects on neuronal cell bodies or axons leading to an increased output from the stimulation site onto afferent structures via ortho- or antidromic fibre conduction. Therefore, our study results indicate a stimulation effect fundamentally different from lesional procedures in the STN target.

*Keywords:* Parkinson's disease; positronemissiontomography.

**2A19****Localization of the Electrodes and the Active Contacts in the Subthalamic Nucleus on Magnetic Resonance Imaging**

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*Objective:* Control on Magnetic Resonance Imaging (MRI) the position of the active contacts of the electrodes implanted for subthalamic nucleus (STN) deep brain stimulation (DBS)

*Material and methods:* 31 parkinsonian patients were implanted bilaterally with electrodes Activa 3389. The localization procedure was performed on a postoperative 3D T1-weighted magnetization prepared rapid acquisition gradient echo (MPRAGE) MRI sequence in the AC-PC referential using the midcommissural point as origin. The coordinates of the distal tip of the electrode artifact and the projected angle of the electrode with the vertical on sagittal and coronal planes were measured. Based on the knowledge of the relation between the distal tip of the artifact and the center of the distal contact (C0), the coordinates of C0 and the 3 others contacts were deduced using an algorithm based on trigonometric and Pythagorean relations. The contact producing greatest reduction in UPDRS motor scale with monopolar stimulation was considered as the best motor stimulation point.

*Results:* The coordinates of 248 contacts and 62 active contacts were collected. For C0 we obtained AP = -3.47 mm (± 1.20), LAT = 11.34 mm (± 1.43), VERT = -5.39 mm (± 1.76). The coordinates of the best motor stimulation point were AP = -2.34 mm (± 1.63), LAT = 12.24 mm (± 1.49), VERT = -2.57 mm (± 1.36).

*Conclusion:* The knowledge of the relation between the distal artifact and C0 provides a way to improve the precision in localizing the implanted electrodes on MRI. According to the Schaltenbrand and Wahren atlas, C0 projects in the inferior portion

of the STN, whereas the best motor stimulation point projects in the dorsal and lateral portion of the STN.

*Keyword:* Parkinson's disease.

## 2A20

### Unilateral Thalamotomy in Tremor Dominant Parkinson's Disease

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*Objectives:* Tremor dominant Parkinson's disease/PD/patients constitutes 10 to 15% population of all parkinsonian patients. Severe rest and postural parkinsonian tremor unresponsive to pharmacological treatment is well known indication for stereotactic thalamotomy. The aim of this study is to evaluate the effectiveness of unilateral thalamotomy on rest parkinsonian tremor in upper and lower extremity and also postural parkinsonian tremor in upper extremity.

*Methods:* The study was conducted among 38 patients with tremor dominant/PD/. Special attention was paid to assess separately all components of parkinsonian tremor in contralateral hemibody. Rest and postural components of parkinsonian tremor were assessed according to items 20 and 21 of UPDRS. Other motor symptoms of PD were assessed according to part III of UPDRS. The follow-up period was 3 years in 18 patients.

*Results:* At 3 years follow-up there was marked amelioration of rest and postural components of parkinsonian tremor/mean presurgery UPDRS item 20 for upper limb rest tremor 3.34; mean postsurgery UPDRS item 0.68), (mean presurgery UPDRS item 20 for lower limb rest tremor 2.13; mean postsurgery UPDRS item 20 0.8), (mean presurgery UPDRS item 21 for upper limb postural/action tremor 2.53; mean postsurgery UPDRS item 0.74). There was also some improvement in rigidity after thalamotomy in the majority of patients. There was no effect of thalamotomy on bradykinesia or other manifestations of Parkinson's disease such as balance or gait. Transient complications were noted in 34% of patients and permanent minor complications occurred in 15% of patients.

*Conclusion:* Thalamotomy alleviates effectively all components of parkinsonian tremor in contralateral hemibody. The rest component of tremor in contralateral upper limb is best controlled by stereotactic thalamotomy.

*Keywords:* Spasticity; rest tremor; postural tremor; thalamotomy.

## 2B11

### Radiosurgical Treatment of Paediatric AVMs

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*Objective:* AVMs are the leading cause of haemorrhagic stroke in the young, often resulting in lasting morbidity. Children may differ in their radiosensitivity, and therefore, the response of paediatric AVMs to radiosurgery and the attendant complications encountered are of major clinical interest.

*Materials and methods:* A systematic, retrospective analysis of 174 radiosurgery AVM treatments in 151 children between 1985 and 2002. Mean age at treatment was  $11.8 \pm 3.3$  years. Mean AVM volume was  $3.1 \pm 3.9 \text{ cm}^3$ . Mean Spetzler-Martin grade was  $3.0 \pm 0.7$ . Seventy-one AVMs (47%) involved the basal ganglia, thalamus or brain stem. All treatments used angiographic localisation and were delivered with the Leksell Gamma Knife prescribing  $22.8 \pm 2.4 \text{ Gy}$  to the AVM margin, with  $3.4 \pm 2.7$  isocentres per treatment. Outcome measures included angiographic obliteration (i.e. no early filling vein or persistent shunt) of the AVM, complications attributed to the radiosurgery and evidence of re-haemorrhage. Values are mean  $\pm$  SD.

*Results:* One hundred and fourteen children (76%) were cured of their AVMs. Of the 23 patients undergoing second treatments, nine completed thrombo-obliteration (39%). Two patients (with AVM volumes of 24 and  $5 \text{ cm}^3$ , and doses of 25 and 20 Gy) had evidence of radionecrosis reactions. Fifteen patients rebleed, of who two died, a mean of 19 months following treatment.

*Discussion:* Paediatric AVMs remain a challenging problem, particularly those deemed inoperable. The gravity of the condition is illustrated by the 10% rebleed rate, this significantly increasing morbidity and mortality. Radiosurgery as a procedure is safe, only two patients developing complications. The obliteration rate of 76% illustrates that the majority of these children can be cured.

*Keywords:* Radiosurgery; paediatric AVM.

## 2B12

### Radiosurgery for Children and Infants Using a Robotically Controlled Linear Accelerator (The 'Cyberknife')

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*Objectives:* Radiosurgical treatment of children with systems such as the gamma knife is difficult because of the special discomfort and anesthetic risk associated with the use of a rigid frame in the pediatric population, and is prohibited in young children with fragile skulls. The availability of frameless radiosurgery using a robotically controlled linear accelerator (the 'Cyberknife') may offer advantages to children and allow radiosurgery for infants.

*Methods:* 29 Cyberknife radiosurgical treatments were delivered to 22 children (ages 7 months to 16 years,  $7 \pm 5$  years s.d.) for a variety of intracranial tumors (3 craniopharyngiomas, 2 pilocytic astrocytomas, 3 rhabdoids, 4 ependymomas, 4 medulloblastomas, 1 PNET, 1 anaplastic astrocytoma, 1 meningioma, 1 angiofibroma, 1 pineoblastoma, 1 metastatic lesion). Five of the patients were infants (age less than 3 years). 20 of the treatments

used a single shot regimen ( $15 \pm 3$  Gy, using the  $57 \pm 9\%$  isodose line), 3 were fractionated ( $42 \pm 10$  Gy delivered in 17 to 25 fractions, using the  $63 \pm 23\%$  isodose line), and 6 were hypofractionated ( $20 \pm 3$  Gy delivered in 4 or 5 fractions to the  $60 \pm 3\%$  isodose line).

*Results:* Treatment plans met precision requirements in all cases. Followup was  $15 \pm 11$  months (range 4 to 29 months, median 11 months). 10 patients remained clinically well with no radiological progression; 4 remained clinically well with nodular recurrences treated subsequently; 1 remained clinically well with local progression; and 7 died. There was no evidence of radionecrosis in any patient.

*Conclusion:* Frameless Cyberknife radiosurgery is feasible for children, eliminates the discomfort and anesthetic risks associated with use of a rigid frame, and allows radiosurgical treatment of infants.

*Keywords:* Radiosurgery; spasticity.

## 2B13

### Intensity-Modulated Radiosurgery (IMRS) for Childhood AVM

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*Purpose:* Presentation of intensity-modulated radiosurgery (IMRS) for the treatment of complex shaped pediatric AVM. Evaluation of core parameters that characterize dose conformality and dose inhomogeneity. We also report preliminary clinical outcomes.

*Methods:* IMRS was delivered to doses of 17.5 to 20 Gy (median 18 Gy) using a sequential tomotherapy IMRT technique (Peacock IMRT, Nomos Corp., Sewickley, PA) over 2 to 4 couch angles. Pencil beam dimensions were 10 mm by either 8.5 mm or 4.0 mm. Treatment planning employed an inverse treatment planning optimization algorithm. Entered parameters were: prescription dose (PD), volume of target allowed to receive less dose (standard 3%), minimum dose (0.5 Gy less than PD), and maximum dose (200% of PD). Planning system specific IMRS target and tissue types were selected to prioritize dose conformality over dose homogeneity. The prescription isodose was chosen to encompass at least 95% of the target volume. We calculated conformality (CI) and homogeneity indices (HI) to characterize the quality of IMRS plans.

*Results:* Target volumes ranged from 0.71 to 63.02 cm<sup>3</sup> (median 16.27 cm<sup>3</sup>). Median CI was 1.23 (range 1.06 to 1.7) according to RTOG criteria. Median HI was 1.12 (range 1.09 to 1.23). During limited follow-up, two AVM completely obliterated at 19 and 22 months, partial obliteration (>50%) was observed in two cases at 9 and 11 months, and two AVM appear unchanged at 2 and 7 months of follow-up. No treatment-related side effects, other than temporary headaches interpreted as being associated with changes in cerebral blood distribution, were observed.

*Conclusion:* IMRS can allow for highly conformal delivery of radiosurgery radiation doses even if pediatric AVM target volumes are relatively large and highly complex in shape. This technique has been proven to result in favorable outcomes (occlusion and significant nidus reduction) in complex shaped, large AVM, which had been rejected for treatment by local facilities using alternative radiosurgery techniques.

*Keywords:* Radiosurgery; AVM.

## 2B14

### LINAC Radiosurgery of Pontocerebellar Angle Schwannomas

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*Objectives:* The purpose of this study was the retrospective evaluation of patients following Linac Stereotactic Radiosurgery (LSRS) for schwannoma of pontocerebellar angle area.

*Methods:* From 1992 to 2003 we radiosurgically treated 510 patients, 105 of them for pontocerebellar angle tumors mostly present on the brainstem, 74 patients had the acoustic schwannoma, schwannoma of the trigeminal nerve had 3 patients. In indeavour not to cause a complication to the patients, we administered doses about 12.0 Gy, in average 14.2 Gy.

The amount of therapeutic dose (TD) depended on tumor volume, its relation to adjacent structures, histology, former RT and patients neurological status.

*Results:* Radiographic and clinical Follow-up were compared annually after SRS. The difficulty with pontocerebellar angle tumors is a correct diagnose – is it acoustic schwannoma, schwannoma of another nerve or meningioma? For MRI diagnostic of meningiomas the infiltration and thickening of dura (so called “dura sign”) are monitored in the tumor area. The examination of hearing by audiometry and EMG (by the paresis of facial nerve) are mandatory.

*Conclusions:* The projection of results is built on the patient's neurological status and the tumor volume on the MRI. Digitalized preoperative and postoperative MRI and CT images help us to estimate a tumor volume.

*Keywords:* Radiosurgery; vestibular schwannomas; linac radiosurgery.

## 2B15

### Cranial Nerve Preservation and Outcome Following Gamma Knife Radiosurgery for Acoustic Neurinomas

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*Introduction:* Gamma knife radiosurgery has become a popular modality of management of acoustic neurinomas yielding good functional preservation. Our aim was to evaluate cranial nerve preservation following radiosurgery for acoustic neurinomas with a relatively low 12 Gy margin dose.

*Materials and methods:* We have treated 118 patients with 129 tumors (11 had bilateral tumors). Ninety tumors received primary Gamma Knife therapy.

These tumors with a mean volume of 4 CC were treated with a 12 Gy median margin dose generally prescribed to the 50% isodose volume. Multiple isocentres (mean of 5.2 per tumor) were used to ensure conformal planning.

*Results:* We have clinical follow-up for 75 patients at a median of 25.6 months (8–62 months). Forty three ears had pre-gamma knife functional hearing with follow-up available for 33. Two improved, 4 deteriorated and 27 ears retained the same level of hearing. Hearing preservation rate for functional hearing was 88%. Improvement/deterioration of hearing takes place within a year. The hearing preservation rate among NF-2 patients was only 50%. One case (1.3%) each of trigeminal and transient lower cranial

nerve dysfunction (due to perilesional edema) was observed. No permanent 7th nerve dysfunction was seen. Cranial nerve dysfunction always occurred within 1 year. One patient with a tumor associated cyst had recurrent cyst increase with ataxia and trigeminal neuralgia requiring cyst tapping thrice.

Radiological follow-up is available for 55 patients at a median of 26 months (8–55 months).

Among the non NF-2 tumors, 9 decreased, 2 increased, and 34 remained stable. Of 10 NF2 patients, 2 had increase in size on one side, 1 had decrease while 7 had stable size. Tumor growth control was 80% in NF-2 patients and 95% in non-NF2 patients. Tumors decreased at an average latency of 28 months from radiosurgery.

**Conclusions:** Cranial nerve preservation following radiosurgery has undergone a quantum jump with the adoption of lower doses, MR-based conformal planning using multiple isocenters, various collimator sizes, field weighting and adroit use of the Gamma angle. However this improved cranial nerve outcome using a 12 Gy margin dose needs long term analysis to ensure no compromise in tumor control though preliminary results seem encouraging.

**Keywords:** Radiosurgery; acoustic-neuromas.

## 2B16

### Conformal Stereotactic Radiosurgery for Vestibular Schwannoma

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**Introduction:** To assess the feasibility of single isocenter Conformal Stereotactic Radiosurgery for vestibular schwannoma.

**Methods:** From February 1998 to February 2002, 74 consecutive previously untreated patients (median age: 63 years, range: 26–81 years) with vestibular schwannoma (median volume: 1.74 cm<sup>3</sup>, range: 0.14–3.7 cm<sup>3</sup>) were prospectively treated. The median follow-up time is 28.3 months, with 42 patients having a follow-up of at least 24 months. In 33% of patients the vestibular schwannoma was located on the left side and in 67% on the right side. Twelve patients had only intrameatal growth and in 29 patients the vestibular schwannoma had brainstem contact. On initial presentation eleven patients complained about trigeminal neuralgia as the leading symptom, and 3 patients complained about a grade II facial nerve neuropathy according to House-Brackmann. Vertigo was the main complaint in ten and tinnitus in 26 patients. In all patients target delineation and treatment planning was based on CT and MRI image fusion. Patients were treated with the Novalis high-resolution beam shaper (m<sup>3</sup> mMLC) using 6 to 11 static beams (28 patients) or 3 Dynamic Conformal Arcs (45 patients). In all patients the isocenter dose was limited to 13.5 Gy and at the periphery to 12 Gy resulting in a conformity index of 1.4 to 2.1 (median 1.7) and a homogeneity index of 1.15 according to the guidelines of the Radiation Therapy Oncology Group (RTOG).

**Results:** Deterioration in pre-treatment impaired hearing was noted in 16% patients. Improved hearing was found in 12%, and no change in 72% of patients. A temporary facial nerve weakness was observed in 1 patient with an intrameatal schwannoma. Temporary impairment of trigeminal neuropathy was seen in 8%, an improvement in 44% of the cases. Only 1 patient developed a temporary trigeminal neuropathy as a new complaint. Impaired dizzy-vertigo was observed in 20%, no change in 20% and improvement in 20% of patients. A decrease in tumor volume was found in 67% of patients and no patient has shown progression.

**Conclusions:** To date Conformal Stereotactic Radiosurgery for vestibular schwannoma provides excellent local control and only minimal acute and late side effects.

**Keywords:** Radiosurgery; vestibular schwannoma; conformal stereotactic radiosurgery; micro-multileaf collimator; single isocenter; static beams; dynamic arc.

## 2B17

### Gamma Knife Radiosurgery in the Management of Glomus Jugulare Tumors – A Volumetric Study of 16 Cases

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**Objective:** A retrospective analysis of clinical and radiological outcome following gamma knife radiosurgery (GKRS) for glomus jugulare tumors.

**Material and methods:** Twenty patients with glomus jugulare tumors underwent GKRS at the Cleveland Clinic during a 6 year period from 1997 to 2002. Four patients with follow up of less than 10 months were excluded from analysis. Clinical and radiological data from 16 patients was retrospectively analyzed in this IRB-approved study. MRI tumor volumes at treatment and follow-up were assessed using proprietary software.

**Results:** There were 14 women and 2 men, with an average age of 63.1 years (range 22 to 87). Follow up was 10 to 79 months. Six patients had undergone previous surgical resection of the same tumor, two had multiple tumors and one had a functional chemodectoma. Clinical features were tinnitus (n=11), hearing loss (n=11), lower cranial nerve paresis (n=6) and otalgia (n=5). Seven patients clinically improved, 2 patients worsened (hearing loss) and 7 patients were unchanged. Tinnitus and otalgia were the symptoms that responded most favorably to GKRS. Initial tumor volumes ranged from 0.4 to 26.1 cc's. Tumor volume showed a transient increase in 9 patients though ultimately the tumor volume decreased in 6 patients (3 clinically improved, 2 clinically unchanged & 1 clinically worse), increased in 4 patients (2 clinically unchanged, 1 clinically improved, 1 clinically worse) and was unchanged between the first and last scans in 6 patients (3 clinically improved and 3 clinically unchanged).

**Conclusion:** GKRS is a safe effective treatment for glomus jugulare tumors, particularly in elderly patients and patients with serious medical conditions. Longer follow up is required to assess the long term effects of GKRS on glomus jugulare tumors.

**Keywords:** Radiosurgery; glomus jugulare.

## 2B18

### Novalis Shaped Beam and Intensity Modulated Radiosurgery and Stereotactic Radiotherapy for Spine Lesions

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**Objective:** Since survival of patients with malignancies is increasing, spine radiosurgery becomes an important tool to improve quality of life. Selected benign lesions can also be treated with this technique.

**Materials and methods:** From July/2002 to October/2003, 11 patients (19 lesions) were treated at UCLA, 6 females, mean age 56.2 years (23–82). Nine were treated with stereotactic radiosurgery (SRS) and 2 with stereotactic radiotherapy (SRT). There were 8 metastasis (lung, renal cell, breast, colon carcinoma) and one meningioma, neurofibroma, chondroma. Six lesions were cervical, 9 thoracic and 4 lumbar. Eight patients had pain, 3 were asymptomatic. Six patients underwent previous spine surgery (3 instrumentations). All but 2 patients received conventional radiation before SRS/SRT, 7 received chemotherapy. Mean total dose of 13.9 Gy (8–54) was prescribed to mean 91% isodose (88–97). Mean tumor volume was 26.64 cc (0.75–91.75). Treatment plan applied using intensity modulated radiosurgery/radiotherapy (IMRS/IMRT) fields in 12 lesions, conformal beams in 3 and dynamic arcs in 4. Mean follow-up was 5.97 months (10–330 days).

**Results:** Two patients were pain free, 4 experienced considerable pain relief. Asymptomatic patients remained so. Three lesions decreased in size, 6 remained stable, 7 progressed and 3 had no follow-up (2 patients deceased before undergoing scan). No complications of shaped beam and IMRS/IMRT techniques were observed so far. Three patients died in this series, 2 due to the systemic disease and 1 due to thoracic lesion progression.

**Conclusion:** Spine shaped beam and IMRS/IMRT with Novalis SRS/SRT may delay neurological deterioration, improving quality of life. It is precise and useful to safely deliver radiation to spine lesions involving the cord. The lack of complications of SRS/SRT suggests that higher doses can be delivered to improve the control rate in patients with metastases.

**Keywords:** Radiosurgery; spine; stereotactic radiotherapy.

## 2B19

### LINAC-Radiosurgery for the Treatment of Hormone Secreting Pituitary Macroadenomas

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**Objectives:** To assess long term effects following linear-accelerator (LINAC) based radiosurgery of pituitary macroadenomas with reduced therapeutic dose.

**Methods and material:** From August 1990 through December 2003, 177 patients with progressive and/or hormone secreting pituitary macroadenoma underwent LINAC-radiosurgery in our department according to a prospective protocol. The therapeutic radiation dose (prescribed upper limit: 20 Gy) was in 84% of the procedures applied with multiple spherical fields, in 16% using a micro-multileaf collimator (mMMLC). Definitions for “normalization” of hormone secretion were: acromegaly: GH < 5 µg/L and normal IGF-1, Cushing’s disease: normal serum cortisol, urine cortisol and/or ACTH, Nelson-tumor: normal ACTH, prolactinoma: normal prolactin.

**Results:** 102 patients with hormone-secreting macroadenomas (GH: 62, ACTH/Cushing: 17, ACTH/Nelson: 9, prolactin: 12, TSH: 2, median tumor volume: 2.2 cc) and a minimum actuarised FU time of 12 months (median: 56.4 mth, range: 14–112 mth) were selected for analysis. A median therapeutic dose of 16 Gy (median maximum dose: 33.7 Gy) gained tumor control in 93.1% and normalization of hormone hyper secretion in 57.7% of the

patients (median cumulative time to normalization: 43.6 months, probability at 5 yrs: 65%). Type of adenoma, and therapeutic dose had no statistically significant impact on normalization (log-rank test,  $p > 0.05$ ). Only in prolactinomas a maximum dose of >30 Gy was associated with a significantly higher normalization rate ( $p = 0.003$ ). Adverse events were deterioration of anterior pituitary function (16/102 patients (15.7%), probability at 5 years: 18%), temporal lobe necrosis (2.9%) and visual field defect (1%).

**Conclusions:** LINAC-RS using multiple isocenters or mMMLC with a reduced therapeutic dose is highly effective for local tumor control and normalization of hormone secretion with a low incidence of side effects. If compared to protocols applying higher therapeutic doses (>20 Gy), the time to normalization seems to be increased.

**Keywords:** Radiosurgery; pituitary adenoma.

## 2B20

### LINAC Stereotactic Radiosurgery (LSRS) of Patients Harboring Residual GH-Secreting Pituitary Adenoma (GH-PA)

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**Objectives:** To better realize the role of LSRS as a supplemental therapy to pituitary surgery, the possibility of radiosurgical GH response rate improvement and the possibility of pituitary function (PF) preservation.

**Material/methods:** Out of 511 LINAC stereotactic radiosurgeries – 48 ones of residual pituitary adenoma (PA), 16 patients with GH-PA were treated from 1993 to 2003. In them, we irradiated residual tumor after proceeding pituitary surgery. The mean dose was 19.9 (14–27) Gy. The irradiation of visual pathways did not exceed 8 Gy and the dose to brainstem was up to 12 Gy. The mean follow-up (FU) was 49.2 months. During the physical examinations, neuroradiological changes of the residual tumor, GH-response rate, pituitary function and vision were observed.

**Results:** The study showed a good residual tumor control rate (100%). No worsening of the vision field and no deterioration of postsurgically preserved PF was found during the FU. On the other side, the overall results showed a complete GH response rate only 12.50% (2 patients), partial GH response rate 43.75% (7 patients) and no GH level changes in 18.75% (3 patients). Therefore in 1 patient the LSRS had to be repeated after 28 months and in other 2 ones the repeated LSRS is eligible. The death of 2 patients (12.50%; subarachnoid hemorrhage and suicide respectively) shorted their FU as well as 9 and 7 months seem to be short FU in 2 another patients (12.50%).

**Conclusion:** LSRS itself is safe and minimally invasive supplemental therapeutic method, which is taken into account by the neurosurgeon during a pituitary surgery, so that the patient is not exposed to unnecessary risk in effort to reach radicality during it. In contradiction to good tumor control, the complete normalisation of GH production is not satisfactory.

**Keywords:** Radiosurgery; LINAC; GH pituitary adenomas; residual tumors.

## 2C10

### **Camptocormia. A Rare Dystonic Disorder Treated with Bilateral Pallidal Stimulation**

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**Objectives:** Camptocormia, meaning bent-spine, is a rare disorder involving involuntary truncal flexion induced by sitting or standing. It has been described as a form of segmental dystonia, or an extreme manifestation of parkinsonian rigidity or dystonia. Previous experience shows that pallidal stimulation is effective in a wide variety of dystonic conditions as well as parkinsonian rigidity and dyskinesias. We report a case of camptocormia in a Parkinson's disease patient treated with bilateral pallidal stimulation.

**Material and methods:** A 65 year-old man, diagnosed of Parkinson's disease 8 yrs before, with a 4 yrs process of progressive truncal flexion, appearing in the standing or sitting positions, that increased while walking and disappeared in the supine position, with a history of previous spinal surgery for correction of the deformity, was referred to our Clinic for further surgery. Initial evaluation showed an absence of primary spinal pathology. No neurological deficits were demonstrated while laying down. When attempting to correct the deformity severe lumbar pain appeared. After having ruled out all other possible aetiologies of the disease, the patient had a bilaterally implanted stimulating electrode in the GPi. Microrecordings-based techniques allowed for GPi activity recording along all tracks (Leadpoint, Medtronic).

**Results:** Although no benefit was seen initially the patient reported a feeling of lack of continuous contraction or spasms of the abdominal wall. Currently after a FU of 1 yr he is able to keep in a near-standing position for longer periods of time.

Microrecordings findings along tracks in the GPi are presented and discussed.

**Conclusion:** Bilateral GPi stimulation has proven to be effective in a case of camptocormia after a FU of 1 year. The improvement is not due to a placebo effect as it disappears after switching off the stimulator. Microrecordings are specially useful in this rare condition.

**Keywords:** Dystonia; microelectrode recording; pallidal stimulation.

## 2C11

### **Neurosurgical Management of Cervical Dystonia: A New Denervation Method**

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**Purpose:** Bertrand's selective peripheral denervation is a preferred treatment for cervical dystonia. However, it always accom-

panies postoperative sensory loss in the C2 region. Bleeding from epidural venous plexuses may also be a problem. The author developed a new denervation procedure to avoid such complications.

**Methodology:** The new procedure consists of intradural rhizotomy of C1 and C2 ventral roots, extradural peripheral ramisectomy from C3 to C6. This procedure was performed in 30 patients (Group A). The results were compared with those of a matched group of 31 patients who underwent Bertrand's operation (Group B).

**Results:** Changes of cervical dystonia rating score at follow-up did not differ between the two groups. One patient in Group A showed a sensory deficit in the C2 area, while all the patients in Group B had C2 sensory disturbance. No patients in Group A but four patients in Group B experienced occipital neuralgia. The average amount of the intraoperative blood loss was  $115 \pm 30$  ml (mean  $\pm$  SD) in Group A and  $233 \pm 65$  ml in Group B ( $P < 0.005$ ). I conclude our new procedure for cervical dystonia carries much less incidence of complications and significant decrease of intraoperative blood loss.

**Keywords:** Dystonia; torticollis.

## 2C12

### **Writer's Cramp: A Neurosurgically Curable Condition**

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**Purpose:** Writer's cramp is a type of focal dystonia due to dysfunction of the pallido-thalamo-cortical circuit. The symptom is refractory to most conservative treatment, and botulinum toxin injection is generally used for symptomatic relief. Theoretically focal hand dystonia can be controlled by interrupting the abnormally functioning pallido-thalamo-cortical circuit with stereotactic nucleus ventrooralis (Vo) thalamotomy.

**Methodology:** MRI guided Vo thalamotomy was performed in 12 patients (8 men, 4 women, age 26–40 yrs, mean 32.1 yrs) with medically intractable writer's cramp.

**Results and conclusion:** The mean duration of the symptom ranged from 3 to 6 years (mean, 4.5 yrs.) All patients had complained of difficulty of writing. Seven patients were professional workers, and, because of the dystonic symptoms, they had stopped pursuing their profession. All patients showed immediate post-operative disappearance of dystonic symptoms, and the effect was sustained during the follow up period (9–39 months, mean 21 mo). Two patient showed partial recurrence of the symptom and underwent second thalamotomy. The score of the writer's cramp rating scale significantly ( $p < 0.001$ ) decrease after Vo thalamotomy. There was no mortality or permanent morbidity. Although a longer follow-up is needed, stereotactic Vo thalamotomy is a useful and safe therapeutic option for writer's cramp.

**Keywords:** Dystonia; writer's cramp.

## 2C13

### **Stereotactical MRI Demonstrates Grey Nuclei Lesions in Dyt1 Dystonic Patients**

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**Background:** In primary dystonia, diagnostic criteria include normal MRI. In more than 30 of cases it is associated with the autosomal DYT1 mutation.

**Objective:** To describe abnormal signals observed on stereotactic MRI in the basal ganglia of DYT1 positive patients.

**Methods:** Twenty four patients (14 girls, mean age: 22.5 y, from 8 y to 66 y) suffering from genetically identified DYT1 generalized dystonia underwent stereotactical MRI, under general anesthesia for DBS. The mean improvement was 79% (mean follow-up: 91 months, from 10 m to 185 m).

**Results:** Thirteen of the 24 patients presented hyposignals (equivalent intensity with cerebrospinal fluid) between 2 and 5 mm in the basal ganglia. These hyposignals were in the ventral-posterior part of: putamen (11 patients), GPe (4 patients) and GPi (4 patients), usually identified as dilated Virchow-Robin spaces. This can be correlated with neuronal death and signal a grey nuclei atrophy. They were measured to be more than 5 mm in 6 patients. In one of them the hyposignal in the putamen was described as a round liquid image of 6.5 mm radius. Diffuse hyposignals (senescence calcification) located in the anterior part of the GPi have been described in another one.

**Conclusion:** The diagnosis criterion of normal MRI interpretation for primary dystonia has to be reevaluated. The presence of abnormal signals on MRI does not influence negatively the post-operative evolution after GPi stimulation.

**Keywords:** Dystonia; MRI.

## 2C14

### Median Nerve Somatosensory Evoked Potentials in Multifocal DBS for Complex Dystonia Show Different Profiles from Pallidal and Thalamic Electrodes

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**Objective:** Deep brain stimulation (DBS) in patients with movement disorders allows to gain new insights into the physiology of subcortical structures. Thus far, the origin of the P18 peak in median nerve somatosensory evoked potential (SEP) scalp recordings has been unclear, although it has been assumed to be of subcortical origin. We therefore studied median nerve SEPs from electrodes implanted in the pallidum (GPi) and the Thalamus (VIM) for chronic DBS.

**Methods:** In 10 patients with segmental or generalized dystonia quadripolar electrodes were implanted for chronic DBS. Six patients underwent multifocal stimulation (GPi and VIM), and four patients underwent pallidal stimulation only. SEPs after 3 Hz median nerve stimulation were recorded in bipolar and unipolar (reference Fz) technique in the interval between electrode implantation, and implantation of the impulse generator. Raw signals were band pass filtered from 5 to 1000 Hz, amplified with 10 uV/d; 500 sweeps were averaged. Neck SEP were additionally recorded from the levels of the cervical spinous processes C2.

**Results:** There were no intraoperative complications. Unipolar SEP revealed a N18 potential with a mean latency of 18.2 ms ( $-1.2$ ) from GPi electrode contacts, and with a mean latency of 17.6 ms ( $-1.5$ ) from VIM electrode contacts. Bipolar recordings from VIM resulted in a distinct potential with a N18 at 17.9 ms ( $-1.9$ ), whereas bipolar recordings from GPi in most cases failed to show a SEP.

**Conclusions:** Our findings confirm that the P18 originates from subcortical structures. Furthermore, they indicate that it is generated within the thalamus or thalamocortical projections.

**Keywords:** Dystonia; SEP; DBS.

## 2C15

### Long-Term Outcome of Deep Brain Stimulation for Dystonia (3 Years or Longer)

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**Objective:** Chronic deep brain stimulation (DBS) for treatment of medically refractory dystonia has been introduced only recently. It has been shown to yield marked improvement up to 2 years upon chronic stimulation in primary dystonia. Thus far, however, data on long-term follow-up has been missing. The purpose of the present study therefore was to evaluate outcome of chronic DBS after 3 years or longer.

**Methods:** From 1995 until 1999, a total of 12 patients with dystonic movement disorders underwent implantation of quadripolar electrodes at the Department of Neurosurgery in Berne. All patients, except the first two cases, were enrolled in a prospective study protocol including assessments with the Burke-Fahn-Marsden dystonia scale, the Unified Dystonia Rating Scale and standardized videotaping. The seven patients available for recent follow-up included four patients with complex cervical dystonia (CD), and one patient each with generalized dystonia (GD), posttraumatic hemidystonia (HD), and peripherally-induced paroxysmal non-kinesigenic dystonia (PNKD). The patients with HD and PNKD had secondary dystonia, while the etiology was idiopathic dystonia in the other patients. All patients underwent pallidal DBS, except the patient with PNKD who had chronic DBS of the ventro-intermediate (Vim) thalamic nucleus.

**Results:** For complex CD follow-up was available at 4 years (1 patient), 5 years (2), and 6 years (1). One patient had three episodes of clinical deterioration because of fractures of the electrode and the wire to the pacemaker. At the last follow-up, three patients had sustained benefit as compared to short-term outcome, whereas in one patient scores had returned almost to baseline. The other three patients had continued improvement at 3 years follow-up (GD), 7 years (HD), and 8 years (PNKD). Due to the higher energy needed for chronic DBS, replacements of batteries were performed more often as compared to patients with Parkinson's disease.

**Conclusions:** Chronic DBS may lose its efficacy in single patients on long-term. In the majority of patients, however, the beneficial effects of stimulation are maintained.

**Keyword:** Dystonia.

## 2C16

### Deep Brain Stimulation in Myoclonus-Dystonia Syndrome (MDS)

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**Objective:** To evaluate the efficacy of electrical stimulation of the internal globus pallidus for suppressing abnormal movements and improving quality of life in a patient with myoclonus-dystonia syndrome (DYT11).

**Background:** The long term efficacy of deep brain stimulation for treating primary dystonia is now established. In two patients with PGD associated with myoclonic jerks, we previously noticed an excellent post-surgical result.

**Methods:** An 8-year-old boy presented with medically intractable MDS due to a mutation in the *Ú-sarcoglycan* gene (SGCE). Typical lightning myoclonic jerks involved the head, neck and upper extremities and were present at rest and during movement. Dystonia of the right upper limb was action-induced during the execution of specific tasks (i.e. during writing and eating). Myoclonus were assessed by the Unified Myoclonus Rating Scale, while dystonia by the Burke Marsden Fahn's Dystonia Rating Scale.

The child underwent bilateral stimulation of the GPI (globus pallidus internus).

**Results:** Myoclonus, dystonic movements, postures and motor function considerably improved, with subsequent improvement in the quality of life. After twenty months, UMRS and BMFDRS scores remains improved, the child being free of symptom.

**Conclusions:** We confirm the beneficial effects of deep brain stimulation on both myoclonus and dystonia in a child with severe DYT11-MDS.

**Keywords:** Dystonia; DBS; myoclonus.

## 2C17

### **Anatomical Study of the Mammillothalamic Tract in Humans using 3D T1-Weighted SPGR MR Imaging**

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**Objective:** Experimental studies have demonstrated the significant anticonvulsive effect of lesioning mammillary bodies (MB) and mammillothalamic tracts (MTT). We hypothesized that similar anticonvulsive effect might be achieved in epileptic patients as well. Therefore, we have conducted a human anatomical study to collect 3D *in vivo* measurements of MB and MTT and to define the cortical entry point of stereotactic implanted electrodes targeting simultaneously MB and MTT.

**Material and methods:** Image reformation and measurements on similar 3D T1-weighted SPGR MR sequence covering the whole brain were performed on fourteen healthy adults. Only subjects in whom the MTT were bilaterally delineable in the three orthogonal planes underwent further assessments.

**Results:** Only nine adults fulfilled the inclusion criteria. The width of their MB varied between 4.2–5 mm. Due to the MTT arc-shaped on sagittal section, an inferior and superior segments were defined and particular attention was given to the inferior one. The inferior segment starts at the MB and ends at mid-flexure of the MTT; the superior segment begins at the mid-flexure and reaches the anterior thalamus. The width of the inferior segment varied between 2.2–2.9 mm. This segment in the sagittal plane had an upward-posterior direction of 62° to the AC-PC line, and in the coronal plane an upward-lateral direction of 64° to the AC-PC plane. In the sagittal plane, the

two segments showed an anterior angle of 133° and in the coronal plane an internal angle of 150°. When considering the average volume occupied by the MTT inferior segment, the line drawn from the MB and going through this volume reached the posterior part of the middle frontal gyrus.

**Conclusion:** MR yielded precise 3D biometrics of MB and MTT and identified a relative safe cortical entry point for simultaneous targeting of MB and of the inferior segment of MTT.

**Keywords:** Epilepsy; mammillothalamic tract; anatomical study; SPGR.

## 2C18

### **Intractable Epilepsy Associated with Taylor-Type Focal Cortical Dysplasias with Subtle MRI Abnormalities. Operative Strategy and Outcome**

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**Objectives:** Seizure-free outcome after resection of Taylor-type focal cortical dysplasias (TTFCD) depends on a complete resection of the dysplastic cortex. Such resection may be difficult to achieve, especially in eloquent areas, when MR imaging is normal or shows only subtle abnormalities.

**Methods:** Seventeen patients were operated for early onset severe partial epilepsy associated with a TTFCD during the last three years. In ten of them – aged 12 to 32 (mean 20.4 yrs), standard MRI was considered normal, despite clinical data suggestive of a TTFCD. High resolution MRI was normal in 3 cases and disclosed subtle aspecific abnormalities in 7 cases. 18FDG-PET was performed in 9 cases and showed in all of them a focal and severe gyral hypometabolism, associated with surrounding mild to moderate hypometabolism in cases with subtle MRI abnormalities. Stereo-EEG with depth electrodes was performed in all cases. Metabolic data were concordant with stereo-EEG findings. Continuous rhythmic spike activity was recorded within the hypometabolic gyrus which was also the site of spontaneous seizure onset. TTFCD was frontal in 5 cases, pre-central in 1, central in 1, parietal in 2 and occipital in one.

**Results:** Image-guided microsurgical en-bloc resection of the abnormal sulcus was performed, associated with adjacent cortex in cases with extended hypometabolism and stereo-EEG abnormalities. When the TTFCD was found in the central region, the resection was limited to the PET and SEEG-defined abnormal gyrus. TTFCD was histologically confirmed in all cases. All patients were seizure free (follow-up of 2 to 43 months, mean 24 months): 4 in Engel's Class I A and 1 in Class I D (follow-up >2 years); 4 had no seizure since surgery and one had rare motor auras (follow-up <2 years). No permanent morbidity was observed except for a partial hemianopsia after resection of the occipital TTFCD.

**Conclusions:** Using PET scan and stereo-EEG in the preoperative investigation, adequate resection of TTFCD with no or subtle MRI abnormalities can be achieved with a seizure-free outcome, even in eloquent cortex, and without significant postoperative neurological deficits.

**Keyword:** Epilepsy.

**2C19****Memory and Intelligence Outcome Following Temporal Lobe Surgery for Intractable Epilepsy**

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*Introduction:* With the success of anteromedial temporal lobectomy for intractable epilepsy having been established in terms of seizure outcome, attention is now directed on the cognitive outcome of such procedures, particularly since the temporal lobe is so intimately involved in the processes of memory. SCANTY LITERATURE exists on whether successful seizure control leads to improved cognitive functioning following surgery for intractable epilepsy. It was therefore, our endeavor to (A) assess memory and intelligence outcome. Following temporal lobe surgery for intractable epilepsy (B) correlate this with seizure outcome and side of surgery.

*Methods:* For memory and intelligence assessment, we used an indigenously developed battery suited to the Indian population. Retest and observer variance reliability of this battery had been established previously. The battery was administered to right handed adults undergoing temporal lobe surgery for intractable epilepsy both pre and post-surgery at a mean follow up of 8 months. The memory scores were overall memory scores including verbal, visuospatial, episodic and semantic memory. Twenty five patients were included, 13 underwent right while 12 underwent left temporal surgery. None had any MRI/SPECT evidence of opposite temporal abnormality. Seizure outcome was assessed using Engel's classification.

*Results:* Among 13 patients who underwent right temporal surgery, while 4 patients with poor seizure outcome had insignificant change in scores, 7 of 9 patients with good seizure outcome had considerable (>20%) improvements in their memory and intelligence scores. Statistical analysis using the students 'T' test and the Mann Whitney Test revealed that patients who had undergone right temporal surgery with good seizure outcome had significant improvement in both memory ( $p=0.007$ ) and intelligence ( $p=0.043$ ) scores compared to those with poor seizure outcome. On the other hand, patients who had undergone left temporal surgery had no significant change in scores irrespective of seizure outcome.

*Conclusions:* Significant cognitive improvement seems to be associated with good seizure outcome in right handed adults undergoing non-dominant temporal lobe surgery for intractable epilepsy with no evidence of pathology in the opposite temporal lobe. The opposite lobe was presumably functional and when freed from the deleterious influence of intractable epilepsy, probably functioned better leading to improvement in cognitive functioning. A good seizure outcome does not translate into cognitive improvement for patients undergoing left temporal surgery probably because the functional right temporal lobe of these patients has a lesser functional reserve than the left, in terms of memory processing.

*Keywords:* Epilepsy; cognitive-outcome.

**2C20****Accuracy of Computer-Assisted Brain Punctures using the Vertek Aiming Device: A Phantom Study**

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*Purpose:* To determine the accuracy of computer-assisted punctures of the major brain regions using our novel targeting device.

*Materials and methods:* A phantom of the head (scale 1:1) was built by filling a plastic model with agar-agar and embedding 10 acrylic glass pins which were fixed to the ground plate in every hemisphere. Glass beads glued to the tip of the pins served as targets. In both hemispheres 2 targets in different levels were considered to be in the frontal, the parietal, the occipital and the temporal lobe as well as in the thalamic region ( $n=20$ ). CT data (1.25 mm slices) and MR data were fused on a navigation system (StealthStation, Medtronic, USA) to plan the punctures. The entry points were defined according to neurosurgical standards. The centers of every bead were defined as target points. According to these plans our patented Vertek targeting device (Medtronic, USA) was adjusted and the puncture was performed using a 1.0 mm surgical pin. On a subsequent CT-scan the distance of the target perpendicular to the axis of the pin and the angle of deviation was determined. This procedure was repeated 5 times ( $N=100$ ).

*Results:* The distance increased slightly with an increasing length of the plan. The mean deviation in the major brain regions ranged between 1.1, b 0.6 mm and 1.8, b 1.0 mm. The mean deviation ranged between 0.9, b 0.5° and 1.5, b 0.8°.

*Conclusions:* The adjustable Vertek targeting device in combination with the Treon navigation systems allows for highly accurate punctures of all major brain regions based on CT as well as MR data.

*Keywords:* Neuronavigation; frameless stereotaxy; brain tumour biopsy; phantom study.

**2C21****Stereotactic Target Localization Using Magnetic Resonance Imaging**

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*Objective:* To evaluate image distortion for magnetic resonance imaging (MRI) in sequences necessary and useful for functional stereotactic targeting.

*Materials and method:* Cylindrical perspex phantom which could be secured to the base of the Leksell stereotactic frame was constructed. Two inserts consisting of glass solid rods were used to assess the accuracy of axial and coronal MRI. The phantom was stereotactically investigated by necessary sequences within the head coil of Siemens 1 T MAGNETOM and Siemens 1.5 T SYMPHONY scanners. As the basic imaging the gradient echo 3D (3D) and classical spin echo in T2 weighting (T2) sequences were chosen. The images were transferred into the treatment planning system and the stereotactic coordinates of the rods were determined. The deviations between stereotactic coordinates based on MRI and real geometrical position given by the construction of the phantom insert were evaluated for each study and further investigated as a function of: a) MRI scanner employed, b) MRI sequence, c) image orientation, d) spatial position of measured points in the investigated volume.

*Results:* Higher distortions were observed for SYMPHONY 1.5 T scanner than MAGNETOM 1 T scanner. Level of distortions varied based on the different sequence for both scanners, image orientation and spatial position of investigated volume. The minimal distortion were measured for 3D sequence (average distortion varied between 0.2 and 0.5 mm) and the most pronounced dis-

tortion occurred for T2 imaging (average distortion varied 0.3–3.0 mm). Higher distortions were observed for coronal slice orientation and typically for non-centrally located slice positions in the investigated volume.

**Conclusions:** The level of distortion for the 3D sequence was minimal and these images can be used as the crucial and basic sequence for stereotactic targeting. Accuracy of the T2 imaging was insufficient and this sequence can be utilized only as auxiliary one.

**Keywords:** Parkinson's disease; magnetic resonance imaging; stereotactic targeting; image distortion.

## 2C22

### Deep Brain Stimulation of the Thalamus can Influence Penile Erection

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Bilateral high frequency stimulation (HFS) of the thalamus was performed in two patients with intractable Tourette Syndrome (TS). Electrodes were implanted in the thalamus at the level of the nucleus ventro-oralis internus (Voi), centromedian nucleus (Cm) and the substantia periventricularis (Spv). Post-operatively, the patients reported changes in penile erection. Laboratory testing of penile erection in response to various erotic video clips was performed in stimulation on and 12-hour off conditions. HFS of the thalamus was found to have a profound impact on the genital response to visual erotic stimulation and sexual fantasy under laboratory conditions. Thalamic stimulation increased erection in patient 1 and reduced it in patient 2. These different penile reactions to visual erotic stimuli might be explained by differences in the stimulation settings. In patient 1, the location of the left electrode is 2 mm medial and the right electrode 2 mm lateral in relation to the position of the electrodes in patient 2. Our findings confirm that the midline and intralaminar thalamic nuclei play an important role in penile erection and suggest that a parallel organization of inhibitory and excitatory projections within the intralaminar and midline nuclei of the thalamus could be responsible for these effects.

**Keywords:** Psychiatric indications; microelectrode recording; tourette syndrome.

## 2C23

### Clinical Evaluation of Post-Traumatic Vegetative State Patients: A Longitudinal Study

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**Introduction:** The clinical course after the acute insult usually begins with coma lasting for several days to weeks during which patients resume partial or complete brain stem and lower diencephalon functions and enter in a vegetative state (VS). 1 to 14% of patients with prolonged post traumatic coma develop persistent vegetative state (PVS). The possibility to predict the outcome of

patients in a VS, that is the possibility to predict which patients will regain consciousness and which will not, is critical for medical and ethical reasons.

Functional-MRI has been used to investigate cortical brain activity associated with visual, auditory or tactile stimulations of patients in coma.

**Patients and methods:** The intensive care unit of S. Raffaele Hospital admits about 70 post-traumatic head injury patients per year. 70% of these patients are comatose with Glasgow Coma Scale (GCS) < 9.

All traumatic brain injury patients admitted to the Neurosurgery intensive care unit were evaluated in for the following inclusion criteria:

- age between 18 and 70 year
- spontaneous breathing
- no sedation requested for the neuroradiological evaluations
- impossibility to carry out simple orders

Exclusion criteria were:

- presence at CT scan of temporo-parietal hypodense lesions bigger than > 3 cm
- presence of metabolic, neurological or major systemic disease preceding the trauma
- pregnancy

Between January 2003 and December 2003, 7 patients fulfilled the eligibility criteria and were included in the study.

All the clinical data relative to: Neurological status; CT scans; clinical status before hospital admission; intracranial pressure; blood pressure and cerebral perfusion pressure; monitoring values of ventilation, diuresis and temperature will be inserted in a database for statistical analysis.

The patients have been referred to the neuroradiology research unit and studied with conventional and functional MRI.

Five patients have been contacted 6 months after the acute event for a clinical evaluation by means of the Glasgow Outcome scale (GOS) to determine the degree of recovery of consciousness and to repeat conventional MRI.

**Results:** Preliminary results seem to demonstrate association of cortical activity in primary sensory and associative areas with regaining of consciousness. More patients and studies are necessary to confirm this preliminary result.

**Keywords:** Post-traumatic coma; functional MRI.

## 2C24

### External Cardiac Defibrillation does not Cause Thermal Injuries in Pigs with In Situ Cerebral Stimulation Electrodes

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Parkinson's disease patients with long term L-dopa syndrome benefit from deep brain stimulation. Other indications are movement disorders like essential tremor, dystonia and intractable pain syndromes. When the advanced life support algorithm demands cardioversion or defibrillation in these patients, undesired effects

of monophasic electroshocks might occur on brain tissue adjacent to the stimulation electrodes (e.g. thermal injury) but also on the stimulation device itself.

The present animal study (n = 6 pigs) investigated the effects of repeated defibrillation ( $2 \times 200\text{J}$  (n = 1) and  $2 \times 360\text{J}$  (n = 5)) at the implantation site of cerebral stimulation electrodes and on stimulation device functionality.

Repeated defibrillation did not cause (thermal) injury at the implantation site of the cerebral stimulation electrodes nor cause injury to the tissue adjacent to the impulse generator. Functionality of the stimulator device following defibrillation, however, ranged from normal to total loss of function.

In conclusion, we here show that repeated external cardiac defibrillation is safe with regard to thermal injury of brain tissue adjacent to the cerebral stimulation electrodes and the impulse generator pocket. When performing defibrillation, however, the greatest possible distance must be maintained to the stimulator device implantation site. Subsequent testing of the stimulator device's functionality is absolutely necessary.

*Keywords:* History of stereotaxy; Parkinson's disease; dystonia; cardiac defibrillation; deep brain stimulation.

## 2C25

### Quality Control Procedure for Stereotactic Magnetic Resonance Imaging during Neurosurgery of Movement Disorders

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*Background:* A critical step in all stereotactic procedures remains accurate target localization. The outcome of the surgery for deep brain stimulation is directly based on imaging accuracy.

*Objective:* To present the technical requirements for implementing a stereotactic methodology using 3D MR imaging alone for deep brain stimulation, of GPi and STN.

*Methods:* Deep brain stimulation systems were stereotactically implanted using Leksell G frame and MRI, under general anesthesia in the STN (1 patient) and in the GPi (80 patients) with clinical improvement. The accuracy of the entire procedure was validated by an immediate postoperative stereotactic MRI. Electrodes were checked to be on the selected target in all the patients.

*Results:* During a stereotactic operation for DBS the following steps must be constantly controlled: (1) the rigidity of the stereotactic frame and dedicated MRI location box; (2) fixation of the adapter and alignment of the frame in the MR unit; (3) absolute inhibition of movement during acquisition (general anesthesia if necessary), (4) control of distortion with a regular check of the gradient fields if necessary (rigorous maintenance protocol) and use of the frame box as a phantom to check the distortion rate (dimensions, forms), (5) a validation of merging methodology if used (pixel size, image orientation, brain movement). The reliability of the MRI-based targeting could be improved using an adapted slice thickness (no more than 2 mm for small structures), an isometric pixel size in the plane of targeting (x, y) (square matrix, scan percentage of 100%), and preferably no gap between slices, and no overcontiguous slices.

*Conclusion:* We designed and validated the use of a stereotactic methodology using 3D MR imaging alone for deep brain stimulation procedure. The procedure is safe (very low morbidity), accurate (100% of electrodes are positioned on the chosen target) and short (30 minutes per electrode).

*Keywords:* History of stereotaxy; Parkinson's disease; dystonia; MRI.

## 2C26

### Quantification of True In Vivo ("Application") Accuracy in Image-Guided Surgery

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*Background:* Although image-guidance systems are now widespread and in extensive use worldwide, there are few reported studies that have quantified the true accuracy (= application accuracy) of these systems in an operative "in vivo" setting. We have previously reported a measured accuracy of 2.3 mm when image-guidance is optimized by using implanted skull markers. In this study we measured surgical accuracy of neuronavigation based on different modes of registration: 1) Point to point solid body transformation using adhesive scalp markers. 2) Point to point solid body transformation using anatomical landmarks. 3) Surface matching using scalp points. 4) Surface matching using scalp points in conjunction with relief points in the auditory canals and across the bridge of the nose.

*Methods:* Studies were performed in 30 patients with intracranial pathology who underwent surgery. An optical tracking image-guidance system (StealthStation) was used. All patients had multiple registrations performed and saved. During surgery, identical target points were localized and saved sequentially for each registration. Skull targets were defined by drilling partial thickness twist-drill holes in the outer table. Deep targets were defined intra-operatively by 1 mm titanium hemoclips in cases where access to the tentorium, falx or skull-base was available. Post-operative fused CT located the true position of these targets in relation to the saved locations. The Euclidian measure of localization error was then measured.

*Results:* Measured accuracy for superficial (skull) targets was  $3.5 \pm 1.0$  mm when using adhesive scalp markers,  $4.5 \pm 2.0$  mm when using anatomical landmarks,  $4.8 \pm 2.6$  mm using scalp surface matching and  $4.5 \pm 2.0$  mm with scalp & relief surface matching.

Measured accuracy for deep (hemoclip) targets was:  $3.6 \pm 2.8$ ,  $3.4 \pm 1.5$  mm,  $4.1 \pm 1.9$  mm and  $2.7 \pm 1.9$  mm for the same registrations respectively.

*Conclusions:* Not surprisingly, application accuracy of image-guidance is worse without implanted skull markers. Unexpectedly, there was no major difference in localization of deep targets between the different registrations tested in this study. At the present time we still recommend implanted skull markers or a stereotactic frame when the highest levels of accuracy are required.

*Keywords:* Neuronavigation; application accuracy.

## 2C27

### Optical Markers for Guidance during Stereotactic Neurosurgery

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*Objectives:* In order to increase precision, accuracy and safety during functional neurosurgery, optical markers could help to

serve as target identifiers. The aim of this study was to investigate if in-vivo optical measurements could be used as markers for differentiation between various brain structures.

**Material and method:** A 2 mm in diameter monopolar radio-frequency electrode with optical fibres along the shaft was designed. At the electrode tip an optical window was used to send and receive light to/from the tissue and at the same time act as insulation. During lesioning the electrode was connected to Leksell® Neuro Generator (Elekta Instrument AB). During this process, the electrode was also connected to a digital laser Doppler system used for microvascular measurements and to a reflection spectrometer (AVS-MC2000, Avantes, The Netherlands). During stereotactic surgery on the pig brain (study approved by the local ethical committee), measurements were performed in white, grey and lesioned matter along the path towards the target area positioned in the central grey. The recorded optical values were correlated to tissue type by means of MR-images (1.5 T, GE Medical).

**Results:** Distinct different spectral characteristics were found for white, grey and lesioned matter. This was also valid for the laser wavelength used (632 nm) and showed a clear difference between grey, white and lesioned tissue. Grey matter demonstrated higher microvascular values than white. During lesioning the laser Doppler signal decreased until it reached a stable level.

**Conclusion:** Optical markers have a potential to identify boundaries between grey and surrounding white matter as well as lesioned and unlesioned tissue. Furthermore, it should be possible to identify larger vessels with laser Doppler measurements, this however need to be investigated in future studies. In practical use, optical fibres could be introduced in any surgical instrument used for stereotactic neurosurgery.

**Keywords:** Neuronavigation; biomedical optics; laser Doppler; brain electrodes.

## 2C28

### Cell Fusion as a Repair Mechanism in Brain Injury

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**Objectives:** Previous studies have shown an improvement in neurological function after transplantation of haematopoietic precursors in rodent models of brain injury, but the exact mechanism used by these cells remains elusive. Recently, cell fusion has been described as an alternative mechanism to rescue injured hepatocytes after bone marrow transplantation [1]. Our purpose is to assess the role of cell fusion as a possible mechanism used by haematopoietic cells to repair injured brain.

**Materials and methods:** Based in the CRE/lox system, we have recently developed a method to detect cell fusion “in vivo” [2]. Briefly, R26R cells carry a floxed stop codon which blocks the expression of the lac-z gene, which codes for  $\beta$ -galactosidase. If these cells fuse with a CRE expressing cell, the CRE-recombinase excises this codon and permits the expression of lac-z reporter gene. Consequently, a fused cell can be detected by x-gal staining. We used CRE expressing transgenic mice lines as donors of bone marrow cells. These cells were transplanted intraperitoneally into R26R transgenic mice. Recipients were subjected to different mechanical or ischaemic brain injury models.

**Results:** Three to seven days after lesion, evidence of cell fusion was found in the surrounding area of brain tissue injury. Also,  $\beta$ -

gal positive Purkinje cells were found at the normal cerebellar cortex, as has been previously reported.

**Discussion:** The results suggest that transplanted haematopoietic cell migrate to the lesioned area, fusing with host cells. Cell fusion may be a mechanism to rescue apoptotic-prone cells, and may account for the early improvement of function after transplantation of haematopoietic precursors in rodent models of acute brain damage. These results may support the use of haematopoietic cells as a treatment option for brain injury repair.

**Keywords:** Neurotransplantation; cell fusion.

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## 3A11

### Long-Term Follow Up of Unilateral Stimulation of the Posterior Subthalamic Area in Patients with Intractable Essential Tremor

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**Objectives:** Tremors prominent in the proximal part are often refractory to standard thalamic surgery. Several articles reported that ablation of the posterior part of the subthalamic white matter (pSTWM) ameliorated various tremors including proximal type in the 1960's. This target should be reapplied with advances in a less invasive method, deep brain stimulation (DBS). We present the long-term results of unilateral DBS of pSTWM.

**Materials/methods:** Eight patients with disabled essential tremor involving the proximal arm were enrolled. The tentative target was positioned at the white matter between the red nucleus and the subthalamic nucleus on MRI-CT fused images. Macro-stimulation was used to find the optimal site suppressing tremor. Through a quadripolar DBS lead, a characteristic diphasic pattern of somatosensory-evoked potential (SEP) was recorded as the electrophysiological endorsement. Anatomical locations of all contacts were stereotactically assessed after operations and represented on the Schaltenbrand-Wahren atlas. Improvement of tremor was evaluated by a modified clinical tremor rating scale after follow up period of 18–48 months.

**Results:** Both proximal and distal tremors were remarkably improved in all patients. The average improvement rate was more than 80%. Axial tremors in the head and the legs were also ameliorated. The beneficial effect of stimulation has not declined during the follow-up period. In some patients, stimulation benefits were sustained for more than 12 hours, 2 weeks at longest, after stimulation had been switched off. Most of the contacts that provided remarkable improvement were located in the pSTWM (the zona incerta and the prelemniscal radiation). No major complication was observed.

*Conclusion:* We conclude that DBS of the posterior part of the subthalamic white matter with SEP recording is a safe and effective method to ameliorate severe intractable tremors.

*Keywords:* Essential tremor; zona incerta.

### 3A12

#### Usefulness of Short Latency SEP for the Detection of the Deep Brain Stimulation's Target (DBS)

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The aim of this work has been to evaluate whether short latency SEP recording, shortly after the electrodes' implantation in basal ganglia in parkinsonian patients for DBS, determines morphologic changes of subcortical components in order to help the detection of such targets.

SEPs were recorded in 43 parkinsonian patients who had been undergone to neurosurgical treatment for the implantation of electrodes in GPi, STN, and thalamus' VIM and CM nuclei.

SEPs were recorded shortly after the electrodes' implantation, when the macro-electrode (3387, 3389, Medtronic USA) is still external, after a period of drugs' withdrawal and before the beginning of test stimulations. The electrode's contacts have been used as intracerebral recording sites.

We have found that SEPs, recorded from these targets, showed specific morphologic features, and these features were specific for each target, stable in different trials and they showed a constant pattern among the homologous nuclei of all implanted patients.

These features are capable to assist in detecting the target. These potentials allow to check the correct position of the target. They give, also, useful information about the functioning of the macro-electrode and help in choosing the contacts for the therapeutic stimulation.

Such a quick, safe and cheap method could then support effectively other surgical diagnostic methods, to check the correct position of the electrode.

In fact, careful position of the targets is essential in stereotaxic neurosurgery to improve the outcome, reducing "side-effects" of the electric stimulation.

*Keyword:* Deep brain stimulation.

### 3A13

#### Hardware-Related Complications of Deep Brain Stimulation: A Ten Year Experience

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*Objective:* To report the long-term frequency of hardware-related complications in patients with deep brain stimulation (DBS).

*Method:* A retrospective analysis of all patients operated with DBS at our institution between 1993 and 2002.

*Results:* 119 consecutive patients underwent 139 procedures with implantation of 161 electrodes. Sixty-eight procedures were

performed for Parkinson's disease, 49 for essential tremor and 18 for various other conditions (pain, dystonia, multiple sclerosis). The target was the subthalamic nucleus (STN) in 22 procedures, the Globus pallidus internus (GPi) in 11, the ventral intermediate (Vim) nucleus of the thalamus in 96, the sensory thalamus in 8 and the centrum medianum nucleus of thalamus in two. Six procedures were aborted due to lack of effect. The minimum follow-up was 12 months. The follow-up time was 540 electrode-years. The rate of hardware-related complication per electrode-year was 4.3%. In total, 17 patients (15%) had 23 hardware-related complications. These included 8 electrode breakage, 4 electrode migration, 2 stimulator migration, 3 erosions, 2 erosions and infections, 2 infections and 2 cases of stimulator malfunction. The majority of these complications occurred during the first 4 years following introduction of DBS in our institution.

*Conclusions:* With increased experience and modification of surgical technique, several of the hardware-related complications of DBS may be avoidable.

*Keywords:* Deep brain stimulation; stereotactic surgery; complications.

### 3A14

#### Deep Brain Stimulation for Severe Intention Tremor: The Subthalamic Area is Superior to Ventrolateral Thalamic Nuclei and Asymmetric (Subthalamic/Thalamic) Stimulation can Prevent Side Effects

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*Objectives:* Although deep brain stimulation (DBS) in the ventrolateral thalamus proved effective for the treatment of severe intention tremor the optimal site for stimulation remained obscure.

*Patients and methods:* DBS electrodes were implanted into one of five tracks explored by microrecording and microstimulation in seven patients with essential tremor and six patients with multiple sclerosis. Stereotactic coordinates of individual contacts were determined from postoperative stereotactic x-rays. The efficacy of each contact was assessed by a lateralized Fahn-score as well as analysis of accelerometry measuring high-amplitude batwing tremor and grasping movements using a magnetic tracking system.

*Results:* Contacts located ventral to the intercommissural plane reduced the lateralized Fahn-score by  $63.6 \pm 21.1\%$  (right) and  $67.9 \pm 18.3\%$  (left) whereas dorsal contacts were less effective ( $20.5 \pm 16.4\%$  and  $17.6 \pm 16.2\%$ , respectively). Similarly, stimulation below but not above the ACPC-plane resulted in pronounced reduction of accelerometer total power as well as markedly reduced intention tremor as assessed by magnetic tracking of grasping movements. The mean coordinates (x, y, z in mm relative to the midcommissural point) of the most effective contacts (right:  $12.9 \pm 1.6$ ,  $-7.4 \pm 1.0$ ,  $-1.6 \pm 1.3$ ; left:  $-12.3 \pm 1.2$ ,  $-7.3 \pm 1.7$ ,  $-2.6 \pm 1.1$ ) suggested stimulation within the subthalamic area which is corroborated by correlation

of the position of optimal contacts with intraoperative microrecordings. Furthermore, chronaxie values for suppression of tremor ( $27 \pm 14 \mu\text{s}$ ) and induction of ataxia ( $52 \pm 15 \mu\text{s}$ ;  $p < 0.05$ ) suggested that tremor suppression is due to modulation of large myelinated fibres. Notably, optimal contacts could not be used for bilateral (permanent) stimulation in all instances because this was associated with side effects, e.g. paraesthesias or dysarthria. Interestingly, the superior contact was generally chosen on the dominant side (left electrode) whereas contralateral stimulation was frequently performed with less effective contacts located more dorsally.

**Conclusion:** Intention tremor appears to be controlled best by modulation of fibre tracks in the subthalamic area (zona incerta, prelemniscal radiation/cerebellothalamic projections, fields of Forel H2) and not of neuronal cell bodies within ventrolateral thalamic nuclei. Bilateral (permanent) stimulation is frequently performed asymmetrically in order to prevent side effects.

**Keyword:** Tremor.

### 3A15

#### Experimental Studies and Clinical Results of Staged Lesions Through DBS Electrodes

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**Background:** Deep brain stimulation (DBS) is an effective but expansive treatment for essential tremor, Parkinson's disease, dystonias and dyskinesias. Localized lesions could be an alternative. To evaluate in fresh egg whites and cadavers the parameters required to make appropriate lesions through a DBS electrode.

**Méthode:** To evaluate the efficacy and the safety of this new surgical procedure in the thalamus, globus pallidus and subthalamic nucleus, size of coagulation (length, width) through a DBS Metronic electrode (3387 and 3389) was studied in fresh egg whites and in 6 cadavers, using a video camera and microscope. A Radiofrequency (RF) generator (Radionics) was used to create lesions. Only bipolar lesions were studied. Currents through the adjacent contact to the contact used were also measured.

Eight unilateral thalamotomies, one unilateral pallidotomy and two subthalamotomies (one unilateral, the other bilateral) were performed in our center between 1998 and 2003. In the case of thalamotomies and pallidotomy, the technique was used since the patients were not suitable for classical DBS. Infection was the reason to perform subthalamotomies before removing DBS material. When possible, the lead was left in place to perform further lesion if necessary.

**Résultats:** Experimental studies: there is clear threshold for the lesion size in the eggs and in cadavers. After 20 milliseconds, the lesion size reach a plateau. Current through adjacent contacts were almost nil.

Clinical studies: all patients had a clear improvement of their symptoms in the body contralateral to the lesion: tremor (Vim) and dyskinesias (Gpi lesions) were almost nil. Parkinsonian symptoms (STN lesions) was improved by more than 60% compare to preoperative status. A small taille oedema around tissue was observed on T2-weight MRI 48 h after the surgery but was not visualized 3 months after indicating that size of the lesions were probably inferior to the lead artefact size. No side effects were observed after surgery. One patient presented a transient confusion and one other dizziness.

**Conclusion:** Staged lesions through DBS electrode appears to be a safe and effective treatment of various movements disorders. This technique could be applied unilaterally in patients who are not considered for DBS treatment or used when infection requires to remove the implanted material.

**Keywords:** Parkinson's disease; staged lesions; new surgical procedure.

### 3A16

#### Surgical Complications of Deep Brain Stimulation for Movement Disorders

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**Objective:** The aim of this study was to define the incidence of surgical complications of deep brain stimulation (DBS) in patients with movement disorders.

**Methods:** The authors retrospectively reviewed the cases of 110 procedures on 104 consecutive patients (64 male, 40 female, median age 61 years, range 27–73 years) who underwent implantation of 210 deep brain stimulation electrodes (bilateral  $n = 100$ ; unilateral  $n = 10$ ) between January 1999 to December 2002 with a follow up of at least 6 months. Underlying disease was Parkinson's disease in 79 cases, tremor in 19 cases and dystonia in 6 cases. Implantation sites were as follows: subthalamic nucleus (STN)  $n = 81$ , ventral intermediate nucleus (VIM)  $n = 23$ , globus pallidus internus (GPI)  $n = 6$ .

**Results:** Five clinically evident hemorrhages occurred during the implantation of 210 electrodes (2.3%) requiring surgical intervention (subdural hematoma  $n = 1$ , epidural hematoma  $n = 2$ , intracerebral hematoma  $n = 1$ , venous infarction with secondary hemorrhage  $n = 1$ ) in the first part of the series. Mortality was 0.9% ( $n = 1$  intracerebral hemorrhage,  $n = 1$  resuscitation due to acute respiratory insufficiency). Operation had to be interrupted in 6 patients (hemorrhage  $n = 3$ , disturbance of ventilation  $n = 2$ , intraoperative psychosis  $n = 1$ ). While no infection of the hardware occurred, other complications were dislocation of the hardware ( $n = 3$ ), pain at the site of the stimulation device ( $n = 1$ ), scar formation at the electrodes ( $n = 1$ ). Revision of the hardware was necessary in 6 patients (2.8%).

**Conclusion:** Although complications of DBS surgery performed for treatment of movement disorders are rare, some of them can be serious and even fatal. Therefore a careful patient selection and informed consent is crucial, combined with experienced intraoperative surgical routine in high-load centers.

**Keywords:** Surgical complications; deep brain stimulation.

### 3A17

#### Methodology for Assessment Tremor Activity during Deep Brain Surgery for Dyskinesia

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**Objective:** The present study was focused on tremor assessment during deep brain surgery for dyskinesia under the effects of electrical stimulation.

*Patients and method:* Surface EMG of index finger abducting contractions and an optional elastic resistance pressure variations were recorded. The three parameters, frequency (Hz), amplitude, and occurrence of tremor were analyzed in Labview environment.

In a total number of 26 dyskinesia patients where different stereotactic targets (Vim and GPi) were used for movement disorders control. There were 14 men and 12 women. The mean age was 56 years old with a range between 32 to 74 years. There were 16 pallidotomies and 10 thalamotomies. All patients exhausted drug therapy or did not respond or tolerate it. They were assessed sequentially using United Parkinsonian Disease Rating Scale, Schwab and England Scale and Hohen and Yahr Score.

*Results:* An improvement was recorded in all patients. No major complications were encountered. We review the relationship between target neurophysiological electrical stimulation and electromyographic activity during tremor. These results demonstrated an earlier reaction at lower stimulation thresholds when compared to direct observation of a trained neurologist. In stereotactic pallidotomy and thalamotomy for Parkinson's disease, care must be taken to choose the best target and to avoid unnecessary large lesions. Intraoperative EMG monitoring provides an adjunct to improve reliability of assessment of target stimulation while grounding documentation of lesion effects.

Tremor inducing neurons responses to stimulation were analyzed. The lowest stimulation tremor suppression electrical threshold was used to select the optimal lesion site.

*Conclusion:* Use of EMG recording during stimulation and lesioning is a objective and efficient method.

*Keywords:* Radiosurgery; tremor; electromyography; targeting.

### 3B11

#### **Amygdalohippocampal Deep Brain Stimulation for Refractory Temporal Lobe Epilepsy**

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*Objectives:* To develop a novel treatment modality for patients with refractory temporal lobe epilepsy, who are not good candidates for respective surgery.

*Materials/methods:* Nine patients suffering from refractory temporal lobe epilepsy with complex partial seizures but negative MRI findings were investigated invasively. Amygdala and hippocampus were bilaterally provided with two electrodes of four contacts each, by which a uni- or bilateral ictal onset in the temporal lobe structures was proven. The same electrodes were used for deep brain stimulation (DBS) in an acute setting (external battery). If a more than 50% reduction of interictal spikes could be obtained, the treatment was continued with an implanted pulse generator.

*Results:* Eight patients are being treated in a chronic setting. The follow-up period ranges from 6 to 22 months. In 4 patients, seizure frequency was reduced by more than 50%, with 1 patient being seizure-free. In 1 patient seizure frequency reduction was 25%; another patient was a non-responder. The results were obtained without adding any anti-epileptic drug. In 4 patients, one or two anti-epileptic drugs could instead be tapered. No side-effects were observed.

*Conclusion:* Amygdalohippocampal DBS seems to be a safe and promising novel treatment for this subgroup of patients with refractory temporal lobe epilepsy.

*Keywords:* Epilepsy; deep brain stimulation; temporal lobe.

### 3B12

#### **Preliminary Results of Deep Brain Stimulation of the Mammillary Bodies and Mammillothalamic Tracts in Chronic Refractory Epilepsy**

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*Objective:* To document the safety and the potential efficacy of chronic electrical stimulation (ES) of the mammillary bodies (MBs) and the mammillothalamic tracts (MTTs) in patients with chronic refractory epilepsy (CRE).

*Patients and methods:* It is a prospective, randomised and double-blinded study. Three chronic epileptic males (41–43 years) were included in this study after obtaining the ethical committee's approval as well a written informed consent from each patient. Their seizures remained intractable despite the different antiepileptic treatment trials. Vagus nerve stimulation (VNS) was implemented in all patients but without significant antiseizure benefit. The epilepsy aetiology was a hypothalamic hamartoma in the first patient while it was cryptogenic in the other two. VNS was turned off six weeks before implantation without modifying the antiepileptic treatment. EEG-video, PET scan and neuropsychological examinations were performed through the different phases of the study.

*Results:* We implanted our three patients between May and September 2003. So far, the following important observations can be reported. The MB and the MTT can be targeted safely without transient or permanent postoperative complications. We did not observe any aggravation or alteration of the seizures' pattern. No neuro-cognitive function impairment was recorded. Ictal epileptic discharges for the first time were recorded in the normal MBs in the second patient. All patients reported to be improved after surgery even if they did not know whether the stimulator was on or not. However, conclusions regarding this procedure must wait the study completion.

*Conclusion:* At this time of our study, we observed that the electrode implantation and brief stimulation tests within the MB and MTT did not induce any neuropsychological deficits. We registered epileptiform activities, and ictal discharges from the MB without any simultaneous scalp changes.

*Keywords:* Epilepsy; deep brain stimulation; mammillary bodies.

### 3B13

#### **Centromedian Thalamic Nucleus Stimulation in the Treatment of Difficult to Control Seizures of the Lennox-Gastaut Syndrome**

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*Introduction:* Electrical stimulation of the centromedian thalamic nucleus (ESCM) has been used to treat refractory seizures in

patients not candidates for standard ablative procedures. Best results have been obtained in controlling generalized tonic clonic seizures (GTCS) and atypical absences (AA) that are severe in Lennox-Gastaut Syndrome (LGS).

**Methods:** Eleven patients were studied. All of them had LGS i.e. GTCS and AA, slow spike and wave (SK-W) complexes; 5 with demonstrable lesions in the MRI and 6 idiopathic. All of them were resistant to medical treatment and regardless of using supra-therapeutic AED presented from 18 to 2000 seizures/month (1353 average). Bilateral Deep Brain Stimulation (DBS) electrodes were stereotactically implanted through a frontal parasagittal approach guided by ventriculography. The target was the angle formed by the AC-PC and VPC lines, 10–12 mm lateral to the midline in each side. Recruiting responses elicited by 6 cps stimulation through different contacts of the electrodes confirmed correct position of the electrodes. Intermittent ESCM in each side, 1 min ON, 9 min OFF, alternating right and left sides at 0.45 ms duration, 2.5–3.5 V amplitude and 60–130 Hz frequency of stimulation was used for chronic ESCM.

**Results:** Improvement of the total number of seizures ranged from 53.1% to 100% (mean 85.5%), 2 patients became seizure free and 8/11 had over 80% improvement. GTCS disappeared in 7/11. SK-W complexes decreased 83.8% and in 4 patients EEG normalized. AED were maintained in all patients at therapeutic levels except in the 2 seizure free patients in whom medication was stopped. Seven patients are back to school of work. Five patients (3 of them children) presented skin erosions over the internalized stimulation device. There were no deaths. ESCM is a safe and effective procedure to control seizures in the LGS.

**Keywords:** Epilepsy; neuromodulation; centromedian nucleus; Lennox-Gastaut Syndrome.

### 3B14

#### Interstitial Stereotactic Radiosurgery for Lesional Epilepsy

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**Objective:** Small circumscribed low-grade gliomas mainly present with intractable epilepsy. Interstitial stereotactic radiosurgery as an alternative to surgery has been effective for temporal lesional epilepsy. We performed a study on extra temporal lesional epilepsy using interstitial radiosurgery.

**Methods:** 23 patients with histologically proven low-grade gliomas have been studied with a median follow-up of 16.2 months after Iodine-125 interstitial radiosurgery. Maximum tumour diameter was 3.5 cm. All patients were treated with 60 Gy to the tumour margin. Dose rate was 10 cGy per hour. Follow-up was done clinically with MRs and a comparison of pre-radiosurgery to post-radiosurgery Proton-MR spectroscopy every 6 months.

**Results:** Out of 23 patients, 19 have become seizure free (Engel class I) 3 patients had a significant, more than 75% reduction of seizure frequency (Engel class II) and 1 patient had no change. According to the MacDonald classification of tumor response 4 patients had a complete response. 17 patients had a partial response. 2 patients had stable disease. All patients with a complete response had Engel class I outcome and the other 15 patients with Engel class I outcome had partial responses. The choline/creatinine ratio was of tumours dropped from a median of  $1.62 \pm .4$  before radiosurgery to  $1.02 \pm .31$  after radiosurgery (3 month follow-up) in patients with Engel class I with no change ( $1.38 \pm .4$ ) in the rest.

**Conclusions:** Interstitial stereotactic radiosurgery in small circumscribed low-grade gliomas is not only an efficient tumour treatment but highly effective for the treatment of concomitant epilepsy. Furthermore MR spectroscopy might allow to predict seizure outcome early after interstitial radiosurgery using the choline/creatinine equation.

**Keywords:** Epilepsy; radiosurgery.

### 3B15

#### Surgery for Posterior Quadrantic Epilepsy (Temporo-Parieto-Occipital): Evolution of Techniques and Results

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**Objectives:** Describe the evolution of the surgical techniques and the results obtained in the treatment of multilobar temporo-parieto-occipital refractory epilepsy in 11 patients.

**Material and methods:** 11 patients 6 males, 5 females; age 3½ months to 42 years (mean 17.6, median 18); age at seizure onset, birth to 24 years (mean 4.7, median 3.1); duration of seizures, 0.2 to 39 years (mean 12.9, median 11.5); seizure frequency 4 to 40 per day; laterality of lesion/focus, 7 right, 4 left. All underwent an epilepsy presurgical evaluation. Six patients underwent an anatomical temporo-parieto-occipital resection, 4 a temporal lobectomy and parieto-occipital disconnection, and 1 a temporo-parieto-occipital disconnection. Pathology: dysplasia in 3, Sturge-Weber in 2, ruptured AVM in 1, prenatal vascular insult in 5.

**Results:** Follow-up ranges from 1 to 15 years (mean 7.6, median 6); there were no surgical complications; there were no permanent morbidity; one patient suffered a transient worsening of hemiparesis; seizure outcome according to Engel's classification is as follows: 9 patients Class IA, 1 patient Class IB, 1 patient Class 3A.

**Conclusion:** Posterior quadrantic refractory epilepsy is amenable to surgical treatment with excellent seizure outcome and low surgical morbidity.

According to the anatomical/pathological substrate, three surgical techniques to eliminate the influence of the temporo-parieto-occipital lobes are available. One consist in anatomical removal, one in a combination of excision and disconnection, and the other in disconnection. The three surgical approaches offer similar results.

**Keywords:** Epilepsy; multilobar surgery.

### 3B16

#### Selective Transsylvian Amygdalohippocampectomy for Mesial Temporal Lobe Epilepsy – An Analysis of Postoperative Seizure Outcome

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**Purpose:** To study the postoperative outcome with respect to epileptic seizures after a particular surgical procedure used for treatment of medically intractable mesial temporal lobe epilepsy.

**Patients:** 110 patients suffering from mesial temporal lobe epilepsy were operated between the years 1994 and 2003 at the Department of Neurosurgery of the Medical University of Vienna using the transylvian approach for selective amygdalohippocampectomy. The choice of the operative procedure was based on data from the presurgical evaluation and decision was made in interdisciplinary case conferences. Outcome was analyzed at the time points 12, 24, and 60 months after the operation. Seizure outcome was evaluated according to the new ILAE classification proposed by Wieser *et al.*

**Results:** Postoperative follow up was available for 99 patients at 12 months, for 82 patients at 24 months, and for 48 patients at 60 months after surgery. 12 months after surgery seizure outcome was class 1 in 62%, class 2 in 6%, class 3 and 4 in 14%, and class 5 in 4% of the patients; 24 months after surgery seizure outcome was class 1 in 63%, class 2 in 2.4%, class 3 in 12%, class 4 in 16%, and class 5 in 6% of the patients; 60 months after surgery seizure outcome was class 1 in 71%, class 2 in 4%, class 3 in 10%, and class 4 in 8% of the patients. In 2 patients surgery could not significantly reduce the number of seizure days per year (class 5), in one patient an increase of baseline seizure days was reported 60 months after the operation (class 6).

**Conclusion:** Selective amygdalohippocampectomy is an effective surgical treatment of mesial temporal lobe epilepsy. The seizure outcome accords with results of larger temporal resections that include mesial temporal structures. Thus, these data support the concept of a limited resection in selected patients with mesial temporal lobe epilepsy.

**Keyword:** Epilepsy.

## Reference

Wieser HG, Blume WT, Fish D, Goldensohn E, Hufnagel A, King D, Sperling MR, Lüders H (2001) Proposal for a new classification of outcome with respect to epileptic seizures following epilepsy surgery. *Epilepsia* 42(2): 282–286

## 3B17

### The Intractable Epilepsy Problem in Developing Countries: Is there a Way Out?

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**Introduction:** Epidemiological studies estimate one million people in India with intractable epilepsy. However, like all developing countries, epilepsy surgery is underutilised in India with only 650 cases having been operated at two major centres. Evidently, this is just a drop in the ocean. The non-availability of intra-operative electrocorticography (ECoG) and SPECT/video-EEG (VEEG) used for preoperative evaluation has restricted this programme to big centres.

**Aims and objectives:** We wished to see how many of our operated cases could have been operated without VEEG, SPECT and ECoG at slightly smaller centers with only EEG, MRI and facilities for a standard anteromedial temporal lobectomy (AMTL).

**Results:** All 155 cases of intractable epilepsy operated at our centre have been included—this included 7 corpus callosotomies, 3

hemispherotomies and 46 lesionectomies under ECoG guidance. Ninety-nine patients underwent standard AMTL without ECoG guidance for Mesial Temporal Sclerosis (MTS)/lesional temporal lobe epilepsy. Among these 99, MRI identified the side of MTS/temporal focus correctly in 90. Three had features of bilateral MTS, 2 had bilateral foci of gliosis and 4 had normal MRI's, all these patients evidently requiring detailed evaluation. Among the 90, VEEG revealed discordant foci (to the MRI identified focus) in 13 and was non-contributory in 8. Ultimately, even the 13 patients with discordant VEEG underwent AMTL on the MRI identified side and all 13 had good seizure outcome. SPECT was non-contributory in 9 of these 90 patients and revealed discordant foci in 4. All the 4 with discordant SPECT localisation ultimately underwent AMTL on the MRI identified side with good outcome. SPECT/VEEG was therefore USEFUL in only 9 patients with EQUIVOCAL MRI findings. All 90 patients with CLEAR-CUT MRI localization had NOTHING ADDED BY VEEG/SPECT. Therefore 90 of our 155 patients (58%) could have undergone surgery at a centre equipped with only EEG, MRI and AMTL facilities. Our Class I seizure outcome rates are comparable to international standards (75% for AMTL and 73% for lesionectomies).

**Conclusion:** The need of the hour for developing countries is to create AWARENESS regarding epilepsy surgery and creation of a 2 TIERED epilepsy surgery programme. The FIRST TIER equipped with EEG, MRI and trained neurologists, neurosurgeons and neuroradiologists can undertake AMTL which is a large proportion of the epilepsy surgery burden. More complicated cases can be referred to bigger centres. This strategy is likely to popularise epilepsy surgery but would definitely require strict surveillance.

**Keywords:** Epilepsy; developing-countries.

## 3C11

### Stereotactic Coregistration of Thallium SPECT and MRI Applied to Brain Tumor Biopsies

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**Objective:** MR or CT images acquired under stereotactic conditions are often used to plan and guide brain tumor biopsies. The objective of this study was to improve and validate our methodology to increase target selection reliability by acquiring stereotactic 201TI-SPECT data and by integrating them into the surgical planning.

**Methods:** The three-headed Philips gamma camera system (Prism 3000) was adapted to stereotactic acquisitions: An examination table as well as a clamp fixed to the table were specifically designed to secure the stereotactic LEKSELL G-frame and to provide perfect alignment of the localizer with the SPECT gantry. A homemade software was applied for the stereotactic target determination based on SPECT images (pixel with the highest metabolic activity inside the tumor). The whole system accuracy

was tested with the ELEKTA phantom adapted to SPECT imaging. The methodology was applied to two brain tumor biopsies.

**Results:** Comparison of the specific phantom coordinates evaluated in SPECT with the theoretical ones did not reveal any significant difference. In this way, our methodology including our homemade software (identification of the stereotactic frame, determination of the pixel with highest metabolic activity within the tumor in the stereotactic coordinate system) was validated. No significant geometric deformations were detected. Clinical feasibility was confirmed in two patients presenting with brain gliomas.

**Conclusion:** This study illustrates the feasibility and the accuracy of SPECT acquisitions with the stereotactic Leksell G-frame. The clinical relevance of this methodology is under evaluation. This definition of the target, based on the point with the highest metabolic activity within the tumor, might lead to actually biopsy the zone with the highest grade of malignancy and to improve patient management. Furthermore, it might prepare the future for therapy aimed at delivering a therapeutic agent within a tumor.

**Keyword:** Brain tumors.

### 3C12

#### **Molecular and Immunohistochemical Determination of FAS Receptor Encoding Gene and FAS Protein in Stereotactic Biopsies of Brain Gliomas**

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**Introduction:** The search for additional markers indicating a proliferative or apoptotic cell activity is continuously under way. One of the serious diagnostic problems is accurate determination of the type of glioma, that affects treatment and prognosis for further course of the disease.

An attempt was made to supplement such evaluation with molecular examinations of stereotactic biopsies cytologic slides and immunohistochemical investigation in paraffin slides of different gliomas.

**Objective:** The objective of the study was to determine transcriptional activity of the FAS receptor encoding gene, which is capable of transmitting cell death and proliferation signals, and to correlate it with the intensity of immunohistochemical FAS reaction in various gliomas.

**Materials and methods:** The material used in the study was RNA extract obtained from 15 gliomas: 5 fibrillary, 5 gemistocytic and 5 anaplastic astrocytomas. The expression of the genes examined was evaluated with the RT-QPCR technique (TaqMan), using an ABI PRISM 7700 sequence detector and hybridisation probes marked with fluorescent markers FAM and TAMRA. The immunohistochemical reaction was done using Novocastra monoclonal antibodies. The tumor diagnoses were based on WHO 2000 classification.

**Discussion and conclusion:** The presence of FAS receptor mRNA was found in all cases. The number of copies of mRNA RFAS, recalculated into  $\mu\text{g}$  total RNA were lower in fibrillary than in gemistocytic astrocytomas and the higher in anaplastic astrocytomas. The intensity of immunohistochemical reaction for FAS was increas-

ing with the degree of astrocytomas malignancy. The observed phenomenon may be related to a more pronounced tendency of the gemistocytic astrocytomas to become malignant, it suggests too the correlation of the presence of FAS receptor encoding gene and FAS protein with the astrocytic tumors malignancy degree.

**Keywords:** Stereotactic biopsy of tumors; astrocytoma; FAS receptor encoding gene; FAS protein.

### 3C13

#### **Gamma Knife Radiosurgery for Idiopathic Trigeminal Neuralgia Using 90-Gy at the Plexus Triangularis**

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**Introduction:** Gamma Knife Radiosurgery (GKR) is an increasingly used surgical option for patients with medically refractory idiopathic trigeminal neuralgia (iTN). However, the optimal irradiation dose and target remains to be defined. We analyzed the results of GKR using a high dose and a distal target.

**Materials and methods:** Forty-seven patients with iTN were treated using a distal intracisternal (plexus triangularis) target and a maximum dose of 90 Gy. All patients were followed clinically and with MRI at 6 weeks, 6 months and 1 year after surgery. We analyzed 15 potential prognostic factors of effective pain control after GKR.

**Results:** Mean follow-up was 16 months (range 6–42 months). Initial pain relief was excellent (100% pain control) for 32 patients, good (>90% pain control) for 7 patients, fair (<90% pain control) for 3 patients and poor (<50% pain control) for 5 patients. Actuarial curve of pain relief showed excellent or excellent good pain control at 42 months after GKR for respectively 59% and 71%. Radiosurgery-induced facial numbness was bothersome for 2 patients and mild for 18 patients; no other complication occurred. Three prognostic factors were found to be statistically significant factors of successful pain relief: a shorter distance between target and brainstem, a higher irradiation dose to the brainstem and the development of facial sensory disturbance after GKR.

**Conclusions:** To obtain a low rate of complications and a high rate of pain control, we recommend placing the irradiation target at a distance of 5 to 8 mm of the brainstem, in order to irradiate the first 1 and 10 mm<sup>3</sup> of the brainstem with a dose of 13 to 15 and 10 to 12 Gy, respectively. We postulate that the response of iTN to GKR may be, at least partially, due to the structural modifications into the brainstem induced by the radiosurgical irradiation.

**Keywords:** Radiosurgery; pain.

### 3C14

#### **Deep Brain Stimulation for the Treatment of Chronic Pain**

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**Objective:** Electrical intracranial stimulation (deep brain stimulation = DBS) is a tool for the treatment of chronic pain states which did not respond to less invasive more conservative treatment techniques. Careful patient selection, accurate target localization

and identification with neurophysiological techniques as well as blinded test evaluation are the key requirements for a good long-term outcome.

**Methods:** 52 patients with different forms of neuropathic and mixed nociceptive/neuropathic pain were treated with DBS according to a rigorous protocol. The follow-up ranged from 1 year up to 8 years with a mean of 3.5 years. Electrodes were implanted in the medial thalamus and lateral thalamus. A careful double-blinded test evaluation was carried out to test the effect of each electrode itself and combined stimulation with different parameter settings.

**Results:** The best long-term results were yielded in patients with chronic low back and leg pain, e.g. in failed back surgery syndrome. Also patients with neuropathic pain of peripheral origin (e.g. CRPS II) responded well to DBS. Disappointing results were yielded in patients with central pain syndromes as pain due to spinal cord injury and poststroke pain.

**Conclusion:** According to the results in this study DBS can be helpful and add to quality of life in highly selected patients with chronic pain syndromes. However patients should be treated in a multidisciplinary pain clinic before being referred to a neurosurgeon for DBS and finally psychiatric and psychological testing should be carried out before considering a patient for DBS implantation. Possible reasons for the therapeutic failures as central reorganization and neuroplastic changes of the pain transmitting pathways and pain modulation centres after brain and spinal cord lesions are discussed.

**Keywords:** Pain; DBS.

### 3C15

#### **A Dorsal Unilateral Minimal Invasive Laminotomy Technique for Placement of Epidural Electrodes for Spinal Cord Stimulation: The “Duffel Technique”**

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**Objectives:** To develop a surgical procedure to use for laminectomy-style electrodes for spinal cord stimulation (SCS), which has to be less painful than the classical laminectomy.

**Materials and methods:** Electrode placement by laminectomy for SCS is a technique with advantages on the long term compared to the percutaneous electrode placement. Though only a small laminectomy is performed, this procedure is rather painful and uncomfortable for the patient, the first postoperative days. Often later the patient has tender spots on the laminectomy site. This new technique tries to avoid too much soft tissue damage by performing a unilateral muscular deglovement and by avoiding the interspinous ligament. Then a small laminotomy is performed with a high speed drill, followed by a partial flavectomy. If this is done up to the midline, a correct placement of the electrode is possible.

**Results:** The patients on whom we applied this technique had less postoperative pain and a lower postoperative visual analog score than the previous laminectomies, concerning the dorsal postoperative pain. That's why a single blind prospective study with independent observer is currently being made.

**Conclusion:** The first results of this “Duffel technique”, a variation on the laminectomy technique for placement of epidural electrodes, show not only its feasibility but also its utility on the postoperative pain, though statistical analysis cannot yet be made.

**Keywords:** Pain; spinal cord stimulation; operative nuances.

### 3C16

#### **Microsurgical DREZ Operation Utilizing Two Different DREZ Lesioning Techniques – Comparative Analysis of the Results Achieved in Treating Pain of Spinal Cord and Cauda Equina Injury Origin**

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The DREZ (Dorsal Root Entry Zone lesion) operation has been designed to destroy anatomical structure involved in paraplegic pain generating i.e. dorsal horn of the deafferented cord segments thus interrupting neuropathic pain mechanism. The DREZ surgery has been performed by using different DREZ lesioning, such as Radio-frequency, Laser, Ultrasound, Microsurgical DREZotomy (MDT) technique. It is believed that the long-term result of the DREZ surgery depends on size and completeness of the DREZ lesion performed.

The purpose of the study was to assess the influence of the DREZ lesioning technique on the long term result in treating paraplegic pain using DREZ operation.

**Materials and methods:** We analysed the result of the pain treatment in the group of 30 patients (27 males and 3 females, of mean age 38 years and follow-up period 37–73 months) operated on by employing two different DREZ lesioning technique.

The Sindou's Microsurgical DREZotomy was utilized in 18 patients.

12 patients were operated on by employing a modality of the Microsurgical DREZotomy technique that included suction of the dorsal horn gray substance as a lesioning method instead of bipolar coagulation. The dorsal horn suction as a DREZ surgical lesioning technique has been established on the difference in tissue elasticity between white and gray cord substance. Experimental testing revealed that dorsal horn suction lesioning achieved more extensive lesion of the dorsal horn comparing to the lesion achieved with bipolar coagulation technique.

**Results:** In the follow up period observed, Microsurgical DREZotomy achieved good long-term pain relief in 67% patients while the MDT modified with dorsal horn suctioning achieved good long-term pain relief in 83% patients.

**Conclusion:** Our results implied that the size and shape i.e. completeness of the DREZ lesion may play a significant role in providing better long-term results of the DREZ operation used for the paraplegic pain treatment.

**Keywords:** Pain; spinal injury; neuropathic pain; DREZ surgery.

### 3C17

#### **Medial Thalamotomy in Chronic Pain Management – Still an Option in Selected Cases**

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**Objectives:** This study analyzes experience with medial thalamotomy in patients with chronic refractory pain in the head region.

*Materials/methods:* After resuming stereotactic operations in 2003 during one year period 8 medial thalamotomies were performed in 7 patients (1 male, 6 females). Mean age of patients was 62. Six patients had refractory atypical pain due to trigeminal neuralgia, one patient had refractory cluster headache. All patients previously had undergone microvascular decompression and partial rhizotomy of appropriate cranial nerves without expected pain relief. For stereotactic operation ZD stereotactic frame (Stryker-Leibinger) was used. CT scanning with stereotactic frame was performed and acquired images were fused with MRI 3-D sequence scans without frame. Coordinate calculation was done using Medtronic FrameLink Mach 4.1 software on Stealth Station neuronavigation workstation. As target points in the thalamus the following structures were selected – centrum medianum, dorsomedian nucleus, ventral posteromedial nucleus. Macrostimulation using Neuro-50 device was performed for target verification. Up to 3 to 4 thalamic RF lesions were done in each patient.

*Results:* All patients reported at least partial pain relief in the early postoperative period during hospital stay. In one patient additional lesioning was performed after 6 months with finally satisfactory effect. One patient had developed pain in another trigeminal branch. Three patients had partial pain relief after 3–6 months follow up.

*Conclusion:* Medial thalamotomy still may be beneficial pain relieving procedure, but possibility of recurrence remains. Appropriate patient selection is important.

*Keyword:* Pain.

### 3C18

#### **The Effect of Changes in the Auditory Brain-Stem Responses on Hearing during Microvascular Decompression for Trigeminal Neuralgia – An Assessment**

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*Objective:* To assess the significance of minor changes in brain stem auditory evoked responses during microvascular decompression for trigeminal neuralgia on postoperative hearing thresholds.

*Materials and methods:* Hearing was monitored preoperatively and post-operatively in 75 consecutive patients undergoing microvascular decompression for trigeminal neuralgia. Hearing thresholds were established preoperatively and two days postoperatively. During the surgical procedure the cochlear nerve was monitored using auditory brain stem responses by recording the waves I to V.

*Results:* In the majority of the patients there were no changes in hearing thresholds noted postoperatively. In eleven patients the hearing threshold improved on an average by 5 db over the speech frequencies. In nine cases the hearing became worse by an average of 10 db over the speech frequencies. This correlated with a latency shift of wave V preoperatively. In subjects where there was no change in hearing the average change in the I–V interval was 0.06 ms from beginning to end of operation. In the group in which hearing deteriorated the average increase was 0.9 ms.

*Conclusion:* Although well recognised that loss of the auditory evoked response will predict permanent hearing loss postoperatively, more subtle latency shifts (as low as 0.9 ms) are associated with measurable hearing threshold deterioration. This degree of change is often not noticed by the patient.

*Keyword:* Trigeminal neuralgia.

### 3C19

#### **Long Term Outcome of Cervical Spinal Cord Stimulation (CSCS) for Chronic Pain**

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*Introduction:* Although spinal cord stimulation is an accepted treatment for chronic pain, few reports in the literature specifically address the results of CSCS1. A retrospective study was therefore undertaken to assess the long-term outcomes indications and complications of CSCS.

*Methods:* Those patients treated by CSCS between 1994 and 2001 were included. Case records were reviewed to obtain information concerning indications, complications and in particular the clinicians' assessment of pain relief. Additionally a postal questionnaire was administered to measure patients' assessment of pain relief and overall satisfaction.

*Results:* 42 patients were identified with CSCS implants during this period. The mean follow up was 44 months (range 13–88 months). All patients underwent a percutaneous trial prior to implantation with a surgical electrode placed by laminotomy. 38% had complex regional pain syndrome, 23% brachial plexus injuries, and other diagnoses included phantom limb, stump, and facial pain. The questionnaire response rate was 71% (30/42). Patient reported pain relief was >50% in 21/30 (70%). Clinician reported relief was >50% in 23/30 (76%) of those who responded, in non-responders this was 8/12 (66%). 14 patients required revision operations.

*Conclusion:* The long-term outcome of CSCS is good or excellent in over 70% of patients, a figure comparable to patients implanted with thoracic electrodes. The revision rate, though significant is not appreciably higher than a comparable group with thoracic electrodes.

It is concluded that this is a worthwhile treatment for these groups of patients.

*Keywords:* Pain; spinal cord stimulation.

### Reference

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### 3C20

#### **Sleep Studies in a Patient with Major Depression Disorder (MDD) Treated by Chronic Electrical Stimulation of the Inferior Thalamic Peduncles (ITP)**

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*Objective:* To investigate the effect of chronic electric stimulation of the ITP (a bundle of fibers connecting the Nucleus Reticularis Thalami with the Orbito-Frontal Cortex) on sleep cycles in a patient with MDD.

**Methods:** In a patient with MDD refractory to psychotherapy, pharmacotherapy, and electroconvulsive therapy, and depth electrodes bilaterally implanted in ITP (coordinates AP = 3.0 mm posterior to AC, L = 5.0 mm from the midline, and H = at the level of the midline) four consecutive all night sleep studies were performed according to International Guidelines: 1) before surgery, 2) after electrode implantation and prior to stimulation 3) after the subacute stimulation (20 days), and 4) after chronic stimulation of the ITP (3 months). Parameters: continuous stimulation with bipolar “Lilly” pulses, frequency = 130 Hz, duration = 0.450 s, and amplitude = 200 to 400  $\mu$ A. Changes in the sleep cycles were compared both: between conditions and with a group of normal patients. Significance of changes was statistically calculated by means of non-parametric Wilcoxon Tests.

**Results:** During the first study, the hypnogram showed a decrease of the sleep efficiency, particularly that of phase II, an increase of wakefulness and number of arousals and absence of REM sleep. During the second study, (electrode implantation), the sleep stages tended to normalize, while during the third study (subacute stimulation) the sleep cycles were again disrupted. In contrast, the fourth study (chronic stimulation) normalized the sleep phases.

**Conclusion:** These data suggest on one hand, that MDD is associated to a disruption in the function of a thalamo-orbitofrontal system responsible for sleep spindles and stage II, and on the other, that the beneficial effect of ITP stimulation in patients with MDD is due, at least in part, to a process that initially increases wakefulness (subacute stimulation) and subsequently, normalizes the night sleep (chronic stimulation).

**Keywords:** Neuromodulation; ITP; thalamo-cortical system; MDD.

### 3C21

#### Spinal Stereotactic Radiosurgery. A Non-Invasive Technique for the Treatment of Spinal Lesions

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**Objectives:** Image-guided Spinal Stereotactic Radiosurgery (SSRS) is a new rapidly growing field applying the basics of Stereotactic Radiosurgery (SRS) to treat spinal lesions by non-invasive means. We present our own technique of LINAC-based SSRS.

**Material and methods:** First we proceed to treatment simulation and planning. A key point is patient's immobilization with the Stereotactic Body Frame (SBF, Elekta). Then we achieve images acquisition through virtual simulation with CT GEMS Prospeed and GEMMS Advantage Sim Station, followed by dosimetry planning with IGR Dosigray System, and calculation of PTV, GTV and CTV Treatment Volumes.

Second we proceed to the irradiation treatment, verifying the coincidence between laser and radiation beams and between the mechanical-laser and radiation isocenters, within 1 mm accuracy. The final radiation treatment is performed in one session with a LINAC Elekta Sli 18 with 15 MV photons and a multileaf collimator (MLCi). A portal view allows for verification of the accuracy of the treatment beam during the irradiation process.

The total dose administered in spinal pathology is 10–12 Gy, with a margin dose of 8 Gy maximum in the spinal cord. An isocenter in the 98–100% volume isodose is established that entails

the required PTV. The maximum tolerance level for the spinal cord is less than 6 Gy.

**Results:** The system described achieves an overall accuracy within 1 mm and delivers a typical treatment dose of 10–12 Gy for spinal lesions, with minimal impairment of the spinal cord. The system has been used in a small series of patients with spinal lesions. System and initial results are presented.

**Conclusion:** A system for image-guided SSRS is presented that achieves great accuracy. Nevertheless as a novel technique greater clinical series and longer FUs are needed to establish its definite indications and results. The neurosurgical community should not undervalue the promising and growing possibilities of this technique.

**Keywords:** Radiosurgery; spinal image-guided radiosurgery.

### 3C22

#### Gamma Knife Radiosurgery Guided by Combined MRI and PET for the Treatment of Glial Tumors in Children

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**Introduction:** The optimal management of children with glial tumors remains a challenge. We have evaluated the safety and efficacy of GKR as an adjunctive therapy for those children, using a procedure under general anaesthesia with a combination of both MRI and PET imaging.

**Materials and methods:** Seven children under the age of 15 years have been treated by GKR for a glial tumor. Median age was 5 years (extreme 2–13). All patients were treated for a post-operative evolutive residue of a histologically confirmed tumor; there was 3 pilocytic astrocytoma, 1 grade II astrocytoma, 1 glioblastoma, 1 low-grade ependymoma, and 1 high-grade ependymoma. All patients underwent a GKR procedure under general anaesthesia with the use of combined MR and PET imagings for targeting. The radiotracer used for PET was fluoro-deoxy-glucose in 2 patients and [11C] methionine in 5 patients.

**Results:** The mean target volume was 3230 mm<sup>3</sup>, and the mean irradiation dose was 14 Gy at the 50% isodose. PET was found to be useful to define the optimal target for 4 patients, because it increased the tumor volume identified on MR. No complication occurred during as well as after the GK procedure under general anaesthesia. The mean follow-up period is 10 months; 1 patient died during follow-up and 6 patients are alive.

**Conclusions:** GKR under general anaesthesia using combined MRI and PET imaging is a safe procedure, and may be an effective treatment as an adjunctive therapy for the management of glial tumors in children. PET guidance can be performed without difficulty during a GKR procedure under general anaesthesia, and seems to improve delineation of the optimal target for infiltrative tumors.

**Keyword:** Radiosurgery.

### 3C23

#### Is Intensity Modulation Useful in Radiosurgery? An Analysis of Clinical Applications of IMRS

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*Objective:* The aim of our study was to analyze treatment plans in order to find the most frequent situations when intensity modulation was used and, thus, to determine the possible indications for IMRS.

*Material and methods:* Thirty-three treatment plans of IMRS of 220 made for radiosurgery between October 2001 and February 2003 were analyzed. The reasons for which radiosurgery was performed are presented in Table 1.

**Table 1.**

Indications for radiosurgery	Count	Percent
Parasellar tumor	4	12
Parapontine meningioma	1	3
Recurrent glioma	5	15
Acoustic tumor	6	18
Residual glioma (boost)	3	9
Brain metastases	11	33
Arteriovenous malformation	3	9

*Results:* IMRS was most commonly used when target volume was localized in the vicinity of organs at risk (17 cases – 51%). In 7 of these cases the need for intensity modulation was caused both by the necessity of sparing organs at risk and geometric complexity of irradiated volume. In 15 cases (45%), including the mentioned above, complex shape of target volume was the reason of intensity modulation application. In 4 cases (12%) – multiple target volumes. In 3 cases (9%) – dose escalation within the irradiated volume (boost on gross tumor volume inside the PTV). In two cases the use of intensity modulation was the only way to obtain optimal dose distribution in the target volume of simple shape, located away of organs at risk.

*Conclusions:* Intensity modulation in radiosurgery is a very attractive option when there is a need for irradiation volumes close to organs at risk. It is also useful when “conventional” conformal techniques cannot assure optimal dose distribution in target volumes of complex shapes. Finally, it is a convenient way to boost gross tumor volume inside the PTV when prescribed dose is delivered in single fraction.

*Keyword:* Radiosurgery; IMRS; IMRT; brain tumours.

### 3C24

#### Microsurgical Selective Obturator Neurotomy for Spastic Hip Adduction

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*Objectives:* The main components of the spastic hip are adduction, flexion, and internal rotation. They are harmful at rest and during walking, and threaten the stability of the hip. Especially adduction can lead to coxa valga, subluxation, and then dislocation of the hip. We report the result of microsurgical selective obturator neurotomy for 6 patients of spastic hip adduction with a follow-up longer than 6 months.

*Methods:* Microsurgical selective obturator neurotomy was to perform a microsurgical resection of the anterior branches of obturator nerve. The coagulation of the proximal end was performed to prevent the regrowth and possible neuroma formation. We used intraoperative bipolar stimulation to identify selected motor fascicles.

*Results:* All of them were operated bilaterally. Six of 12 microsurgical selective obturator neurotomies were accompanied by additional tenotomy of adductor longus where contracture was present. Selective tibial neurotomy was done in 3 of 6 patients for their spastic ankle. After operations, all spastic hip adductions without contracture were corrected immediately. There was not any surgical complication.

*Conclusions:* Microsurgical selective obturator neurotomy is an effective procedure in the treatment of localized harmful spastic hip adduction after failure of well-conducted conservative treatment. As muscular contraction is often associated with spasticity in the hip adductors, a tenotomy of them may be added to obturator neurotomy using the same approach.

*Keywords:* Spasticity; microsurgical selective obturator neurotomy.

### 3C25

#### Intrathecal Baclofen: A Mosaic of Indications for a Versatile Therapy

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*Objectives:* Intrathecal baclofen therapy (ITB) was originally developed to treat severe spinal spasticity in adults, but, few years later, it also showed remarkable efficacy in children affected by cerebral palsy (standard indications). More recently, spasticity by stroke and rare genetic and degenerative diseases was successfully treated with this therapy (new indications). The purpose of this study is to compare the efficacy of ITB in “standard” and “new” indications.

*Materials/methods:* 25 patients were treated with continuous ITB between April 2000 and Dec 2003 after an efficacy-screening test with 100 µg (adults) or 50 µg (children) of intrathecal baclofen. 13 patients (10 adult; 3 children) were affected by spinal spasticity due to systemic sclerosis, traumas, transverse myelitis or cerebral palsy (standard indications group SIG). 12 patients (new indications group NIG) were affected by rare spastic pathologies and stroke (2 Strumpell-Lorrain Syndrome, 1 spastic variant of Friedreich’s Ataxia, 2 leukodystrophy, 7 stroke).

The patients were evaluated with pre and post operative digital video clips, Ashworth and spasm scales. Moreover, they were clinically evaluated, with same criteria, in out-patient clinic manner during pump’s refill and dose adjustment (SIG mean follow-up 25 months, NIG mean follow-up 15 months).

*Results:* A stable reduction of two or more points in Ashworth and spasm scale was obtained in both groups, after

titration of the effective dose. No statistical significance in reduction of spasticity was observed between groups. A sensible difference of doses between groups was observed (SIG mean dose 125 µg/day; NIG mean dose 210 µg/day) ( $p < 0.05$ ).

**Conclusion:** Intrathecal baclofen is a versatile therapy. There are few differences about efficacy between spasticity due to systemic sclerosis, traumas, transverse myelitis (SIG) or spasticity related to stroke and rare genetic and degenerative disorders (NIG). However, in the last group of patients, high dosages of baclofen are required, probably, to reach supraspinal pharmacological targets.

**Keyword:** Spasticity.

#### 4A10

##### **Function and Survival of Human Mesencephalic Neural and Neuronal Stem Cell Transplants in the 6-OHDA Parkinson Model of the Rat**

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**Objectives:** The effects of region specific human mesencephalic neural and neuronal SC transplantation were evaluated in the unilateral 6-OHDA rodent model.

**Materials/methods:** Dissociated human brain tissue cultures were prepared and neural stem cells were generated under low oxygen conditions (1 O<sub>2</sub>). Neural SC were sorted following MACS sorting with an ENCAM monoclonal antibody. Rotational behaviour of 6-OHDA-lesioned female Wistar rats was analysed 2 weeks after lesion by rotation test using amphetamine (5 mg/kg). 6 weeks following lesioning, rats received intrastriatal transplants according to the following protocol:

Stem cells Cell number Immunosuppression

Group1 (G1) unsorted neural SC  $2 \times 10^5$  no Cyclosporin A

Group2 (G2) unsorted neural SC  $2 \times 10^5$  Cyclosporin A (10 mg kg<sup>-1</sup>)

Group3 (G3) sorted neuronal SC  $8 \times 10^4$  no Cyclosporin A

After a survival time of 4 months, the brains were processed for immunocytochemistry and stained with antibodies against TH, human Nuclei, GFAP, Macrophages and Nestin. Rotational behaviour was investigated every 4 weeks for a total of 4 months.

**Results:** The test revealed a significant reduction of rotation asymmetry in animals of group G1. 80 showed less than 4 turns min<sup>-1</sup>. However, only 40 of animals receiving neural stem cells with or without CyA showed less than 4 turns min<sup>-1</sup>.

All animals showed a profound loss of dopaminergic neurons in the Substantia nigra (SN). Of all groups revealed that compensated animals showed transplant survival with human nuclei and TH immunoreactive cells. Transplanted SC showed a high potential of migration within the striatum but also along the ventricles towards the aqueduct and the lesioned

SN. In a second study SC were transplanted intrastriatal and intranigral ( $4 \times 10^4$  cells, G4), intrastriatal and intrapallidal ( $4 \times 10^4$  cells, G5) and the SN alone ( $8 \times 10^4$  cells, G6). Rotational effect and immunocytochemical analysis are expected.

**Conclusion:** Thus, this is a first report about successful transplantation of human neural and neuronal SC compensating the dopamine deficiency in 6-OHDA lesioned rats (G1-3) without major immune responses at least in animals receiving sorted neuronal cells despite lack of immunosuppression.

**Keywords:** Neurotransplantation; Parkinson's disease.

#### 4A11

##### **In Vitro Differentiation of Expanded Human Fetal Neuronal Precursor Cells**

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Cell replacement therapy, based on human fetal cell transplantation, proved to be beneficial under experimental conditions and in clinical trials. The ethical concerns and limited availability of the aborted tissue make it difficult to become a routine clinical strategy. One way to overcome these obstacles is the in vitro expansion of human fetal-derived neural precursor cells, their characterization and differentiation into the desired phenotype for further clinical applications.

Cortex (CTX) ganglionic eminences (STR), ventral mid-brains (VM) and spinal cord (SC) were obtained from elective abortions up to 12th week post conception and expanded as a free floating aggregates (neurospheres) for prolonged period of time in medium supplemented with basic fibroblast growth factor (bFGF) and epidermal growth factor (EGF). For spontaneous differentiation cells were dissociated and cultivated in mitogen-deprived culture conditions for 14 days. The induction of several neural subtypes (GABA, DA, Serotonin, ChAT) characteristic for distinctive parts of CNS was investigated applying the mitogens (SHH, FGF8, FGF4, BDNF, GDNF) involved in phenotypic specification during development of the nervous system. Immunostaining against lineage specific markers – type III  $\alpha$ -tubuline (TuJ1), microtubule associated protein 2 (MAP-2), glial fibrillary acid protein (GFAP), galactocerebroside (Gal-C) and nestin was performed. Neurons were characterized with several phenotype specific markers. The proliferative activity of the cultures was investigated with BrdU incorporation assay.

The present study demonstrates the successful long term proliferation of human fetal-derived neural precursors and differentiation into all cellular components of the CNS. The differentiation pattern was directly linked to the type of the tissue and age of the donor – resembling, in part, the ontogenetic maturation of the neuraxis. The in vitro proliferation of human fetal neural precursor cells might therefore be an alternative cell source for experimental and clinical research directed towards neural restorative strategies.

**Keywords:** Neurotransplantation; human fetal precursors.

**4A12****Primate Adult Brain Cell Autotransplantation, A New Tool for Brain Repair?**

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**Objectives:** Restoring function of the central nervous system is a challenging task, since the mature brain and spinal cord have a limited ability for self-repair. The large fetal transplantation experience mainly acquired the last two decades in the context of Parkinson's disease and Huntington's disease, has offered promising results, however, despite the great enthusiasm generated by this approach, ethical controversies and lack of fetal donors remain a major problem. Therefore, autotransplantation of adult brain cells represents an attractive restoration alternative to bypass the caveats of fetal grafting.

**Materials/methods:** Primocultures were obtained in a monkey, from an open right prefrontal cortical biopsy. Cells were grown in vitro for one month and stereotactically reimplanted in the donor. The first site was located in a ibotenic acid lesioned area of the left motor cortex corresponding to the right hand. The second site was chosen in a normal postcentral parietal cortical area. Just prior to reimplantation, cells were stained with fluorescent viable dyes (red PKH 26 for the lesioned site and green PKH 67 for the normal site). The animal was sacrificed one month later.

**Results:** Immunohistochemistry and morphological studies were performed on both sites. Autotransplanted labeled cells were shown to survive in vivo at least one month in both, the lesioned and the intact site. Moreover, migration was observed in distal areas and in the direction of the subventricular zone. Only a few cells expressed GFAP and NeuN and most of the implanted cells were nestin positive.

**Conclusion:** Primate adult brain cells can easily be obtained, kept in culture, be reimplanted in the donor and survive in vivo. The long-term impact of the reimplanted cells and their roles in brain repair remain to be demonstrated. These attractive results open new perspectives in the field of brain repair in the central nervous system.

**Keyword:** Neurotransplantation.

**4A13****Long-Term Improvement of Parkinsonism by Autotransplants of Carotid Body Cells Aggregates in MPTP-Monkeys**

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**Objective:** To investigate if striatal autotransplants of carotid body cell aggregates (CBCA) elicit a sustained motor improvement in MPTP-monkeys.

**Background:** In previous studies, autotransplants of CBCA markedly improved parkinsonism in MPTP-monkeys, but the time of survival after grafting was very short. As many cell types induce a transient improvement (6 months) of parkinsonism when striatum of MPTP-monkeys was grafted, we wanted to know if these autotransplants induce a sustained improvement of parkinsonism in a large number of monkeys.

**Design/methods:** Twelve monkeys (*Macaca fascicularis*) with a severe and stable MPTP-induced parkinsonism were divided into 3 groups: Group I (n = 5) received an unilateral autotransplant of CBCA, group II (n = 4) was treated with a bilateral graft and group III (n = 2) received either unilateral or bilateral striatal injections of saline. Behavior and fine motor tasks were assessed through a 4-grade disability motor scale and through the time spent in reaching 4 pieces of fruit independently with each hand, respectively. Evaluations were performed before surgery and monthly after grafting. One or both carotid bodies were removed to obtain CBCA, which were stereotactically injected into the post-commissural putamen at two different rostro-caudal levels.

**Results:** Unilateral and bilateral grafts of CBCA brought out in all animals a sustained motor improvement, which was already evident 1 month after grafting and maintained until sacrifice (12 months later). Disability motor scales significantly improved in MPTP-grafted monkeys while sham group did not improve. Fine motor tasks of group I improved contralaterally, and even more in the less severe parkinsonian monkeys. In group II, the improvement of fine motor tasks occurred in both sides and persisted until perfusion.

**Conclusions:** Our results confirm the long-term benefit of CBCA in MPTP-monkeys. Motor improvement was more obvious in the less parkinsonian monkeys indicating that the alleviation of parkinsonism might be related to CBCA trophic factors acting on the nigrostriatal pathway.

**Keywords:** Neurotransplantation; Parkinson's disease.

**4A14****Comparison of Neurotransplantation and Deep Brain Stimulation of Subthalamic Nucleus in Suppression PD-Symptoms**

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**Objectives:** Akinesia (A) has been the stumbling block in functional neurosurgery of PD. A serious progress in this direction was related to introduction of neurotransplantation (NT) and deep brain stimulation (DBS) of subthalamic nucleus (STN). We evaluated the clinical effects of NT and DBS STN in PD patients during 1, 5–8 years postoperatively.

**Materials and methods:** 26 PD patients underwent NT (NECTAR protocol) (N = 11) or DBS STN (N = 15). All patients were assessed using UPDRS preoperatively, once every 3 months during the first postoperative year and 2–3 times per year in follow-up. All patients were assessed in medication OFF and in DBS OFF. At two years, one patient (NT7) was lost to follow-up.

**Results:** After 3 months, NT and DBS STN were equally effective for suppressing of A and in decreasing of UPDRS with a slight prevalence in NT-group. In the follow-up the value of UPDRS in NT-group returned to the preoperative state or became worse. In DBS STN-group the value of UPDRS progressively decreased and became below to preoperative condition par 45% on average. The comparison of the effects of NT and DBS STN was statistically significant ( $t = 11,76$ ;  $p < 0,001$ ). The main reasons for deteriora-

tion or improvement of values of UPDRS were significant changes in severity of A, rigidity (R), gait (G) and dyskinesias (D). Bilateral NT (2) has not changed the main direction of the postoperative dynamics. Bilateral DBS STN (2) was more effective than unilateral. There were no complications in NT-group. In DBS STN we performed reoperations (2) because of dislocation of the electrode without neurological complications.

*Conclusion:* The NT seems to be a poor effective procedure for correction of A in PD patients. DBS of STN is more preferable method of suppression of A, R and D in PD patients.

*Keywords:* Parkinson's disease; neurotransplantation; deep brain stimulation.

## 5B11

### Interest of In Vivo 1 h Magnetic Resonance Spectroscopy (MRS) with Chemical Shift Imaging (CSI) for Planning a Stereotactic Biopsy in Primary Brain Tumours: Experience with 10 Patients

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*Introduction:* Histological analysis is the «gold standard» for the diagnosis and treatment of primary brain tumours. However due to their heterogeneity serial stereotactic biopsies are mandatory to characterize unresectable tumours. In selected cases, when CT and MR- imaging were inconclusive, metabolic imaging with proton spectroscopy was performed to select the location of the biopsy.

*Method:* A CT-guided stereotactic biopsy was done in 10 patients on the basis of both contrast enhancement and proton spectroscopic imaging. The procedure was realized on a Magnetom Vision 1.5 T imager (Siemens, Erlangen, Germany) with the Siemens MRS software. Lesion location was achieved with a T1-weighted sequence prior to CSI acquisition (matrix 16'16, resolution 10'10'15 mm<sup>3</sup>, number of excitations 2, acquisition time 12 min, TR 1500 ms). A spin-echo sequence with TE = 135 ms was carried out. Biopsies were performed along a single trajectory with a minimum of three staged samples.

*Results:* In all the patients, stereotactic biopsies guided by choline imaging made histologic diagnosis possible with 3 low grade astrocytomas, 3 anaplastic astrocytomas and 4 glioblastomas. Indeed, this metabolite reflects the activity of the cellular turn-over and the membrane metabolism.

*Conclusion:* In non contrast-enhancing or necrotic tumours, the diagnostic yield of spectroscopic imaging with choline seems crucial to choose the location of the biopsy. Moreover, in vivo 1H MRS with CSI is the only non-invasive metabolic imaging modality.

*Keywords:* Stereotactic biopsy; tumour; spectroscopy.

## 5B12

### Stereotactic Biopsy Followed by Radiosurgery and other RT Methods in Posterior Fossa, Brainstem, Mesencephalic and Thalamic Region Lesions Management

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*Objectives:* Development of brain stereotaxy, radiosurgery, brachytherapy, or conformal radiotherapy, with the application of state of the art medical techniques resulted in major progress in combating brain neoplasms. The cooperation between neurosurgeon, neuropathologist and radiotherapist in the treatment process creates new objectives and values, especially in cases of deeply located lesions.

*Materials/methods:* For over 3 years we have had access to latest generation system for stereotactic biopsy and x-ray treatment planning Brain-Lab (with CT/MR image fusion) as well as to LINAC (Varian Clinac 2300 C/D) based radiosurgery, equipped with micro MLC together with dynamic treatment option. Between December 2000 and February 2004 114 stereotactic procedures of central nervous system (CNS) were performed. Among them were 27 stereotactic biopsies of lesions located within deep brain structures (cerebellar peduncle, pons, mesencephalon and thalamic region).

*Results:* Stereotactic biopsy permitted diagnosing of 14 primary and 8 secondary neoplasms. Described above radiosurgery method was a main treatment in part of cases. Fractionated RT was conducted based on the same equipment. HDR after loading Ir 192 brachytherapy was also used in some cases. The medium volume of the lesion was 18 cm<sup>3</sup> (range from 0.51 cm<sup>3</sup> to 43.46 cm<sup>3</sup>). At the day of current investigation 6 patients are under observation with average follow up of 32 weeks. 14 patients died – average survival time was 18 weeks (range from 2 to 44). We do not have any information about 2 patients. We noticed the shortest survival time in group of patients with metastatic tumours. Most of patients died because of advanced main neoplastic disease.

*Conclusion:* Stereotactic biopsy is efficient and safe, even in cases with pathology located within thalamus, posterior cave and brain stem and enabled to select proper radiation therapy.

*Keywords:* Radiosurgery; stereotactic biopsy; brainstem; thalamus; brain neoplasms.

## 5B13

### Diagnostic Challenge of Brainstem Lesions

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*Objective:* Diagnosis of brainstem lesions remains a challenging problem for the neuropathologist and neurosurgeon. We reviewed our histopathological data of stereotactically biopsied brainstem lesions.

*Methods:* Between 1999 and 2003 diagnosis of 43 brainstem lesions was provided by stereotactically obtained biopsy samples

at Klinikum Großhadern, Munich. Intraoperative cytological examination relied on smear preparations. The number of specimens stereotactically taken depended on the neuropathologist's judgement whether sufficient material for diagnosis had been collected.

Final diagnosis was based on paraffin embedded sections using sophisticated histological and immunohistochemical evaluation. In case of diagnostic uncertainty specimens were sent to another neuropathological department (Bonn) for consultation.

**Results:** Due to inconclusive histopathological findings paraffin embedded specimens were sent to another neuropathological department in 6 of 43 cases (14%). Finally conclusive tissue diagnosis could be achieved in 98%. 7 pilocytic astrocytomas, 24 gliomas (6 diffuse astrocytomas grade II, 10 anaplastic astrocytomas grade III, 3 glioblastomas grade IV, 5 gliomas of the pons (accurate grading not possible)), 4 metastases, 2 inflammatory lesions, 1 cavernoma, 1 cerebellar stroke and inconspicuous glial tissue (4 cases) were diagnosed. In 10 cases (23.3%) the smear preparation (s.p.) findings did not match with the final histology of the paraffin sections (p.s.). 1 pilocytic astrocytoma (s.p.)/inflammatory lesion (p.s.), 1 inflammatory lesion (s.p.)/no pathology (p.s.), 4 astrocytoma grade II (s.p.)/astrocytoma grade III (p.s.), 1 astrocytoma grade III (s.p.)/astrocytoma grade II (p.s.), 1 lymphoma (s.p.)/glioblastoma IV (p.s.), 1 diffuse glioma (s.p.)/metastasis (p.s.), 1 tectum glioma (s.p.)/no pathology (p.s.).

**Conclusion:** The diagnostic value of smear preparations for diagnosis of brainstem lesions is limited. Within the brainstem WHO grading for diffuse gliomas seems to be aggravated. Stereotactic biopsy guided by intraoperative smear preparation findings should be mandatory for accurate diagnosis of brainstem lesions.

**Keywords:** Brainstem lesions; stereotactic biopsy.

## 5B14

### Stereotactic Injection of DTI-015 into Newly Diagnosed Malignant Gliomas

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Malignant gliomas due to the invasive growth are a major challenge for neurosurgery. Use convection enhanced delivery of compounds applied stereotactically, some of the major obstacles inherent to the biology of malignant gliomas could be overcome. We have used DTI-015 (BCNU in ethanol) in conjunction with stereotactic convection enhanced delivery in the initial treatment of malignant gliomas. Four patients with newly diagnosed malignant gliomas WHO III and IV have been investigated using pre-operative physiological characterisation of tumours by FDG-PET, TI-SPECT, MR spectroscopy and regional blood flow and blood volume measurements. After DTI treatment, physiological variables were assessed again to objectively assess the effect on tumour biology. Also, as part of the convection enhanced stereotactic delivery to the tumour, serial biopsies were taken and the tumours were characterised as to the molecular genetics and gene expression profile.

Seventy-two hours after convection enhanced treatment 50% reduction in tumoural blood flow was seen without significant reductions in tumour blood volume or capillary permeability.

FDG-SPECT and TI-SPECT showed massive reduction in glucose utilisation and TI-uptake signifying reduced tumour viability after 6 days or the reduction of the FDG radio tumour to brain from 1.2 0.3 to 0.7 0.1 ( $p < 0.1$ ) and reduction in TI-uptake rates from 3.4 1.1 to 1.3 0.8 ( $p < 0.01$ ). MR spectroscopy performed before and 26 days after convection enhanced stereotactic treatment showed significant increases of lipid/creatinine ratio of 1.48 0.21 to 4.95 3.67 without concomitant changes in NAA/creatinine ratio or choline/creatinine ratio thus signifying massive tumoural necrosis without necrosis of surrounding normal brain.

Thus, convection enhanced delivery of DTI-015 results in rapid tumour necrosis signified already 72 hours after treatment by reduction of tumour cell metabolism most likely mitochondrial inhibition. No immediate effect on the tumour vasculature was seen except for reduction in blood flow which correlates with the reduced metabolic demand of the tumour. Using convection enhanced stereotactic delivery to circumscribed tumours offers a new rational biological approach to the treatment of tumours which can be monitored with functional imaging.

**Keyword:** Stereotactic drug delivery.

## 5B15

### Interstitial Radiosurgery with Stereotactically Implanted Iodine-125 Seeds for Pineal Parenchymal Tumors

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**Objective:** To evaluate the efficacy of interstitial radiosurgery (IRS) for pineal parenchymal tumors (PPT) (pineocytoma, PPT with intermediate differentiation, pineoblastoma).

**Material and method:** We present a retrospective study of 17 consecutive patients (11 male and 6 female; age range, 6–68 years; median age 36 years) with pineal parenchymal tumors which were treated in our institution with interstitial radiosurgery using computer tomography (CT) and magnetic resonance imaging (MRI) based, and stereotactic guided iodine-125 Seed implantation as either primary or salvage treatment.

Pineocytomas were permanent and malignant PPTs were temporary implanted. The cumulative tumor surface dose ranged between 40 and 65 Gy. An adjuvant fractionated radiotherapy of the brain, respectively craniospinal was done in patients with PPT grade III and grade IV. The mean follow-up periods from the time of IRS were 67.3 months (range: 20–133 months).

**Results:** The Overall actuarial 2-, 5- and 10-year survival rates after IRS were 88%, 88% and 76%, respectively. Follow-up MR images demonstrated complete remission in 88% ( $n = 15/17$ ) and partial remission in 12% ( $n = 2/17$ ), in one patient an out of dose recurrent tumor was occurred 7 years after partial tumor remission. One patient developed IRS related morbidity.

**Conclusion:** This study revealed that stereotactic IRS for the management of PPT has a very low treatment-related morbidity and no mortality and might be an alternative to microsurgery as a safe strategy for treating patients with PPTs, as primary therapy in case of pineocytomas and as one arm of a multimodality therapy including conventional irradiation for malignant PPTs.

**Keywords:** Radiosurgery; iodine-125 seed implantation; pineocytoma; pineoblastoma.

**5B16****Improved Outcome with Adequate Dural Tail Coverage in Patients with Intracranial Meningiomas Treated with Gamma-Knife Stereotactic Radiosurgery**

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*Purpose:* To determine the long-term outcomes and prognostic factors in benign intracranial meningiomas treated with gamma knife stereotactic radiosurgery (GK-SRS).

*Materials and methods:* Between 1992 and 2000, 162 patients with benign meningiomas were treated with GK-SRS at the University of Maryland Medical Center. Complete follow-up was available in 137 patients. All patients underwent MRI-based treatment planning. Serial MRI's and clinical exams were performed to assess tumor response. GK-SRS was the primary treatment in 85 patients (62%) while 52 patients (48%) had prior surgical resections. Two patients had 2 separate procedures for lesions in different locations. The median prescribed dose was 14 Gy (range, 4–25 Gy) to the 50% isodose line. The median tumor volume, treatment volume, and conformity index were 4.5 cc (range, 0.32–80.0 cc), 6.3 cc (range, 1.0–75.2 cc), and 1.34 (range, 0.65–3.16), respectively. The median follow up for the entire cohort was 4.5 years (range, 0.33–10.5 years). The following factors were included in the statistical analysis for DFS and OS: sex, age, dose, gross tumor volume (GTV), and conformity index. The conformity index (CI) was defined as:  $CI = PV/GTV$ . The physician who evaluated these indices was blinded to the patient outcome.

*Results:* Serial MRI analysis was available in 121 patients (88.3%). Decrease in tumor size was observed in 34 patients (28.1%) while there was no change in 77 patients (63.6%), for a crude radiographic control rate of 91.7%. Increase in tumor size was seen in 10 patients (8.3%). New neurological deficits attributed to the treatment developed in 10 patients. The mean progression-free survival (PFS) and overall survival (OS) for the entire cohort are 4.6 years and 5.0 years, respectively. The 5-year actuarial PFS and OS were 86.2% and 91.0%, respectively. Univariate analysis revealed GTV, sex, CI and dural tail treatment to be significant prognostic factors. Females had significantly longer survivals. The 5-years actuarial PFS and OS for females vs males were 90.2% vs 74.2% ( $p=0.0094$ ) and 91.6% vs 89.1% ( $p=0.016$ ), respectively. Patients with GTV „T 10 cc also had longer survivals, with the 5-years DFS and OS of 91.9% vs 68.0% ( $p=0.038$ ) and 100% vs 59.7% ( $p=0.0001$ ), respectively. Patients with CI „d 1.4 achieved a longer PFS, with a 5-year PFS of 95.2% vs 77.3% ( $p=0.01$ ). Patients who had the dural tails treated also had higher 5-year DFS (96.0% vs 77.9%,  $p=0.038$ ). Patients with lower conformity (i.e., CI „d 1.4) tended to have the dural tail covered in the prescription isodose line ( $p=0.04$ ).

*Conclusions:* This report adds to the literature that supports the efficacy and safety of GK-SRS in the management of patients with benign intracranial meningiomas. Our report identified male patients, and patients with  $CI < 1.4$  and tumor size  $> 10$  cc to have worse prognosis. Patients who were treated with less conformal plans in order to cover the dural tail had better outcomes. Our data clearly demonstrates the need to adequately cover the dural tail in patients treated with GK-SRS for benign intracranial meningiomas.

*Keywords:* Radiosurgery; vagal nerve stimulation.

**6A11****Pallidal Surgery for Adult-Onset Generalized or Segmental Dystonias**

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*Purpose:* Generalized or segmental dystonia is refractory to most conservative treatment. Recent success of pallidal surgery in juvenile onset generalized dystonia, especially DYT1 type, lead us to review our series of pallidal surgery for adult-onset medically refractory generalized or segmental dystonias.

*Methodology:* Eighteen patients (15 men, 3 women, age 19–73 yrs, mean 32 yrs) with medically intractable generalized or segmental dystonia underwent pallidal surgery; bilateral deep brain stimulation (DBS): 10 cases, unilateral DBS/contralateral coagulation: 4, bilateral staged coagulation: 2, bilateral gamma knife: 1, unilateral gamma knife: 1. Thirteen cases were idiopathic, and five cases are secondary dystonia. Stereotactic target was chosen at the internal segment of the globus pallidum.

*Results and conclusion:* The preoperative dystonia rating score was 45/25, and the postoperative score was 23/16 ( $P < 0.01$ ). The improvement was judged according to the global outcome scale as follows; excellent: 5, good: 4, fair: 6, no change: 2. There was no subgroup showing favorable outcome, though the secondary dystonia tended to show modest improvement. When there was no brain atrophy, the results were better. There was no mortality or permanent morbidity. Although pallidal surgery is effective in many cases of generalized dystonias, we are still not sure what type of dystonia responds better.

*Keywords:* Dystonia; pallidal surgery; adult-onset.

**6A12****Long Term Outcome of GPi Stimulation in Dystonia: Follow Up of 15 Patients**

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*Objective:* GPi (globus pallidus internus) deep brain stimulation offers a very interesting stereotactic neurosurgical therapy for medically intractable dystonia (generalized, segmental, focal). Immediate post-operative results and clinical follow up for 15 patients are reported.

*Materials/methods:* GPi-deep brain stimulation was performed in 15 patients (age 12–78 years) suffering from primary generalized (3), segmental (10) or focal (2) dystonia. Electrode-implantation (DBS 3387, Medtronic) was performed under propofol anaesthesia with MRI-guided stereotaxy using a modified Leksell/Lerch system. The lowest possible electrode was chosen for stimulation and intensity was set relatively high from the beginning (mean 80  $\mu$ A). After one week of successful stimulation by an external test stimulation system, permanent implantation of the stimulation system (Solettra, Medtronic) was performed. Clinical outcome was assessed using the Burke-Fahn-Marsden (BFM) motor and disability scores. Median follow up was 30 months.

*Results:* All patients experienced a significant improvement of symptoms during the first week. After 3 months, symptom reduc-

tion was considered excellent in 6, fair in 5 and moderate in one patient. No improvement was observed in three patients. The BFM movement scores had improved in the range from 0 to 82% compared to preoperatively. After 24 months, relief of symptoms was unchanged compared to the 3-month status in 12, slightly reduced in two and severely reduced in one patient. Local infection occurred in one patient, making electrode-explanation necessary. Re-implantation was performed three months later without further complications. No other therapy-related morbidity was observed.

**Conclusion:** GPi deep brain stimulation offers a very effective and safe therapy for patients suffering from primary generalized, segmental or focal dystonia. Stable relief of symptoms can be achieved in the majority of patients.

**Keywords:** Dystonia; GPi-stimulation.

## 6A13

### DBS for Dystonia: How Quickly do Patients Respond?

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**Background:** Dystonia appears distinct from the other tremulous disorders in that improvement following deep brain stimulation frequently appears in a delayed and progressive manner. The rate of this improvement and the point at which no further progress can be expected are presently unknown. The establishment of these parameters is important in the provision of accurate and relevant prognostic information to these patients, their carers, and their treating physicians.

**Methods:** We studied 12 consecutive patients with generalised dystonia (n=6) and spasmodic torticollis (n=6) who underwent bilateral globus pallidus internus (GPi) deep brain stimulation (DBS) and were followed up for a minimum of 2 years postoperatively. Standard rating scales were used to quantify their neurological improvement.

**Results:** Both groups experienced a statistically significant improvement in their rating scores at both one and two years following surgery. At 2 years follow-up, the spasmodic torticollis group exhibited a 59% improvement in their total TWSTRS rating score, and the generalised dystonia group attained a 46% improvement in their overall BFMDRS evaluation. Ninety-five percent of the final improvement was attained by 6.4 months in the generalised dystonia group, and by 6.6 months in those with spasmodic torticollis. There was no significant improvement after one year postoperatively.

**Conclusions:** GPi DBS is an effective treatment for generalised dystonia and spasmodic torticollis. Gradual improvement is seen postoperatively, occurring in an exponential manner. Minimal improvement is seen after the first 6 months.

**Keywords:** Dystonia; spasmodic torticollis.

## 6A14

### GPi Neurostimulation in Neuroleptic-Induced Tardive Dystonia

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**Objective:** Aim of this presentation is the report of two young male schizophrenic patients affected from tardive dystonia which obtained immediate and almost complete recovery from this drug induced extrapyramidal disease by bilateral GPi neurostimulation.

**Methods:** Both patients were schizophrenic, DTY1 negative. No familial extrapyramidal disorders was recorded. The first patient (male, 33 yrs) complained gait dystonia, camptocormic posture and cranial nerves involuntary movements developed after 6 years neuroleptics treatment. The second patient (male, 36 yrs) developed torsion dystonia, spasmodic torticollis and involuntary movements of upper limbs which appeared after 7 years of neuroleptics treatment. The extrapyramidal disorders worsened in spite of neuroleptics withdrawal and resulted resistant to clozapine and benzodiazepines. The time lapse between the appearance of dystonia and surgery was respectively 5 and 7 years. Bilateral stereotactic implant of electrodes within the GPi has been performed under general anaesthesia (20 mm laterality, 6 mm below the commissural plane and 2 mm anterior to the midcommissural point). Electrical stimulation (130 Hz, 1 volt, 90 usec) was started the day after surgery.

**Results:** Extrapyramidal symptoms and dystonia disappeared almost completely and dramatically in both patients after 24 hours from the beginning of neurostimulation. Both patients regained autonomy and the first one continued neuroleptics treatment with clozapine. Clinical results are stable at 1 year follow-up.

**Conclusion:** Tardive dystonia develops after long lasting neuroleptics treatment and may become irreversible and resistant to any treatment in about 1 to 4 of patients. The definitive clinical improvement obtained by GPi neurostimulation in tardive dystonia may be estimated about 80–90 and this value seems considerably higher than the improvement score expected in primary DTY1 negative dystonia. The involvement of GPi may be prominent in tardive dystonia versus clinically similar dystonia syndromes with a different etiopathogenesis.

**Keywords:** Dystonia; deep brain stimulation.

## 6A15

### Deep Brain Stimulation of Globus Pallidus Internus for Tardive Dystonia: Position of Effective Electrodes

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**Objectives:** Therapeutic options for tardive dystonia in patients with unsatisfying medical treatment are very limited. Beneficial influence of deep pallidal stimulation on dystonic disorders of Parkinson's disease has increasingly encouraged the use of functional stereotaxy in various forms of dystonia. The optimal target point, however, is yet uncertain. This study reports excellent improvement by deep brain stimulation in three cases of medically refractory tardive dystonia and investigates the relative position of the active electrodes.

**Materials/methods:** Between 12/1999 and 07/2003 three female patients (aged 56 to 70 yrs) suffering from severe tardive dystonia were stereotactically implanted quadripolar electrodes for chronic bilateral stimulation of globus pallidus internus (GPi). Target definition involved intraoperative MRI and ventriculography as well as macrostimulation during awake intraoperative periods. Final position of the electrodes were documented by stereotactic X-ray and postoperative MRI. Active electrode positions were translated into coordinates relative to the anterior commissure-posterior commissure (AC-PC) system and standardized to the scheme

of Guiot (length of AC-PC and thalamic height (TH) in ventriculography). Treatment effect was assessed by the Burke-Fahn-Marsden dystonia rating scale (BFMDRS).

**Results:** All patients showed an impressive improvement of motor symptoms already during the first postoperative week. Mean motor score (part I BFMDRS) was reduced by 85%, the disability score (part II BFMDRS) by 93% (compared to preoperative state). Abnormal involuntary movements also decreased significantly leading to a dramatic increase of quality of life. There was no lessening of the beneficial effect at follow-ups (3 and 6 mos). The position of the active electrode was found to be  $20.1 \pm 0.4$  mm ( $x \pm$  SEM; range: 19–21.7 mm) lateral to AC-PC as well as 7.6/12 of AC-PC-length in front of PC and 1.6/8 of TH below AC-PC line corresponding to the posteroventral pallidum.

**Conclusion:** Our findings suggest that chronic stimulation of the posteroventral pallidum may be a very effective treatment for otherwise intractable cases of tardive dystonia.

**Keywords:** Dystonia; coordinates.

## 6A16

### Pallidal Stimulation to Treat Neuroleptic-Induced Tardive Dyskinesias: Preliminary Results of a Multicentric Prospective Study

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**Background:** TD is a rare side-effect of neuroleptic treatment. It may be sometimes highly disable and its medical treatment poorly effective. Pallidal stimulation has been shown to be an effective treatment of idiopathic dystonia and levodopa-induced dyskinesias in Parkinson's disease. To assess the efficacy of bilateral GPI stimulation on neuroleptic-induced tardive dyskinesias (TD), a multicentric study was performed.

**Methods:** We report the results of 5th patient of the study (planned to include 20 patients) with 3 months follow-up.

All of them resulted from severe and persistent TD despite appropriated medical treatment.

A stereotactic procedure was performed to implant bilaterally a Medtronic (3387) stimulation electrode within internal part of the globus pallidus internus (GPi). The coordinates of the target were Laitinen's coordinates: 18–20 mm lateral to the midline, 6 mm below ACPC line and 2 mm anterior to the midpoint commissure. MRI and/or ventriculography and intra-operative microrecording were used to insure a placement in the medio-dorsal part of the GPi.

**Results:** The severity of TD measured with a composite score from the Extrapyrimal Symptom Rating scale (ESRS) was assessed before and 3 months after the electrode implantation. Improvement varied from 30 to 85% with a mean improvement of 56% ( $p < 0.05$ ). A similar efficacy was observed on the dystonic and the choreic part of TD. One electrode, initially located in the GPi, was reimplanted. In another case, the pacemaker was repositionned due to the development of painful traction on the connexion cable.

**Conclusion:** Our preliminary results already suggest that continuous stimulation applied in the dorsal part of the GPi is an effective treatment for severe TD.

**Keywords:** Psychiatric indications; dystonia; tardive dyskinesias.

## 6A17

### Deep Brain Stimulation in Movement Disorders Due to Post Anoxic Cerebral Palsy

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**Objectives:** To evaluate the efficacy of bilateral stimulation of Internal Globus Pallidus (GPi) for treating the generalized dystonia/athetosis of nine patients with post-anoxic Cerebral Palsy (CP).

**Background:** Post-anoxic CP is a non-progressive encephalopathy causing in the early life an abnormal control of movements. CP associates spasticity and movement disorders, to varying degrees. If baclofen has proven to be efficient for treating spasticity, it is of poor benefit as well as medical treatment for controlling movement disorders (dystonia, athetosis). The promising results of Deep Brain Stimulation in primary dystonia allowed us to propose this treatment in selected patients with CP.

**Method:** Nine patients (4 children and 5 adults) presenting with severe, medically intractable movement disorders associating dystonia and choreo-athetosis due to post-anoxic CP involving the four limbs, trunk, neck and oro-mandibular region underwent surgery for chronic electrical stimulation of the GPi. Mean age at surgery was  $19.9 \pm 11.7$  years.

The patients were pre- and postoperatively assessed by the Burke-Marsden and Fahn's dystonia rating scale (BMFDRS). The mean of the preoperative scores were  $66.7 \pm 17.4/120$  (clinical score) and  $19.0 \pm 6.0/30$  (functional score).

**Result:** DBS proved to be efficient in controlling dystonia and choreoathetosis in these patients. The mean clinical gains at 6 and 12 months were respectively  $29.6 \pm 25.8\%$  (6 patients) and  $38.5 \pm 2.8\%$  (3 patients) and functional gains with the same follow-up  $18.9 \pm 19.7\%$  and  $28.6 \pm 11.2\%$ . The mean follow-up for the nine patients was  $14.9 \pm 10.4$  months and no loss of efficacy was seen over time.

**Conclusion:** Even if the efficacy of DBS in controlling movement disorders in CP patients is lower than in primary dystonia, the improvement of clinical status and quality of life, superior to that obtained by the pharmacological treatment are important arguments to propose it in a targeted population.

**Keywords:** Dystonia; DBS; cerebral palsy.

## 6A18

### Electric Field and Potential Distribution Generated by Deep Brain Stimulation of the Globus Pallidus Internus

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**Objective:** To visualize the brain volume affected by GPi stimulation using a tool able to 1) calculate the distribution of electrical parameters around the electrode (electric field, potential distribution) and 2) visualize them on the 3D stereotactic magnetic resonance images.

**Background:** Many questions remain concerning the regions affected by stimulation and in consequence the optimal electrode parameters and the optimal stimulation mode (monopolar, bipo-

lar). At the moment, the parameter adjustment process in deep brain stimulation in dystonia remains empirical and is based on clinical observation and experience alone. The parameter adjustment process as well as the surgical procedure requires mental representation of the stimulated volume.

**Methods:** Based on a static model, isopotential and isoelectric field magnitude were visualized for four parameter configurations (3 monopolar, 1 bipolar). Three electric field values were chosen arbitrarily (1.0, 0.2, 0.1 V/mm) and correlated with the GPi anatomy (MRI) of one improved patient in order to identify the electrical field value necessary to produce an action potential in GPi neurons.

**Results:** Potential and electric field distribution are different in form and extension in monopolar and bipolar stimulation and depend on the stimulation voltage. Bipolar stimulation affects a more focussed region than monopolar. The reported case shows that only the 1.0 and 0.2 V/mm isofieldlines remain inside the internal lateral GPi border.

**Conclusions:** Visualisation of the electric field and of the defined critical field values facilitates the definition of the stimulated region. Shape and extension of the electric field can not be intuitive. The application of such a computer-assisted methodology to our whole patient population will help to elucidate the mechanism of action.

**Keywords:** Dystonia; electric field.

## 6A19

### The Stereotactic Pallidotomy and Thalamotomy in the Treatment of Primary Dystonia

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**Objectives:** The purpose of the study was to review the experience and present the results of the stereotactic treatment by thalamotomy and pallidotomy in primary dystonia.

**Material and methods:** From 13th December 1999 to January 2004 forty six thalamotomies and pallidotomies were performed in the treatment of the primary dystonia. Average age was 42.2 years with STDEV 14.5 years. We were operated 33 women and 13 men, 29 cases underwent pallidotomies and 17 thalamotomies. To assess the progress in treating and to characterise the clinical course of the presented cases we used following scales: Burke and Marsden Dystonia Rating Scale (BMDRS), Global Dystonia Rating Scale (GRS), Unified Dystonia Rating Scale (UDRS), Global Outcome Scale (GOS), and Karnofsky Performance Scale. The video protocol and genetic investigation of DYT1 were used in the operated cases. Also the complex neuropsychological status was revealed. The results were evaluated before surgeries, and 3–48 months after operations.

**Results:** The results of the stereotactic treatment of the patients with primary dystonia was assessed just before the operation and 5 days, 3 months, 6 months and the next, every 6 months after the surgery.

**Conclusion:** In the presented material, the stereotactic pallidotomy and thalamotomy is an effective treatment, resulting predominantly in contralateral improvement in motor function. There was no severe and persistence complication in the presented material. Wide range of the results were observed in all forms of dystonia but the long-term results seem to be better after the pallidotomies. The efficacy of streotactic, neurosurgical intervention for intractable dystonia should be an alternative consideration in the disabled patients.

**Keyword:** Dystonia.

## 6B11

### Electrical Fields and Neural Responses in Motor Cortex Stimulation

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**Objectives:** This study is intended to analyse the immediate effects of stimulating the precentral gyrus by an epidural electrode, thereby contributing to the understanding of the physiological mechanisms of pain relief by motor cortex stimulation and the optimization of the technique.

**Methods:** A 3D model of the precentral gyrus and the surrounding anatomical structures, based on the geometry and the electrical conductivity of these structures, has been developed. With one or two electrode contacts placed epidurally the electrical field in this model and the response of afferent and efferent nerve fibre models projecting to, or originating in various cortical layers was calculated.

**Results:** The electrical field in the precentral cortex was strongly affected by varying the cerebrospinal fluid layer under the electrode. By widening this layer the current density in the cortex at a given voltage and the load impedance were reduced, whereas the stimulation energy was increased. In bipolar stimulation at a common contact distance (10 mm) the cathodal and anodal fields in the cortex hardly interfered and had a shape similar to the monopolar field. Due to a different load impedance, however, the monopolar field has a larger extent when the same voltage is applied.

The Activating Function predicts that nerve fibres under the cathode and parallel to its surface are depolarized and perhaps excited, whereas fibres normal to its surface are hyperpolarized. Due to the curvature of the precentral cortex the orientation of its afferent and efferent fibres varies, thereby giving position-dependent responses to stimulation. Whereas efferents in the convexity of the gyrus are hyperpolarized by cathodal stimulation, they are depolarized in the walls of the central sulcus. Under an anode the opposite occurs.

**Conclusions:** The cathodal fields in mono- and bipolar stimulation are similar, but monopolar stimulation is more energy efficient. To avoid anodal responses interfering with cathodal responses in bipolar stimulation, the anode should not be placed on the precentral gyrus.

**Keywords:** Pain; motor cortex stimulation; computer modelling; electrical field.

## 6B12

### Motor Cortex Stimulation (MCS) for Refractory Neuropathic Pain. Long-Term Outcome

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**Objectives:** 1) To study the long-term efficacy of MCS on refractory neuropathic pain. 2) To identify predictive factors for efficacy.

**Patients/methods:** 31 consecutive patients were included in a prospective evaluation with pre-operative clinical, psychological, radiological (MRI, fMRI, PET) and electrophysiological (PES, PEL, RIII) investigations. Patients had central pain secondary to haemorrhagic (n = 11; 35.5%) or ischemic (n = 11; 35.5%) stroke, spinal lesion (n = 4; 12.9%), brain trauma (n = 1; 3.2%), complete brachial plexus avulsion (n = 4; 12.9%). One or two quadripolar electrodes were implanted over the precentral cortex corresponding to the motor representation of the painful area, and immediately connected to a subcutaneous stimulator (Medtronic). The parameters for stimulation were: intensity of bipolar stimulation 0.5 to 5 volts under the motor threshold, frequency 30 to 80 hertz, pulse width 60 to 330  $\mu$ s, cyclic mode in all patients. Results with a mean follow-up of 4 years. Pain relief at last follow up: = 70% (excellent result) 3 cases (9.7%), 40–69% (good result) 13 cases (42%), 10–39% (poor results) 11 cases (35.4%) and 0–9% (failure) 4 cases (12.9%). Pharmacological treatments could be withdrawn in 10 (32.2%), decreased in 5 (16.1%) and remained stable in 15 patients (48.3%). For each patient, pain relief at the end of the first post operative month correlated with (simple regression test,  $p < 0.0001$ ) and did not differ ( $p > 0.05$ ) with the mean pain relief at last follow-up. The different parametric tests didn't identify any clinical, anatomical or electrophysiological variables that reached a significant level for the prediction of the outcome.

**Conclusion:** This study suggest that MCS is an effective therapy in a majority of patients with despaired situations of refractory neuropathic pain. No prediction of the post-operative outcome can be performed in our patients from preoperative investigations. The only predictive factor of long-term outcome was the amount of pain relief immediately (one month) after surgery.

**Keywords:** Pain; cortical stimulation.

## 6B13

### Chronic Motor Cortex Stimulation for Phantom Limb Pain

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**Objectives:** The objectives of this case series were: 1) to determine if severe phantom pain could be reduced long-term by chronic motor cortex stimulation (C.M.C.S.), 2) to assess correlation between pain relief, electrode placement and functional imaging studies (fMRI, Pet) following activation by virtual movements.

**Material and methods:** Five patients with intractable phantom pain secondary to upper limb amputation (age range: 33–52 years) were selected for C.M.C.S. Implantation. Motor cortex was defined by pre-operative fMRI activation (by virtual task) fused to 3D neuronavigation sequences, and confirmed by intraoperative cortical somatosensory potentials (central sulcus location), and epidural electrical motor stimulation (stump motor response). The median follow-up after CMCS was 42 months (range: 12–62 months). Analgesic effects were assessed by mean Visual Analogic Scale (VAS), Activities of Daily Living (ADL) and by the Medication Quantification Scale (MQS).

**Results:** All patients obtained initial improvement in phantom pain. Long-term follow-up, outcomes were considered good or excellent for 3 patients, and moderate for 2. The electrode of one patient was revised after a loss of efficacy over 4 months. After adequate repositioning, the patient experienced pain relief until the stimulator was explanted for local infectious complications. Post-operative volumetric MRI and fMRI of the others patients coupled with motor threshold stimulation showed good electrode positioning overlying the pain target: i.e. The upper limb cortical areas.

**Conclusions:** CMCS was an effective method in treating disabling upper limb phantom pain refractory to multiple treatment strategies. Mechanisms of central sensitisation, neuropathic changes after amputation and neural circuits involved in virtual movement of phantom limbs will be discussed. FMRI coupled with a frameless stereotactic device have been useful in correctly positioning of the electrode, thus optimizing long-term pain relief.

**Keyword:** Pain.

## 6B14

### Subdural Motor Cortex Stimulation: A Report of 7 Cases

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**Objective:** Most series reported the therapeutical efficacy of extradural motor cortex stimulation (MCS) in intractable neuropathic pain. We want to report our results in seven patients treated with subdural MCS.

**Patients and methods:** Our population consisted in two trigeminal neuralgia, three post-ischemic stroke pain syndrome (predominant in the face and upper limb in two cases while in one leg for the other) and two post-traumatic pain in an upper limb. Preoperative investigations were sensory evoked potentials (SEP), laser, thermotest and transcranial magnetic stimulation. Intraoperative targeting implied localising the central sulcus by searching its particular omega or epsilon shape, using neuronavigation, detection of inversion of the N20 wave from SEP obtained from median nerve, and motor cortex stimulation while recording muscle contraction in the pain's region. A Specify (Medtronic) permanent electrode was placed through a short linear opening in the skull and the dura. Particular attention was given to keep the arachnoid intact.

**Results:** After 25.1 months of follow-up, the outcomes were considered good (improvement > 60%) in 43 of cases, moderate (40 < improvement < 60%) in 28.5% and poor (improvement < 40%) in 28.5%. Poor results were noted in patients with leg post-ischemic pain and upper limb post-traumatic pain. Only transient complications were recorded: two infections and three partial motor seizures. These seizures were related to a too rapid increase of cortex stimulation. No permanent complication was related to the surgical procedure.

**Conclusion:** Subdural MCS appears to provide therapeutical results similar to the extradural procedure. In addition, no permanent complications were recorded with this simple surgical procedure.

**Keywords:** Pain; subdural-cortex stimulation.

**6B15****PET Imaging in DBS for Chronic Pain**

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*Objective:* Studies have demonstrated the utility of functional imaging in humans with pain. The vast majority of those studies have focussed on acute pain. Most recently a few studies were undertaken to determine the role of therapeutic interventions for chronic pain with PET or fMRI. The mechanisms of deep brain stimulation in humans are poorly understood. The classical targets involve the medial (PVG, CM, PF) and lateral somatosensory thalamus (VPM/VPL). The present study was carried out to investigate the rCBF changes in patients with chronic neuropathic pain treated with deep brain stimulating electrodes in the medial or lateral thalamic structures as well as in combination of both localizations.

*Methods:* 7 patients with chronic implanted deep brain stimulation electrodes in VPL and PVG were examined. Several PET examinations with H2150 boli were performed: Baseline without stimulation, subthreshold stimulation (PVG, VPL), suprathreshold (VPL) and subthreshold (PVG and VPL in combination) were carried out. At the same time pain intensities were evaluated using a VAS score.

*Results:* Subthreshold stimulation in VPL caused activations in contralateral anterior cingulate (BA 32) and visual cortex (BA 18/19), ipsilateral cerebellum, and hippocampus (BA 35) and a deactivation in ipsilateral insula (BA 13) and medial frontal cortex (BA 10, 49). Suprathreshold stimulation activated additionally ipsilateral SI. Subthreshold stimulation in the PVG caused contralateral activation in Lingula (BA 18/19), hippocampus (BA 35) and insula (BA 13) but showed no cingulate activations. In combined stimulation however a bilateral ACC (BA 32) activation and bilateral deactivation of insular cortices (BA 13) was seen.

*Conclusion:* These data shed further light into central pain processing. Most interestingly, no clear segregation of pain processing systems at the diencephalic and cortical level was demonstrated. Areas usually activated, when acute pain is experienced, seem to be involved in pain suppressing mechanisms by deep brain stimulation.

*Keywords:* Pain; DBS; PET imaging.

**6B16****Posterior Hypothalamus, Facial Pain and Aggressiveness**

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*Objective:* The aim of this presentation is to reconsider the role of the posterior hypothalamus originally indicated by K. Sano as a target for stereotactic lesions to treat facial pain and behavioural disorders. In the era of deep brain stimulation (DBS) and functional neuroimaging this target has been successfully utilized to treat facial pain due to chronic cluster headache in 17 patients. Nevertheless the potential value of hypothalamic chronic stimulation seems wider and new indications has been tested.

*Methods:* Since 2000, have been treated with DBS within the posterior hypothalamus 6 more patients: 2 patients were affected from recurrent trigeminal neuralgia previously treated by microvascular decompression, percutaneous termorhizotomy and micro-compression; 1 patients was affected from atypical facial pain; 1 patient was affected from neurogenic continuous facial pain due to mandibular nerve lesion; 1 patient was affected by short-lasting unilateral neuralgiform headache attacks with conjunctival injection and tearing (SUNCT) and 1 patient had intractable aggressive behaviour associated with mental retardation and epilepsy.

*Results:* DBS resulted successful in trigeminal neuralgia patients, SUNCT patient, atypical facial pain patient and allowed to control aggressive behaviour in the single treated case avoiding any sedative drug. Failure occurred in the treatment of neurogenic facial pain due to mandibular nerve peripheral lesion.

*Conclusion:* Posterior hypothalamus is hypothesized to represent a node of a neural network which control some kind of episodic painful conditions of the face and also interacts with the complex neurophysiological mechanisms underlying the development of aggressive behaviour in psychotic patients. Future perspectives of DBS are suggested by the neuromodulation of this network node.

*Keywords:* Pain; psychiatric indications; deep brain stimulation.

**6B17****Postero-Medial Stereotactic Thalamotomy for the Treatment of Cancer-Related Neurogenic Pain**

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*Objectives:* Cancer-related neurogenic pain is caused by a lesion in at least one section of the somatosensory pathways, from nerve to cortex. The medial thalamotomy was shown to bring a selective relief to all pain localisations, without producing somatosensory deficit. Twenty-eight patients suffering from persistent intractable pain due to a variety of cancer-related disorders underwent postero-medial radiofrequency thalamotomy. Authors discuss indications, surgical technique and results of surgery.

*Material and methods:* Twenty eight patients with-cervical (n = 10), lumbar (n = 5), sacral (n = 3) plexus infiltration (secondary to breastcancer, lungcancer, melanoma, Pancoast tumor), multiple vertebral metastasis related (n = 10)-neurogenic cancer-related pain, resistant to opiate therapy, underwent 34 MRI-guided stereotactic thalamotomy. Of the 28 patients 15 were male, and 13 were female. The mean age at onset was  $11.8 \pm 12.4$  months, the mean age at surgery was  $57.9 \pm 10.6$  years. Six patients underwent bilateral thalamotomy due to bilateral pain. Pain was assessed at six timepoints: before the operation, and also at 1st day, at 3, 6, 9, and at 12 months postoperatively using visual analogue scale. The target was localized first on magnetic resonance imaging (MRI) scans obtained with a 1.0 Tesla Siemens Magnetom Impact system. A CRW (Radionics MA) stereotactic apparatus was employed. The medial thalamus including central lateral nucleus, centre médian, parafascicular nucleus, ventromedial nucleus of the thalamus were the targets in all patients. The target was localized first on magnetic resonance imaging. Cellular activity of the targeted area was assessed by semimicro-electrode and bursting cells were proved in all cases.

*Results:* Postoperatively complete pain relief was achieved in 50% (n = 14/28) at 1st day, in 39% (n = 7/18) at 3 months, in

23% (n = 2/9) at 6 months, in 33% (n = 3/9) at 9 and at 12 months of the patients. Fifty to 100% pain relief was achieved postoperatively in 89% (n = 25/28), in 89% (n = 16/18) at 3 months, in 78% (n = 7/9) at 6 months, in 66% (n = 6/9) at 9 and also at 12 months of the patients. Three patients with bilateral thalamotomy developed transient confusion.

**Conclusions:** Postero-medial MRI-guided stereotactic thalamotomy should be considered as a minimally invasive method, that may offer safe and effective alternative for the treatment of cancer-related neurogenic pain especially in those departments where expensive neuromodulation techniques are not available.

**Keywords:** Pain; postero-medial thalamotomy; cancer-related pain.

## 6B18

### Spinal Stimulation for Cardiac Control

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**Objectives:** To summarize old and new data illustrating how spinal stimulation may control and protect cardiac function.

Spinal cord stimulation (SCS), has been used in angina pectoris refractory to other therapies since the mid-eighties. Up to now more than 3200 patients have been implanted.

**Background:** Experimental research and clinical observations have indicated that the mechanisms involved in SCS therapy in ischemic and neurogenic pain syndromes are fundamentally different.

In ischemic pain resolution of the tissue ischemia is the primary event; alleviation of pain being secondary to this.

Experimental studies have demonstrated at least two different mechanisms proportionally activated depending on the tonus in the sympathetic system. One is suppression of sympathetic efference reducing peripheral vasoconstriction, the other antidromic activation of primary afferents inducing peripheral CGRP release.

**Results:** For angina pectoris early animal data demonstrated inhibitory effects of SCS on cardiac nociception, but it was subsequently demonstrated that SCS is not merely a pain blockade; resolution of cardiac ischemia remains the primary factor. Some researchers favour a stimulation-induced flow increase or redistribution, while others interpret the reduction of coronary ischemia as mainly due to decreased myocyte oxygen demand. Experimental studies have hitherto been unable to demonstrate a local flow increase in the myocardium by SCS, but instead preemptive SCS seems to induce protective changes in the myocardium making it more resistant to critical ischemia. Recent studies indicate that SCS-induced local catecholamine release in the myocardium could trigger protective changes related to mechanisms behind "ischemic pre-conditioning". In ischemia the intrinsic cardiac nervous system is profoundly activated, which – if uncontrolled – may result in dysrhythmias and critical ischemia. SCS stabilizes the activity of the intrinsic ganglia especially at ischemic challenge and may thus protect the heart from more severe ischemic threats.

**Conclusions:** SCS induces changes in multiple systems the common result of which is to protect the cardiomyocytes and resolve coronary ischemia. Future applications include rhythm control and ischemia protection.

**Keywords:** Pain; spinal stimulation; angina pectoris; ischemia.

## 6B19

### Peripheral Nerve Stimulation Technique in the Treatment of Craniofacial Pain

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**Introduction:** Peripheral nerve stimulation is a treatment option in variety of pain syndromes, including the posttraumatic neuropathic pain and certain peripheral neuralgias. Recently, use of this modality has been reported in patients with pain involving the craniofacial region, and the results have been encouraging.

**Methods:** During 2000–2003, we used neurostimulation in a total of 29 peripheral nerves (19 occipital, 5 supraorbital, 5 infra-orbital) in 17 patients (11 female, 6 male, age range 22–73, mean 47 years) with pain due to traumatic, iatrogenic or idiopathic neuropathy. Standard wire electrodes were inserted into epifascial plane crossing the nerve to be stimulated. All patients underwent a stimulation trial of 5–7 days. If the patients experienced more than 50% pain relief, they had a permanent stimulation device implanted.

**Results:** In 76% of patients (n = 13), trials were successful and patients underwent permanent stimulator implantation. However, one device had to be removed because of infection; another patient lost stimulation due to electrode migration; there was an erosion of skin over one electrode requiring the electrode revision. Overall, subcutaneous peripheral neurostimulation was initially successful in 76% of cases (22/29 stimulated nerves). At 16 months follow-up (7–45 months) 79% of patients continued to enjoy satisfactory pain relief (>50% of pain intensity). Complications were rare, with infection rate of 4% per electrode implanted and electrode migration observed in 7% of cases.

**Conclusion:** Peripheral nerve stimulation of both the trigeminal nerve branches and the occipital nerves is a straightforward, safe and effective treatment option of medically intractable pain, related to trigeminal neuropathy or occipital neuralgia. With accurate surgical technique and meticulous post-operative care, the risk of migration and infection is negligent comparing to the benefit that a patient may experience from this procedure. We encourage other clinicians to try this modality for their patients with intractable craniofacial pain.

**Keywords:** Pain; neuropathic pain; occipital neuralgia; trigeminal nerve; electrical stimulation; peripheral nerve stimulation.

## 6C11

### Unilateral Subthalamic Stimulation for Early-Stage Parkinson's Disease

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**Objectives:** According to evidenced based criteria, the surgical treatment, subthalamic stimulation, indicate advanced Parkinson's disease with severe motor complication. Nowadays, the treatment

has indicated the patients who medical treatment will fail to provide with a normal life even if they are still in an early stage. Our aim of this study is to clarify the efficacy and safety of unilateral subthalamic stimulation for patients with early-stage Parkinson's disease.

**Methods:** We evaluated the Unified Parkinson's Disease Rating Scale (UPDRS) and the Schwab England ADL score before and 6 months after the treatment for 6 patients with early-stage Parkinson's disease who dominated unilateral parkinsonian symptoms. We implanted the stimulation electrode (model 3387 or 3389) unilaterally for the dominated side, using both MRI and electrophysiological guidance.

**Results:** At 6 months after beginning of the stimulation, UPDRS motor score without medication improved by 64% and the Schwab England ADL score improved by 23%. No adverse events occurred except for asymptomatic intra-ventricular haemorrhage in one patient.

**Discussion and conclusions:** Unilateral subthalamic stimulation is useful treatment for patients with early-stage Parkinson's disease who dominated unilateral parkinsonian symptoms. Long-term result of subthalamic stimulation for early-stage patients remains unclear.

**Keywords:** Parkinson's disease; STN DBS for early-stage PD.

## 6C12

### STN Standard Track Quality Index (STQI)

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**Objectives:** Microrecording is a safe and useful guidance tool to improve STN localisation. In order to give a qualitative judgment on an electrode track, we have tried to correlate some neurone firing properties with electrode depth along a standard trajectory. Using this simple statistical approach we are able to compute a quality index for any given standard trajectory.

**Material and methods:** 597 neurones on 65 standard tracks from 48 patients were analysed. Electrode entry-point was chosen 3 mm in front of the coronal suture and 3 cm lateral to the midline plane. Trajectory end point was chosen at the infero-lateral part of the subthalamic nucleus. Signal characteristic such as cell spiking activity (frequency, amplitude, slope, burst index) and signal rms was computed using the signal recorded at 10 KHz.

**Results:** Signal rms, neurones spiking frequency and action potential slope were positively correlated ( $R > 0.85$ ) with electrode depth. In same way, neurone spiking amplitude and burst index were negatively correlated to electrode depth ( $< -0.85$ ). These correlations allow us to compute for each individual track a quality index ranging from 2 (electrode track with characteristics highly different from the mean track) to 0.02 (electrode track with characteristics close to the mean track).

**Conclusion:** Using standard entry and ending points, some cell characteristics correlate with electrode depth. This allows to compute a quality index that compare the characteristics of any given track to a "model" track (STQI) that represent the average of all the neurones. Using this simple statistical approach, the neuro-physiologist can give to the surgeon a qualitative analysis of the electrode trajectory.

**Keywords:** Microelectrode recording; Parkinson's disease.

## 6C13

### Changes in Cognitive Performance Following Bilateral Stimulation of the Subthalamic Nucleus are Amplitude- and Frequency-Dependent

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**Introduction:** The subthalamic nucleus (STN), a key component of the basal ganglia circuitry, functions as an internal clock that regulates the correct sequence of movements in a motor response. The importance of the STN in motor function is evidenced by its involvement in Parkinson disease (PD). However, this nucleus has also been associated with the attentional and emotional aspects of motor behaviour through its connections with the limbic and prefrontal areas of the brain. As lesions of the STN have been shown to increase premature responding in a serial reaction time task in rats, indicative for its involvement in cognitive performance, the present study aimed to investigate whether bilateral deep brain stimulation (DBS) of the STN affects cognitive functions and whether these are dependent on certain stimulation parameters.

**Material and methods:** Rats were trained in a choice reaction time task and implanted bilaterally with electrodes. Stimulation parameters (amplitude, frequency and pulse width) were varied during the test procedure, after which rats were sacrificed and the brains processed for histochemical staining.

**Results:** Results show no change in reaction times or motor times during stimulation. However, a linear decrease in premature responses, indicative for an improvement in cognitive performance, was observed with decreasing amplitudes and at high frequencies only.

**Conclusion:** This latter result is in contrast to findings following lesions of the STN, and suggests that current strength and frequency of stimulation are parameters that are integral to the mediation of stimulation effects on cognitive performance. Furthermore, the overall effects of DBS on neuronal cells cannot be classified simply as being "inhibitory" and evidently mediates its effects by more complex mechanisms than lesions of the same brain area.

**Keywords:** Parkinson's disease; microelectrode recording.

## 6C14

### Thalamic Versus Pallidal High Frequency Stimulation in Tourette Syndrome: A Report of 2 Cases

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**Objectives:** The aim of this study was to evaluate the effects of pallidal and thalamic high frequency stimulation on tics and behav-

ioral disorders in two patients with intractable Tourette Syndrome (TS).

*Material/methods:* In the two patients (both men, 45 and 27 yrs old, resp.) the diagnosis of TS was made according to the criteria of the Tourette Syndrome Classification Study group. Both patients suffered from associated behavioral disorders. Any conservative treatment had failed in both cases.

In case 1 two quadripolar electrodes were placed bilaterally in the medial part of the thalamus and connected to the pulse generator, and in case 2, four electrodes were implanted: two in the thalamus and two in the GPi. Only the latter were connected to the pulse generator. The effects on tics and behavioral disorders were evaluated with videotapes, questionnaires and interviews. All evaluations were performed in five conditions: stimulation on, on day 1 and, stimulation on (two times) and off (two times) on day 2, each time with 30 min intervals. Patients and investigators were blinded to the state of the stimulation.

*Results:* In case 1 there was an increase of 53.3% in the total amount of tics (from  $33.7 \pm 11.6$  tics/min to  $72.4 \pm 12.6$  tics/min) when the stimulator was switched off for the first time.

In patient 2 there was an increase of 79.2% in the total amount of tics (from  $16.7 \pm 13.0$  tics/min to  $80.3 \pm 14.7$  tics/min). During the second "off" period the increase in target tics was less pronounced. In both patients there was a clear increase in behavioral symptoms when the stimulators were switched off.

*Conclusion:* Thalamic as well as pallidal high frequency stimulation had a good effect on tics and behavioral disorders in these two patients.

*Keywords:* Thalamic stimulation; pallidal stimulation; tourette syndrome; HFS.

## 6C15

### Role of VIM DBS in the Treatment of Essential Tremor

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*Objectives:* Essential tremor is troublesome problem and sometimes causes severe disabling which is refractory to medical therapy. Thalamic lesioning and deep brain stimulation (DBS) have proved to be beneficial to the treatment of essential tremor. But it is not known which one is superior. The authors compared the effects and complications of two modalities.

*Methods:* A total of 34 patients with essential tremor who were treated surgically were selected in the period May of 1999 to May of 2003. Criteria for consideration of these lesioning or stimulation consisted of severe tremor refractory to medical therapy. The procedure of lesioning of the ventral intermediate (VIM) nucleus of the thalamus was performed as usual manner with microelectrode recording. Stimulation was performed with implanting a quadripolar brain electrode stereotactically in the thalamic VIM nucleus or subthalamic nucleus. Postoperatively, utilizing the various combinations of frequency, voltage and pulse width optimized the stimulation. The degree of improvements of tremor and the complications were monitored postoperatively and at follow-up.

*Results:* There were 37 procedures, including 27 with VIM nucleus lesioning and 10 with DBS, in 33 patients. Of the thalamotomy group, left VIM lesioning is twenty-five and right one is two. In two patients stimulation electrodes were implanted bilaterally at the same time. During the follow-up period of mean 17.0 (12–47) months, twenty-two cases (81.5%) obtained free of tremor

in thalamotomy group and nine cases (90%) did in DBS group. In thalamotomy group, complications consisted of memory impairment in three, sensory change in six, transient dysarthria in four, motor weakness in one and small thalamic hemorrhage in three. In DBS group, dysarthria was noted in one patient although other two dysarthric patients were improved with adjustment of stimulation parameters.

*Conclusions:* Although limited cases, the results of tremor improvement with DBS are encouraging. Relative paucity of complications and the adjustment of stimulation parameter that enables complication rate to lower seem to be outstanding benefits of DBS.

*Keywords:* Parkinson's disease; essential tremor.

## 6C16

### Treatment of Parkinson's Disease by Deep Brain Stimulation: Evaluation of an MRI-Based Surgery under General Anesthesia

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*Background:* Placement of deep brain stimulation (DBS) electrodes in brain structures is often a lengthy procedure. Most centers use physiologic monitoring, including microelectrode recording (MER) and macro-stimulation, for increasing the precision of electrode placement. The vast majority of literature regarding DBS, dictates the procedure to be performed in a patient in the off state with minimal or no sedation.

*Objective:* To describe a neurosurgical technique for implanting stimulation electrodes in Parkinson patients under general anesthesia, without the resort to MER and clinical testing, based only on stereotactical MRI and anatomical direct localization of the GPi.

*Methods:* Eight patients suffering from Parkinson disease were treated by DBS of the GPi (1-year follow-up). Surgical procedure was performed under general anesthesia using the Leksell G frame. Target coordinates were calculated on a 1.5-T MRI system acquisition. The immediate post-operative stereotactical MRI under general anesthesia should be a crucial prerequisite to check the reliability of MR acquisition (magnet stability) and the exact localization of each electrode reflecting the precision of the entire procedure.

*Results:* This technique allowed us to reduce the duration of the operation: 4 hours including general anesthesia, frame fixation, MRI acquisition, implantation of 2 electrodes under radioscopy control, immediate post-operative stereotactic MRI and frame removal. Surgery-related morbidity was very low with a 0% hemorrhage rate. Electrodes were checked to be on the selected target for all the patients. Improvement of Unified-Parkinson's disease Rating scale motor score after 12 months of DBS off medication, was 28.48%, without any neuropsychological or psychiatric secondary effects. Speech, akinesia, rigidity, tremor, and postural stability improved.

*Conclusion:* The advances of 3D-MR imaging allow to propose the electrode implantation for DBS for Parkinson's disease under general anesthesia without the resort to any complementary intra-operative techniques. The post operative course confirmed the efficiency and the good tolerance of this treatment. It is comparable to published results with long lasting surgery (8 to 12 hours) using MER and macrostimulation.

*Keywords:* Parkinson's disease; history of stereotaxy; MRI.

## 6C17

**Dorsal Column Stimulation for Treatment of Primary Orthostatic Tremor**

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**Objective:** Primary orthostatic tremor (POT) is characterized by an intense sensation of unsteadiness and shaking of legs and trunk when standing quiet. The diagnosis is confirmed by a typical 14–16 Hz burst activation pattern in EMG recordings. If medical therapy fails, the patient's daily activities can become very limited. Here, we studied the effects of chronic dorsal column stimulation (DCS) on POT as a new therapeutic option.

**Methods:** Quadripolar plate electrodes (Symmix, Medtronic) were implanted via a limited laminotomy approach with the patients in prone position under intravenous analgesia. Electrodes were externalized for test stimulation for several days. Two patients with POT, a 58-year-old woman and a 72-year-old man were selected for this study. The duration of POT was 10 years in patient 1, and 8 years in patient 2. Patient 1 also suffered from diabetic neuropathic pain. Medical therapy was not effective in both instances. The prospective study protocol included timed measures of the ability to stand still combined with EMG tremor recordings.

**Results:** Intraoperative electrical stimulation produced paraesthesiae of both legs. There were no adverse events. Test stimulation showed that the ability to stand still improved markedly in both patients. The electrodes then were internalized and connected to implantable programmable impulse generators (Itrel III, Medtronic). Stimulus parameters were gradually adjusted to maximum effect on unsteadiness. Patient 1, who was able to stand still for a maximum of 2 minutes preoperatively, became free of symptoms when standing (amplitude 1.0 V, frequency 100 Hz, duration 210  $\mu$ s). In patient 2, the ability to stand still was 10 seconds preoperatively, and it increased to 150 seconds (3.7 V, 220 Hz, 210  $\mu$ s). In both patients, clinical improvement was stable at 1-year follow-up.

**Conclusions:** Chronic DCS is useful in patients with medically intractable POT. Its effects may be mediated by the modulation of the oscillators responsible for POT via activation of the dorsal columns.

**Keyword:** Ortostatic tremor.

## 6C18

**Is Bilateral Stimulation of the Subthalamic Nucleus Less Effective in Parkinson's Disease When Procedure is Made Under General Anesthesia: A Prospective Study of 75 Patients**

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**Objective:** To assess the long term effect of bilateral chronic subthalamic nucleus (STN) stimulation after a general anesthesia procedure (GA). A precise localization of electrodes is required to obtain the best clinical improvement with STN stimulation. Optimized choice of the final electrodes localization is based on a rigorous protocol defined by Limousin *et al.* (1995): anatomical targeting, electrophysiological recording and clinical testing with stimulation. This evaluation needs that patients remained awakened and cooperative despite important stress and fatigue during the operation. Alternative procedures which may be more comfortable have not been evaluated.

**Material and methods:** We evaluated 75 prospective patients (56 men, mean age: 60/–8.3 years, mean Hoehn&Yahr score: 3.8/–0.8) treated by bilateral chronic STN stimulation. Assessments were performed before and every 6 months for 1 to 3 years after surgery. Stereotactic MRI and electrodes implantation were performed under a single light GA (sevoflurane alfentanil) which allowed us to record the typical signal in all patients (5 microelectrodes on each side). Under this procedure detection of capsular side effects induced by stimulation was possible. Evaluation of UPDRS, Beck Depression Inventory, Mattis Dementia Rating Scale (MDRS), PDQ 39 and psychiatric follow-up was done pre and postoperatively.

**Results:** Five serious postoperative adverse events occurred: one transient delirium, one general infection requiring temporary removal, one pulmonary embolism and two electrodes repositioning. The motor disability was improved by 67% (mean motor score while OFF medication before surgery (43/–13) compared to the last evaluation performed after surgery (mean: 24 months) while OFF medication-ON stimulation (14/–8). Activity of the daily living (UPRS II) improved by 47% in OFF condition. The dose of the dopaminergic treatment was reduced by 60.2% MDRS score remained unchanged in 72 patients. The main behavioural change observed in near 30% of the patients was a reduction of spontaneous activity (apathy) despite dramatic motor improvement. New cases of depression were not found, no suicidal risk was noted, 2 transient hypomania resolved spontaneously.

**Conclusions:** Comparison of these results to the main previous studies which used local anesthesia show no significant difference. The peroperative microelectrode recording and the detection of the most severe side-effects induced by capsular stimulation are still reliable but are conditioned to a specific GA procedure. Immediate postoperative follow up was simple.

The efficacy of STN stimulation is not modified by GA which gives more comfort to the patient. Nevertheless, the procedure still requires a very rigorous technique at each step: carefully selected patients, high quality anatomical targeting, multiple microelectrodes recording.

**Keywords:** Parkinson's disease; microelectrode recording; neuronavigation; general anesthesia.

## 6C19

**Contribution of 4.7 Tesla MRI in the Analysis of the MRI Anatomy of the Human Subthalamic Area**

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Although MRI is increasingly used in the determination of stereotactic targets, it is still uneasy to clearly identify on 1.5 T images the brain micro anatomy.

**Objectives:** To analyse the subthalamic area we compared, by a matching method, 1.5 T images obtained in stereotactic conditions with images obtained at 4.7 T.

**Material/methods:** After fixation of a stereotactic frame on an anatomic specimen (formaldehyde-fixed), 3 orthogonal plans of acquisition (3 sets) were performed on a 1.5 T-MRI machine (Siemens, Germany) with a turbo spin echo sequence used in clinical routine. After extraction of two blocks (right and left) of the basal ganglia area, they were transferred to a phosphate buffering saline solution and studied on a Biospec 4.7 T-MRI system (Bruker, Germany) with a 3D spin-echo sequence. We analyzed the micro anatomy of the basal ganglia on the 4.7 T images and we compared the 1.5 T sets and the 4.7 T set (Iplan, Brainlab, Germany). We also compared the 1.5 T sets of the anatomical specimen with these of a Parkinsonian obtained in the same MRI conditions.

**Results:** The 1.5 T anatomic information given by the specimen and the patient were quite similar. The information given by the 4.7 T was significant, revealing the nature of structures, in the three plans, e.g. sub thalamic nucleus, substantia nigra, zona incerta and ansa lenticularis.

**Discussion:** The data could be used as an anatomical book offering better analysis conditions than those currently given by stereotactic atlas, in particular because of the 3D information (isotropic voxels,  $250 \mu\text{m}^3$ ). It seems already possible to help a physician to properly define an MRI target in the basal ganglia region. The next step could be a matching with the in-house data and/or the use of higher field MRI.

**Keywords:** Parkinson's disease; psychiatric indications; MRI; basal ganglia; anatomy.

## 6C20

### Unilateral Low Frequency Epidural Motor Cortex Stimulation in Advanced Parkinson's Disease

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**Objectives:** A role of Motor Cortex Stimulation (MCS) in treatment of PD was proposed very recently in patients who are poor candidates for DBS. To confirm this we used unilateral MCS in two patients with advanced PD (H-Y scale IV and V).

**Methods:** In both patients flat quadripolar electrode was positioned in the epidural space over left Motor Cortex (MC) through two burr holes. MC had been previously marked on skin using a neuronavigator that also allowed to confirm the electrode correct position during the operation. Subthreshold test stimulation period was 1 week for first patient and 3 weeks for second patient. Stimulation parameters were: amplitude 2.5–4 mA, duration 150–200 msec, frequency 30 Hz, 3/0-setting; stimulation was on during daytime and off during night. The electrode was then connected to an implanted pulse generator.

**Results:** Clinical improvement was bilateral in both cases: it concerned rigidity, bradykinesia, postural tremor and gait, and also verbal understanding and fluidity, spatial orientation, dysphagia, void and fecal control. Especially axial symptoms (standing, gait, reezing, facial hypomimia) and long term Dopa syndrome symptoms (motor fluctuation and dyskinesia) were dramatically improved. Results remained unchanged during the follow-up (12 months and 10 months).

**Conclusions:** Unilateral motor cortex stimulation is a promising technique for treatment of advanced PD patients who do not meet the inclusion criteria for DBS. It is safe, without effects on voluntary movements and with bilateral effectiveness. Bilateral effects

may be explained by interhemispheric transfer of activity through corpus callosum.

**Keywords:** Parkinson's disease; neuronavigation; Motor Cortex Stimulation.

## 6C21

### Comparison of Dexmedetomidine to Propofol or no Anesthetic During Microelectrode Recording of the Globus Pallidus During DBS Surgery for Dystonia

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**Objective:** To compare the effects of Dexmedetomidine to Propofol or no anesthetic on the quality of microelectrode recordings (MER) of the globus pallidus during DBS surgery for torsion dystonia.

**Methods:** Retrospective analysis of intraoperative MER data from 39 DBS lead implants performed in 20 dystonia patients. Patients were sedated during surgery with Propofol (20 mg/kg/min; 16 implants; X patients) or Dexmedetomidine (0.2 to 0.7 mg/kg/hour; 4 implants; X patients) only if necessary. Sedation was not required for 19 implants (X patients). Single-unit recordings were analyzed using the "Clamp-Fit" software that accompanies our commercial recording system (Axon Systems/FHC, Inc., Bodheim, Maine). There were no surgical complications.

**Results:** A total of 16 recording tracts were performed. When recordings were performed without anesthetic the globus pallidus exhibited high amplitude single unit activity that were easily distinguishable from background (Frequency range:  $76.5 \pm 1.0$  Hz). Recordings from patients who were sedated with Propofol exhibited both reduced amplitudes and frequencies (<50 Hz) within the globus pallidus. This activity was more difficult to distinguish from background increasing the difficulty of interpreting the recordings. The use of Dexmedetomidine impacted the quality of recordings marginally. Globus Pallidus firing rates of 20 to 90 Hz were identified and were easily distinguished from background. There was no difference in cellular amplitudes as compared to recordings from awake patients.

**Conclusions:** Either Propofol or Dexmedetomidine may be used to achieve conscious sedation during stereotactic implantation of DBS leads; however, single-unit recordings under Dexmedetomidine sedation exhibit superior signal to noise ratios as compared to recordings obtained under Propofol sedation.

**Keywords:** Dystonia; microelectrode recording; Parkinson's disease; anesthetic.

## 6C22

### EMG Recordings as a Measure of Parkinson's Treatment

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EMG recordings taken immediately before and after Pallidotomy or DBS procedures were analyzed to determine the power and

frequency of resting tremor. The power and frequency values for before and after surgery were then compared in an effort to quantitatively determine the success of the procedure in eliminating the patient's tremor.

**Methods:** Electrodes are placed on the anterior surface two electrodes placed approximately 2 cm apart traverse the flexor carpi radialis, flexor palmaris longus, and flexor carpi ulnaris muscle groups. On the posterior surface, a similar pair of electrodes traverses the extensor carpi ulnaris and extensor digitorum muscle groups. After lesioning (Pallidotomies) or after placement of the DBS electrode, additional EEG and EMG recordings are taken at 2 mm around the target. To analyze the EMG recordings, each waveform is rectified and the envelope of the waveform is taken. The power and frequency of peaks found in pre-lesion or pre-electrode placement recordings are then compared to the power and frequency of peaks found in post surgery recordings.

**Results:** In most cases, the two remaining peaks were the upper first and second harmonics: a first harmonic between 8 and 9 Hz and a second harmonic between 12 and 13 Hz. In post lesion recordings, peaks were found between 20 and 40 Hz.

Similar results are obtained with DBS with a clear differentiation of the pre- and post-electrode implantation.

**Conclusion:** It appears that the methods presented here provide a relatively consistent way of providing quantitative analysis of Parkinsonian resting tremor. It would also appear that these methods provide an additional tool in evaluating the success of Pallidotomy and DBS procedures. In DBS, the method is used before and during surgery, while stimulation is under way.

**Keywords:** Parkinson's disease; EMG recordings.

## 6C23

### Target Localisation for Deep Brain Stimulation of Dystonic or Parkinsonian Patients with a Deformable Atlas Based on Histological and MR Data

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**Objectives:** Bilateral high-frequency stimulation of deep brain nuclei under stereotactic conditions was introduced in the early 1980s as a non-destructive technique for the surgical treatment of Parkinson disease (PD) and more recently dystonia. One condition of success is an accurate identification of the targets.

**Material and methods:** An atlas of the basal ganglia was constructed from a postmortem human brain. MRI sequences were acquired before brain extraction. The left hemisphere was processed for histology on which contours of the basal ganglia were delineated, as well as functional (sensori-motor, associative and limbic) territories (striatopallidal complex, Karachi *et al.* J. Comp. Neurol. 2002-450(2)). All atlas data were fused by means of automatic registration algorithms. Eighty surfaces were generated from the resulting serial contours. Automatic hierarchical registration between atlas and patient T1-weighted MR images allowed deformation of atlas surfaces onto patient right and left hemispheres, leading to a bilateral 3D mapping of the patient basal ganglia. Atlas

validity was evaluated on retrospective series of Parkinsonian and dystonic patients treated by deep brain stimulation.

**Results:** For all patients visual inspection of atlas deformation towards pre- and post-operative T1-weighted MR images revealed accurate atlas mapping of structures visible on MRI. Patients with high clinical improvement were found to have their therapeutic contacts within the STN or GPi. Localisation of the contacts was more accurate than in previous work (Yelnik *et al.* J. Neurosurg. 2003-99(1)) where a digitized Schaltenbrandt and Wahren atlas was reported on patients MR images by a semi-automatic and linear deformation technique.

**Conclusion:** Using this new deformable atlas, the basal ganglia of patients can be delineated automatically with high accuracy. This method can be used pre-operatively for target definition and post-operatively for localisation of the stimulating electrodes. Mapping functional territories accurately could yield, on retrospective series, knowledge improvement about optimal targets by correlation with clinical outcome.

**Keywords:** Parkinson's disease; dystonia; neuronavigation; atlas.

## 6C24

### Surgical Treatment of Bilateral Upper Limb Tremor in Wilson Disease

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**Objectives:** Wilson disease (WD) is an autosomal recessive hereditary copper metabolism disease with the gene mutation on the long arm of chromosome region 13q14. The failure to excrete unneeded and excessive copper packaged in ceruloplasmin in the bile for loss with the stool, leads to accumulation of copper in organs. Hepatic manifestation is common in childhood; the neurological symptoms are predominant after age 20.

**Methods:** Two 28 years old male patients were treated with severe, medically unresponsive bilateral upper limb action and postural tremor. The diagnosis based on low serum ceruloplasmin, abnormal serum copper, 24-hour urinary copper excretion, levels neurological symptoms with subsequent rapid progression of tremor, ataxia and dysarthria. Somatic symptoms included hepatomegaly, splenomegaly, thrombocytopenia, bilateral Kayser-Fleischer rings, and signal-intensity changes in the basal ganglia on the T2-weighted MRI scan. The target has been defined with MRI anatomy-based CT-guidance. In the first case stereotactic Vim thalamotomy was performed on the left side. Two years later a quadri-polar electrode (model 3387, Medtronic Inc.) was implanted to the right Vim nucleus. After 4 days of external screening the system was completed with implantation of pulse generator (model 7425) for chronic deep brain stimulation (DBS). Second patient was treated with simultaneous right Vim thalamotomy and left Vim implantation (electrode model 3389, pulse generator model 7426).

**Results:** In the first patient a complete abolishment of right side tremor, and sufficient control of left side tremor, and a slight right hand residual ataxia could be observed. In the second case, slight residual tremor observed in the thalamotomy side with complete control of tremor with DBS of the contra-lateral side. No adverse effects occurred.

**Conclusions:** Vim nucleus is an effective target for surgical modalities in drug resistant cases. Ablative surgery and DBS find to be highly effective for tremor with a consequent improvement of the quality of live in patients with WD.

**Keywords:** Wilson disease; tremor; deep brain stimulation; Vim nucleus; thalamotomy.

## 6C25

### Accuracy of Stereotactic Targeting in Deep Brain Stimulation

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**Objectives:** To analyse the in vivo accuracy and precision of stereotactic targeting during deep brain stimulation (DBS) procedures, using the Leksell G frame, a model widely used by functional neurosurgery groups.

**Methods:** 51 electrodes (27 left) were implanted in 27 consecutive patients for Parkinson's disease, dystonia or essential tremor. All patients underwent preoperative and postoperative stereotactic MRI or CT. For subthalamic and pallidal targets, stereotactic MRI was used for direct targeting. Coordinates were calculated manually and using Framelink software. The final DBS electrode location and trajectory on post-operative images was determined.

**Results:** The mean difference between pre and postoperative coordinates of mid-commissural points was  $<0.5$  mm. The mean Euclidean distance between the location of the electrode and the intended target coordinate was  $1.4 \pm 0.8$  mm. The most consistent discrepancy between electrode site and intended target was for the X coordinate in the left hemisphere, where the electrode location was medial (i.e. to the right) in relation to the planned target. This concerned medially located targets such as the subthalamic nucleus (STN) and ventral intermediate nucleus (VIM) but not the more laterally located globus pallidus internus (GPI). Further analysis confirmed a strong correlation between the observed electrode deviation and the trajectory angle as recorded on the Leksell arc (R squared  $>0.6$ ). For medially located targets a more lateral trajectory angle is often required to avoid the ventricle.

**Conclusions:** An accuracy of 0.6 mm is claimed for the Leksell G frame based on phantom data. However, our results suggest that other factors may influence the accuracy of targeting in vivo.

**Keywords:** Neuronavigation; Parkinson's disease; dystonia; accuracy.

## 6C26

### Bilateral Staged Pallidotomy in Advanced Parkinson's Disease

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**Objectives:** Many patients with Parkinson's disease/PD/suffer from severe bilateral appendicular off (bradykinesia, rigidity, tremor) and on/dyskinesia, dystonia/symptoms. After unilateral pallidotomy some of these patients still suffer from severe bradykinesia, rigidity, or dyskinesia of the ipsilateral side. These patients seem to be good candidates for bilateral staged pallidotomy. The aim of this study is to assess motor symptoms after staged bilateral pallidotomy in advanced PD patients.

**Methods:** 39 patients were studied. The patients were evaluated in nonblinded manner using UPDRS version 3, Hoehn and Yahr scale, Schwab and England scale before and up to 36 months after surgery in off and on state. The evaluations were conducted 3 months/37 patients/, 1 year/30 patients/, 2 years/17 patients/and and 3 years/12 patients/postpallidotomy.

**Results:** All cardinal symptoms of PD improved at 3 years in 12 patients in drug off state compared to drug off state before bilateral pallidotomy – parkinsonian tremor/items 20–21/by 34%, rigidity/item 22 UPDRS/by 45% and bradykinesia/items 23–26/by 49%. Gait disturbances including falling, freezing, walking/items 13–14–15 UPDRS/and gait and postural stability/items 29–30 UPDRS/showed some deterioration at 2 and 3 years of follow-up. There was minimal improvement in motor score of UPDRS on state, despite impressive amelioration of duration and severity of levodopa induced dyskinesia/LID//items 32–33 UPDRS/. The reduction of LID was 83% at 3 years after bilateral staged pallidotomy.

**Conclusion:** Bilateral pallidotomy affords impressive elimination of all symptoms in off state and significantly reduces/LID/and painful dystonia. The second pallidotomy although staged is associated with increased number of permanent neurological deficits. Permanent minor complications occurred in 21% of operated bilaterally patients.

**Keywords:** Parkinson's disease; bilateral staged pallidotomy.

## 6C27

### Clinical Assessment of Postural Stability in Parkinson's Disease Patients Before and After Unilateral Pallidotomy

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**Objectives:** Postural instability beside resting tremor, bradykinesia and rigidity accompanies late stages of Parkinson disease/PD/. Often falls and associated with them morbidity impair significantly quality of life in patients with PD.

**Methods:** To measure postural control changes in patients with PD we used static posturography. Such sway parameters as mean path length, velocity, enveloped area, postural sway in antero-postero and medio-lateral directions were evaluated in 27 parkinsonian patients (mean age 58.3 years) after unilateral posteroventral pallidotomy. These sway parameters were studied in two conditions with eyes opened and closed. The evaluations were performed in on and off state preoperatively, 3 months and 6 months postpallidotomy. Sway parameters were also studied in 28 age-matched control subjects (mean age 56.8 years). Postural control changes in PD patients before and after pallidotomy were contrasted with control group.

**Results:** The majority of sway parameters in the off state and also some sway parameters in on state were significantly improved at 3 and 6 months postoperatively. For example the mean path length in on state before pallidotomy was 318/–159 mm with eyes opened and 423/–258 mm with eyes closed. After surgery at

3 months the mean path length was as follows 240/–119.2 mm ( $t = 1.67$ ,  $p < 0.05$ ) with eyes opened and 347/–193 mm ( $t = 2.09$ ,  $p < 0.05$ ) with eyes closed. ANOVA analysis exhibited significant improve of mean path length due to surgical treatment/on state eyes opened and closed/but while comparing these parameter with control group we found no significant difference in sway path length.

*Conclusion:* We found that pallidotomy improves postural stability and axial symptoms of PD when using objective static posturography.

*Keywords:* Parkinson's disease; unilateral pallidotomy posturography postural stability.

## 6C28

### The Influence of Subthalamic Deep Brain Stimulation on Quality of Life in Parkinson's Disease

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*Objectives:* Bilateral subthalamic deep brain stimulation (Stn-DBS) is an effective treatment to improve motor function in patients with advanced Parkinson's disease (PD). The aim of our prospective study was to evaluate the impact of subthalamic deep brain stimulation on the patients' quality of life.

*Methods:* We used the Sickness Impact Profile (SIP) to measure the quality of life. The SIP is a self-report questionnaire that includes 136 items which are divided into twelve subscales. A total score and separate scores for Physical Dimension and Psychosocial Dimension can be calculated. The assessment was carried out on thirty three PD patients before Stn-DBS: six weeks ( $t_1$ ), two weeks ( $t_2$ ) = baseline data ( $t_0$ ) and three weeks ( $t_3$ ), nine weeks ( $t_4$ ), three months ( $t_5$ ), six months ( $t_6$ ), twelve months ( $t_7$ ) after chronic bilateral deep brain stimulation of the Stn.

*Results:* An analysis of variance for repeated measures was performed using six assessment times ( $\alpha = 0.05$ , two-sided). Most of the subscales indicated significant improvements: Sleep and Rest ( $F = 11.645$ ,  $p = 0.002$ ), Emotional Behaviour ( $F = 4.409$ ,  $p = 0.045$ ), Body Care and Movement ( $F = 25.892$ ,  $p = 0.000$ ), Home Management ( $F = 7.307$ ,  $p = 0.012$ ), Mobility ( $F = 6.353$ ,  $p = 0.018$ ), Social Interaction ( $F = 8.489$ ,  $p = 0.007$ ), Ambulation ( $F = 6.757$ ,  $p = 0.015$ ), Alertness Behaviour ( $F = 5.307$ ,  $p = 0.029$ ), Recreation and Pastimes ( $F = 6.558$ ,  $p = 0.016$ ). These scores improved significantly after surgery and were stable over one year. Following subscales showed no significant change after surgery: Communication ( $F = 2.152$ ,  $p = 0.154$ ), Work ( $F = 1.355$ ,  $p = 0.255$ ), Eating ( $F = 1.552$ ,  $p = 0.224$ ). The Physical Dimension ( $F = 21.248$ ,  $p = 0.000$ ), the Psychosocial Dimension ( $F = 14.235$ ,  $p = 0.001$ ) and the total score ( $F = 20.700$ ,  $p = 0.000$ ) demonstrated a stable improvement after surgery.

*Conclusions:* This report shows a significant improvement in the psychosocial and physical dimensions of quality of life. The observed improvement was relatively stable until one year after surgery. Our results suggest that the Stn-DBS reduces the burden of disease and improves the quality of life in patients with PD.

*Keywords:* Stn-stimulation; Parkinson's disease; quality of life.

## 7A11

### Stereotactic Anatomy of the Human Locus Ceruleus

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*Introduction:* The human brainstem nuclei and tracts are well known in their relative positioning, although most of them cannot be directly visualised "in vivo" by Magnetic Resonance Imaging (MRI). They must be therefore localised by indirect means, but the only existing stereotactic atlas of the human brainstem was made before the development of CT and MRI. The Locus Ceruleus (LC) is specially interesting to be studied due to its important functional and pathological implications. The aim of this work is to study the Stereotactic Anatomy of the human LC in order to allow its easy 3-D localisation and targeting, namely on regular brainstem MRI.

*Material and methods:* Twenty LC from 10 normal adult human brainstems were studied. Using a 3-D orthogonal reference system composed by the midsagittal plane, the IV ventricle floor plane, and the pontomedullary junction plane, the brainstems were serially cutted in a cryomicrotome at standard levels and LC images digitised. Then, with an appropriate computer program, LC cells were marked and referenced, 2-D and 3-D cell distribution was analysed and contours outlined.

*Results and conclusions:* The precise 3-D localization of the human LC was determined and disclosed as probability volume contours related to LC center 3-D references. The LC revealed to be a long and thin nucleus along the upper half dorsal pons, with an increasing cellularity and a diverging arrangement in caudal direction.

## 7A12

### Impact of Surgery in the MRI Environment on Infection Rate of DBS/Cortical Stimulator Implants

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*Objective:* Change from traditional operating room (OR) to MRI-OR is becoming common in neurosurgery. This raises concerns regarding the risk of infection. Herein is a comparison between infection incidence in the OR and MRI-OR.

*Material and methods:* DBS/cortical stimulator for movement disorders/pain have been routinely implanted at UCLA since January/1998. During 1998–1999, 48 surgeries were performed at the regular OR. From January/2000 to September/2004, 185 procedures were carried at the MRI-OR. All patients received Cefazolin prophylaxis immediately before surgery. 109 DBS were implanted in the subthalamic nucleus, 73 in VIM, 45 in GPi, 3 in motor cortex and 1 in ventro-postero-lateral thalamic nucleus. Infection was defined by the presence of hyperemia, secretion or fluid accumulation requiring hardware removal with positive culture detected until one year after surgery. Among 233 procedures, 10 presented confirmed infections.

**Results:** There was complete hardware removal in 7 cases and partial in 3. Four patients had positive culture for *Staphylococcus aureus* and one for *Klebsiella*. Remaining 5 cases had multiple positive agents: *S.aureus*, *Corynebacterium*, *Propionibacterium*, *Cocci Gram(-)*, *Serratia* or *Candida*. All patients received long term antibiotics according to antibiogram sensitivity. No meningitis occurred, infections were limited to the wires. Some patients were reimplanted later on. Infection rate at conventional OR was 2.08 and at MRI suite was 4.86 ( $P=0.69$ ). Overall infection rate was 4.29%.

**Conclusions:** Although MRI environment is less restrict to infection control than the regular OR, no significant difference was observed regarding infection rate. The incidence of infection in this series is also in accordance with the literature. Intraoperative MRI for functional procedures offers undeniable advantages. Since the infection risk is not significantly increased, MRI-OR seems to be an important tool to confirm targeting accuracy and to precociously rule out complications in functional procedures.

**Keywords:** MRI-OR; DBS; infection; risk.

### 7A13

#### Ensembles of Human Subcortical Neurons as a Source of Motor Control Signals for a Brain-Machine Interface

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**Objectives:** Patients with severe neurological injury, such as quadriplegics, might benefit greatly from a brain-machine interface (BMI) that utilizes neuronal activity from motor centers to control a neuroprosthetic device. Here, we report an implementation of this strategy in the human intraoperative setting to assess the feasibility of utilizing neurons in subcortical motor areas to drive a human BMI.

**Materials/methods:** Acute ensemble recordings from STN and thalamic motor regions were obtained in 11 awake patients during DBS surgery. During recording, patients simultaneously performed a visual-feedback hand gripping-force task. Offline analysis utilizing perievent histograms in addition to linear and non-linear decoding algorithms was then utilized to explore the relationship between neuronal modulation and gripping force.

**Results:** Individual neurons ( $n=28$  thalamic,  $n=119$  STN) demonstrated a variety of modulation responses, both before and after onset of changes in gripping force of the contralateral hand. Overall, 61% of STN neurons and 81% of thalamic neurons modulated with gripping force. Remarkably, ensembles of 3–55 simultaneously recorded neurons were sufficiently information-rich to predict gripping force during 30-second test periods with considerable accuracy (up to  $R=0.82$ ), after short training periods. Longer training periods and larger neuronal ensembles were associated with improved predictive accuracy.

**Conclusion:** This is the first study to simultaneously record the activity of large numbers of human subcortical neurons. It bridges the gap between the non-human primate laboratory and the human intraoperative setting to demonstrate the potential of subcortical motor regions to drive a human neuroprosthetic BMI.

**Keywords:** Microelectrode recording; Parkinson's disease; neuroprosthesis.

### 7A14

#### Decompressive Neurosurgery in Order to Improve Cognition – Is that Functional Neurosurgery?

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**Objectives:** Intracranial arachnoid cysts are expansive lesions, believed to be associated with clinical symptoms, e.g. headache. However, the clinical manifestations of an arachnoid cyst may be mild, and there is often lack of dramatic symptoms, even in patients with large cysts. As most supratentorial cysts are located adjacent to temporal and/or frontal cortical regions, it is conceivable that cognition may be affected. We have previously demonstrated that arachnoid cysts may affect simple verbal perception and memory, and we wanted to extend our studies to include more complex verbal as well as non-verbal tasks.

**Material and methods:** In two different case – control studies, with a total of 81 patients and 59 healthy controls, verbal and non-verbal cognition was assessed on 6 different cognitive tests pre- and postoperatively, including two different visual attention paradigms. The patients were tested one day before and minimum three months after the surgery. The control subjects had the same interval between the two tests.

**Results:** In general, we found that: 1) the patients performed significantly worse than the controls on the first (preoperative) test for all tests, and 2) the patients showed an overall improvement after cyst decompression.

**Conclusions:** Thus, patients with intracranial arachnoid cysts may have concealed cognitive dysfunction that is reversed by surgical decompression. Our findings indicate that the pressure from the cyst only causes a TEMPORARY SUPPRESSION, rather than a permanent destruction of brain functions. The latter finding may constitute a new, FUNCTIONAL, indication for surgery.

**Keywords:** Psychiatric indications; arachnoid cyst; cognition.

### 7A15

#### Long-Term Results of Thalamic Deep Brain Stimulation for Essential Tremor

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**Objectives:** This study evaluated the long-term efficacy of thalamic deep brain stimulation (DBS) for tremor control among individuals with essential tremor (ET).

**Methods:** A clinical series of 101 consecutive individuals undergoing placement of a DBS system for treatment of ET completed an unblinded battery of subjective and objective measures at post-operative intervals of 1, 3, and 12 months, and annually thereafter up to six years. A total of 165 leads were placed ( $n=37$  and 64 individuals respectively with unilateral vs. bilateral placement). The assessment battery included measures of tremor and activities of daily living (ADL).

**Results:** Both subjective and objective measures showed that stimulation was associated with significant improvement at nearly every post-operative interval as compared to pre-operative and stimulation “off” ratings of ADL functioning, midline tremor, contralateral upper extremity tremor, and contralateral lower ex-

tremity tremor. Ipsilateral tremor showed some improvement with stimulation, but only within the first 3 months. Trend analysis showed stable tremor control over time. Stimulation settings remained largely unchanged after the first 3 months. Dysarthria was more common among those with bilateral stimulation. Ten (6%) of the leads placed required repositioning due to loss of effect ( $n=8$ ) or breakage of the lead ( $n=2$ ).

**Conclusions:** Thalamic DBS is generally a well tolerated and effective treatment for essential tremor. Over the follow-up period, thalamic DBS produced a consistent reduction in tremor ratings, stimulation parameters remained stable, and stimulation induced side-effects were generally easily managed, although bilateral stimulation was associated with an increased proportion of individuals who experience dysarthria.

**Keyword:** Deep brain stimulation.

## 7B11

### The Microvascular Decompression in Trigeminal Neuralgia

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**Introduction:** If conservative treatment of trigeminal neuralgia is ineffective, operative treatment is necessary. Recent literature and our own experiences with 612 operated cases show, that about half of all patients eventually require an operation for pain relief. Nowadays the theory of microvascular compression of the root-entry-zone of trigeminal nerve based upon the original observation of Dandy 1929 and popularized by Jannetta 1976, is widely accepted.

**Clinical material and methods:** During a 2 years period (1999–2000) 88 patients underwent a microvascular decompression by the same surgeon. The mean patient age was 58, with a range from 24–82 years, the mean length of illness was 9.6 years. In the present retrospective study we analysed the postoperative outcome. In 2003 the mean follow-up rate was 47.8 months with a range from 36 to 54 months.

**Results:** Immediately after microvascular decompression 98% (86), up to 2 years 92% (81) and up to 4 years after operation 90% (79) were painfree. 9 patients (10%) had partial-relief and required medication, 5 of them additionally underwent percutaneous radio-frequency rhizotomy. Negative predictors for operation are female sex, symptoms lasting more than 8 years, venous compression of root-entry-zone and possible prior ablative treatment.

**Conclusion:** Microvascular decompression is the therapy of choice especially in patients with good conditions. The key to efficient treatment is to establish whether or not the pain is indeed trigeminal. In our experiences the MR-angiography in 3D-gradient-echo sequence has a high significance of 92 in the identification of an actual deformity at root-entry-zone of the trigeminal nerve. This finding may be helpful in suggesting the causative factor preoperatively.

**Keywords:** Pain; trigeminal neuralgia.

## 7B12

### Operative Findings and Results of Microvascular Decompression for Trigeminal Neuralgia in 35 Patients Affected by Multiple Sclerosis

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**Background:** The concept of vascular compression of trigeminal root as the main etiologic factor in idiopathic trigeminal neuralgia has achieved widespread acceptance and microvascular decompression (MVD) is a well-established surgical procedure for its treatment. Multiple sclerosis (MS) has long been considered as an absolute contraindication to MVD because of the supposed exclusive causative role of a demyelinating lesion affecting the trigeminal root entry zone (REZ). MRI preoperative identification of suspicious vessels along the cisternal course of the trigeminal nerve also in MS patients raises the question of a possible causative role of vascular compression even in MS patients.

**Methods:** We describe MRI, surgical findings and results in 35 MS patients who underwent MVD for medically intractable TN. Results were assessed by clinical follow-up and periodic phone surveys. The mean follow-up was 44 months (6–108 months).

**Results:** MRI revealed the presence of demyelinating lesions affecting the brain-stem trigeminal pathways of the painful side in 26/35 (74%). Intraoperatively, a severe neurovascular compression at the trigeminal REZ was found in 16/35 (46%). The long term outcome was excellent in 39%, good in 14%, fair in 8% and poor in 39%. No statistically significant prognostic factor predicting good outcome could be found. There was no mortality with a 2.5% long-term morbidity (facial nerve palsy in one case).

**Conclusions:** Results of MVD in MS-TN patients are much less satisfactory than in the idiopathic group, pointing out that central mechanisms play a major role in pain genesis. Alternative treatment strategies including cyberknife and deep brain stimulation should be investigated in MS patients.

**Keywords:** Pain; microvascular decompression; trigeminal neuralgia; multiple sclerosis.

## 7B13

### Treatment of Essential Trigeminal Neuralgia with Gamma Knife

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**Objective:** Herein we present 92 patients with essential neuralgia who underwent gamma knife surgery (GKS) minimally five years ago.

**Method and materials:** In 92 patients (F:M = 50:42) the radiation was focused on the root of trigeminal nerve in the vicinity of brainstem (maximal dose 70–80 Gy). The pain relief and side effects were evaluated after GKS.

**Results:** The initial successful results were reached in 73 (80%) pts in the interval between 1 day and 8 months (median 2 months) after radiosurgery. GKS failed in 2 (2%) patients and the recurrence of pretreatment pain appeared in 27 (29%) patients during the interval 3–40 months (median 20 months) after irradiation. Seventeen patients (18%) came for the second treatment with GKS and except for one case the treatment was successful. The repeated procedures were included in the overall evaluation which was as follows: the successful rate was reached in 67 of 82 (72%) pts after 2 years, in 56 of 68 (82%) pts after 3 years, in 49 of 60 (81%) pts after 4 years, in 44 of 46 (96%) pts after 5 years, in 27 of 28 (96%) pts after 6 years, in 12 of 13 (92%) pts after 7 years and in 2 of 2 (100%) 2 pts after 8 years. In 28% of patients the

hypesthesia occurred during the interval 4–60 months (median 30 months) after GKS. A relatively high number of sensory impairment was with relation to high percentage (68%) of other neurosurgical procedures that preceded GKS and with relation to the second GKS.

*Conclusions:* These results suggest that GKS for essential trigeminal neuralgia has a very good and long-lasting effect and that GKS can be repeated and combined with other neurosurgical procedures.

*Keywords:* Pain; radiosurgery; essential trigeminal neuralgia.

## 7B14

### Brainstem and Trigeminal Nerve Radiation Changes After Radiosurgery for Trigeminal Pain

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*Objective:* Evaluate the significance of brainstem radiation changes detected in follow-up MRI scans of trigeminal pain after radiosurgery.

*Material and methods:* Until April/2003, 104 Trigeminal Neuralgia (TN) patients were treated at UCLA, 64 female, mean age 64.6 years (29–88). Seventy-five (72.2%) had Essential TN, 20 (19.2%) secondary TN and nine (8.6%) atypical facial pain. Thirteen (12.5%) patients presented V1 pain, 20 (19.23%) V2, 17 (16.35%) V3, 17 (16.35%) V1-V2, 22 (21.15%) V2-V3 and 15 (14.4%) V1-V2-V3. Target was at the root entry zone (REZ) at the pons. Mean total dose was 86.4 Gy (70–90 Gy) to the 90% isodose line. Eighty-four (80.8%) were treated with a 5 mm collimator, seventeen (16.4%) with a 7.5 mm and 3 (2.9%) with a 3 mm. Mean follow-up was 18.25 months.

*Results:* MRI was ordered after 41 (38.68%) procedures. Indications were: post-SRS paresthesias, no pain relief and patient desire. Radiological abnormalities were noticed in 17 (41.46%) scans. Trigeminal nerve enhancement was observed in 7 (17.07%), brainstem enhancement at pontine level in 4 (9.76%) and brainstem plus nerve enhancement in 6 (14.63%). Mean interval time for detection of radiological abnormalities in post-SRS scan was 8.56 months (4–18). Enhancements were transitory. Clinical outcome in the brainstem enhancement group was: 3 (75%) patients with complete pain resolution and 1 (25%) with partial. In the trigeminal enhancement group, 4 (57.1%) patients were pain free, 2 (28.6%) experienced partial pain relief and 1 (14.3%) case experienced no relief. Among the 5 patients (6 procedures) presenting brainstem and nerve enhancement, 3 (50%) had complete pain relief, 2 (33.34%) had partial response and 1 (16.66%) no response. Pain relief for the series was: complete in 33 (32.7%) cases, partial in 25 (24.5%), none in 25 (24.5%), no follow-up in 19 (18.3%).

*Conclusion:* Brainstem/Trigeminal radiological changes are relatively frequent in follow-up MRIs. There is no correlation between radiological abnormalities and worse clinical outcome. Radiological follow-up demonstrated these alterations to be transitory and without major consequences.

*Keywords:* Pain; radiosurgery; trigeminal neuralgia.

## 7C11

### The Spastic Walking Patient and Intrathecal Baclofen

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*Objectives:* Intrathecal baclofen is presently the most effective treatment of diffuse spasticity whatever the cause. While its efficacy in reducing spasticity is known, no reports were published on its effect on the residual motor performance in the still walking spastic patients.

*Methods:* 100 spastic patients were submitted to long term treatment with intrathecal baclofen after careful evaluation and bolus test. 25 of these patients affected by different diseases were still able to walk both autonomously and with crutches before the treatment.

In addition to the evaluation scales currently used to score spasticity, reflexes and muscle spasms all the patients were evaluated with some functional scales such as the Kurtke scale, the Hauser scale and the disability scale to have a measure of any change in the clinical condition and in the daily activities.

*Results:* Wheelchaired and bedridden patients affected by severe spasticity of any origin had a marked improvement of their clinical condition and quality of life during long term treatment with intrathecal baclofen while the patients still able to walk had no improvement in their motor performance during the treatment with intrathecal baclofen on long term.

*Conclusions:* In conclusion the scale of evaluation used indicated no usefulness of intrathecal baclofen in walking spastic patients apart from a subjective transitory satisfaction in the early phases of the treatments with intrathecal baclofen.

*Keywords:* Spasticity; intrathecal baclofen.

## 7C12

### Minimally Invasive Selective Dorsal Rhizotomy for Children with Severe Spasticity

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*Purpose:* Selective dorsal rhizotomy is a well-established procedure for relief of severe spasticity in children with cerebral palsy. Long-term improvement of locomotor function has been reported after this operation. Generally this surgery is performed with multi-level laminotomy from L1 to S2, but this seems too invasive for small children and may carries higher chance of long-term spine problems like scoliosis.

*Methodology:* The author has been performing selective dorsal rhizotomy with only L1 and L2 osteoplastic laminotomy with preservation of the posterior longitudinal elements. Dural incision is 2.5 cm in length and the conus medullaris and cauda equine are exposed. With a fine concentric bipolar electrode, the rootlets are electrically stimulated and resected according to the evoked EMG findings. Decrease of tonus and disappearance of clonus were assessed with intraoperative physical examination.

*Results and conclusion:* Spasticity was well controlled in all 45 children operated on with this method. No persistent sensory deficits, urinary dysfunction, CSF leakage, nor infection were noted in this series. Although technically difficult for beginners, I conclude this minimally invasive technique is feasible for small children with spasticity.

*Keywords:* Spasticity; rhizotomy.

**7C13****Selective Microsurgical Peripheral Neurotomies in Upper Limb Refractory Spasticity**

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*Objectives:* Among neurosurgical procedures for refractory upper limb spasticity, Selective Microsurgical Peripheral Neurotomies (SMPN) are proposed when spastic muscles correspond to a single or a few peripheral nerves. Our objective is to assess prospectively long-term effects of SMPN with upper limb disabling spasticity.

*Methods:* Patients were selected only if previously nerve block or botulinum toxin had a positive effect. 64 SMPN were performed in 31 patients at the level of the: musculocutaneous nerve (15), median nerve (25) and ulnar nerve (24). Goal of surgery was qualified "functional improvement" when function (active opening of the hand and prehension) is considered or "comfort improvement" when nursing, daily activities, cosmetic appearance and/or pain relief are considered.

*Results:* Long term follow-up (mean 55 months) showed statistically significant improvement in (1) analytic assessment ( $p < 0.01$ ): spontaneous position, active amplitude and motor strength; (2) Ashworth tone scale ( $p < 0.01$ ); (3) hand function assessment ( $p < 0.01$ ) and (4) daily activities. 4 patients with severe painful spasticity had complete pain relief after surgery. On the basis of a visual analogic scale between 0 and 100, the average degree of satisfaction of the patients was 61.5. Complications occurred in five patients (15%): Two post-operative hematomas, one (temporary) hypoesthesia and one transient paresia of flexors.

*Conclusions:* SMPN lead to long-term satisfactory improvement of function and/or comfort, with low morbidity rate, in well-selected patients suffering of severe harmful spasticity of the upper limb resistant to conservative therapy. Patients must be selected after complete assessment by a multidisciplinary team. Timing of surgery is of great importance before the installation of definitive deformities, major drawbacks to good results.

*Keywords:* Spasticity; neurotomy; upper limb; functional neurosurgery.

**7C14****Parameters and Program for Deep Stereotactic Stimulation of Anterior Lobe of Cerebellum**

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*Objective:* The efficacy of the deep stereotactic stimulation of the anterior lobe in treatment of cerebral palsy depends on precise positioning of electrode in the target area and selecting of optimal parameters and program for chronic stimulation.

*Methods:* In 33 patients suffered from cerebral palsy the deep stereotactic high-frequency stimulation of anterior lobe of cerebellum was applied, previously transtentorially, in last three patient by new direct suboccipital approach, where the target area was 8 mm or 3/4 of the height of 4th ventricle rostral from fastigium, parallel to the floor.

*Results:* During monopolar test stimulation applied in the target area the motor response (indicator of proper position of electrode

and adequate electrical stimulus) was achieved at the frequency between 90 to 600 Hz, optimal response at 350 Hz. Sudden application of current induced (latency of 120 ms) bilateral elevation of the tone in the group of muscles mostly affected by the disease. From one side of paramedial area of cerebellum the response was bilateral, accompanied by feeling of pleasure, followed by active diminishing of hypertonicity which persisted usually for 5 to 15 min. The stimulation was discontinued for period as long as the elevation of muscle tone again was observed (individually 2–6 hours). The voltage for chronic stimulation was set according to threshold level at 0.5 to 2.5 V to evoke relaxation, the pulse width at 210 microseconds and for Medtronic system frequency of stimulation at 185 Hz. The patients are aware of stimulation. Gradual improvement of dyskinesias was observed after few weeks of stimulation. The effect tends to be decreased with time and stimulation parameters need to be adjusted.

*Conclusion:* Diminishing of muscular tone and dyskinesias in patients with cerebral palsy during deep chronic stimulation of anterior lobe of cerebellum improves their ability to gain new useful functions in course of physical therapy.

*Keywords:* Spasticity; deep brain stimulation; cerebellum.

**8B01****Accuracy of Frameless Deep Brain Stimulator Placement is Equivalent to Accuracy of Frame-Based Placement**

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*Introduction:* Deep brain stimulation (DBS) has become a well-established treatment for Parkinson's disease and other movement disorders. DBS electrodes are traditionally placed using a stereotactic frame, which can be uncomfortable for the patient and which requires the coupling of imaging and surgery. Frameless techniques offer advantages of patient comfort, decoupling of imaging from surgery, and the opportunity to incorporate real-time tracking of electrode position.

*Methods:* A three-phase multi-center study was designed to evaluate the accuracy of a frameless system for the delivery of DBS electrodes. In phase one, 135 localizations of a standardized target within a stereotactic phantom were carried out at 6 centers using the frameless device. In phase two, a stereotactic frame was used to confirm the trajectory in 21 DBS electrode placements. Final electrode position was measured on postoperative CT scans and compared to the planned position. In the third and final phase, the frameless device was used alone in 16 implants and the post-operative electrode position again compared to the planned pre-operative position.

*Results:* In phase one, the mean localization error of the frameless system was 0.98 mm with a 99% confidence interval of 0.86 to 1.10 mm. In phase two, mean localization error was  $x - 1.62$  mm,  $y - 1.09$  mm, and  $z - 2.26$  mm. In phase three, mean localization error was  $x - 1.32$  mm,  $y - 1.49$  mm, and  $z - 1.64$  mm.

*Conclusion:* Accuracy of frameless deep brain stimulator placement compares favorably with that achievable using a stereotactic frame, matching published accuracy data.

*Keywords:* Neuronavigation; Parkinson's disease; deep brain stimulation.

**8B02****Correlation of Microvasculature within Human Gliomas Identified at 8-Tesla Ultra High Resolution MRI and Histopathology Using Frameless Stereotactic Guided Biopsies**

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*Objectives:* To apply a methodology which integrates ultra-high resolution 8 Tesla (8 T) Magnetic Resonance Imaging (MRI) with biopsies assisted by StealthStation neuronavigation in order to correlate apparently disturbed microvasculature identified at 8 T to histopathologic findings.

*Material/methods:* Fifteen patients with suspected cerebral gliomas prospectively underwent 8 T high-resolution gradient echo magnetic resonance imaging with an in plane resolution of 196 microns. Intended biopsy sites were identified on 8 T MRI and the degree of apparently disturbed microvasculature was semiquantitatively assessed for each biopsy site on the basis of size and density of the abnormal microvascular structures relative to grey and white matter. In addition, each subject underwent 1.5 T spin-echo MRI with fiducial markers for neuronavigation. Biopsy specimens were obtained using image guided stereotactic neuronavigation (StealthStation, MEDTRONIC). Because fiducial markers are not readily identifiable on 8 T MRI, an algorithm was developed to triangulate the position of the biopsy sites and the 1.5 T images to the 8 T images. Stereotactically acquired specimens were independently assessed for degree of microvasculature semiquantitatively determined on histopathology using hematoxylin and eosin as well as reticulin stains in a blinded fashion. Microvasculature identified on the 8 T and histopathology was compared.

*Results:* Areas of intended biopsy were successfully identified on 8 T MRI and 1.5 T MRI. Contingency table analysis indicated that there was a statistically significant correlation between foci of microvasculature identified at 8 T MRI and histopathology ( $p < 0.0011$ ).

*Conclusion:* We have developed an algorithm to triangulate intended biopsy sites on 8 T using 1.5 T MRI neuronavigation which resulted in the accurate identification and characterization of areas of increased microvasculature within gliomas using ultra high-resolution GE 8 T MRI.

*Keywords:* Neuronavigation; frameless stereotactic guided biopsies; glioma; astrocytoma; microvasculature; ultra high field MRI; neoplasms; StealthStation.

**8B03****3D-Ultrasound Allows Intraoperative Resection Control**

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*Objective:* Neuronavigation is subject to anatomical changes during surgery leading to increasing inaccuracies in the course of tumor resection. Intraoperative update of imaging data is essential for correction of “surgical brain shift”. Intraoperative MRI is

rather time consuming and expensive, we therefore evaluated an intraoperative 3D navigational ultrasound system for neuronavigation and resection control.

*Methods:* A high-end ultrasound machine integrated with an optical neuronavigation system as a single rack solution (Mison, Trondheim, Norway) was used in 107 neurosurgical procedures. In 83 intracranial cases preoperative planning was performed with MRI datasets. Before and after dural incision 3D datasets were acquired with a registered 4–8 MHz phased array US probe, displayed and compared with preoperative MRI. The analysis of imaging data included tumor borders, surrounding structures and brain shift.

*Results:* In all cases the acquisition of 3D data sets and updates of intraoperative navigation were possible. Prior to dural opening there was a good alignment between MRI and US data. After dural opening and during surgery an increased “surgical shift” was observed. 49 gliomas, 14 metastases, 7 angiomas and 5 meningiomas and 8 other intracranial neoplasms were operated on. While in all meningioma and metastasis cases tumor borders were well delineated with US, only 75% of gliomas could be clearly separated from surrounding tissue. Especially cases with prior irradiation were difficult to interpret. The possibility of using a flow-mode allows an excellent intraoperative resection control in AV malformation surgery.

*Conclusion:* Intraoperative 3D navigated ultrasound offers an easily applicable real-time imaging for intracranial procedures. The combination of realtime imaging and US allows a comparison with preoperative MRI facilitating the interpretation of the US images. Surgical manipulations lead to deteriorated image quality impairing resection control especially in glioma surgery as compared to intraoperative MRI, a clear advantage is seen in resection of AV-malformations substituting intraoperative angiography.

*Keywords:* Neuronavigation; intraoperative imaging.

**8B04****Evaluation of Language and Hand Motor Function with fMRI in Patients with a Brain Mass Lesion: Validation with Intraoperative Electrocortical Mapping**

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*Objective:* Aim of the study was to evaluate the sensitivity and specificity of preoperative fMRI by correlating activation maps with intraoperative electrocortical mapping (ECM) in patients with brain lesions.

*Methods:* Twenty patients were evaluated preoperatively with fMRI (1.5 T). Histology showed 17 gliomas (12 low grade; 5 high grade), 1 metastasis, 1 meningioma, 1 cavernoma. Twelve patients were evaluated for language (auditory verb generation task), eight for hand motor task. The left fronto-insular-temporal region was investigated with the language task, and the prerolandic or postrolandic region with the motor task. The fMRI data were analyzed with SPM99 software with analysis threshold ( $p < 0.001$ ). The fMRI data were registered in a neurovigational device (Stealth Station, Sofamor Danek). Surgery was performed in asleep awake anesthesia. In order to determine true positive, true negative, false positive, and false negative, a site-by-site correlation

between preoperative fMRI data and cortical stimulated site was performed.

**Results:** fMRI localized Broca's area and the left dorsolateral prefrontal cortical in 85% of patients. In 88% of patients fMRI activated the left superior temporal gyrus. A total of 94 cortical sites (12 patients) were tested for language with ECM (Ojemann cortical stimulator). For the verb generation task the sensitivity was 82% and the specificity 61%. After surgery language was unchanged in 9 of the 12 patients. A total of 41 cortical sites were tested for hand motor function (8 patients); the sensitivity was 87% and the specificity 76%. There were no permanent postoperative deficits in hand and motor function in the patients with lesion adjacent to the central sulcus.

**Conclusions:** fMRI is useful to determine the risk of developing language or motor deficits during removal of a brain lesion. fMRI may help to plan the surgical approach. fMRI results must be interpreted with caution due to conceptual and technical differences from direct ECM.

**Keywords:** Neuronavigation; fMRI.

## 8B05

### Clinical Application of Functional MRI in Neurosurgery

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**Objective:** To assess the clinical usefulness of functional Magnetic resonance Imaging (fMRI).

**Material and methods:** A retrospective review of patients undergoing fMRI in our Institution.

**Results:** A total of 32 patients underwent fMRI scanning as part of the clinical assessment for lesionectomy for epilepsy, motor cortex stimulation for pain, and resections of AVM, cavernoma and tumour. In eight patients fMRI was used with intra-operative neurophysiology to locate the motor cortex in patients undergoing trial of motor cortex stimulation for pain, good correlation was observed. In nine patients fMRI was used to guide the placement of sub-dural grids for telemetry for epilepsy, only four gave good correlations with neurophysiological studies. In six patients (AVM/low grade tumour) the proximity of eloquent areas on fMRI influenced a decision to avoid open surgery. In 5 patients knowledge of fMRI locations in association with image guided surgery aided resections of lesions.

**Conclusion:** fMRI is a useful tool in the pre-operative evaluation of patients undergoing surgery for resectable lesions (low grade brain tumour, AVM, cavernoma).

Caution is needed in interpretation of fMRI and it should not be relied upon exclusively because not always correlation between fMRI and other modalities occur.

fMRI appears to be an useful tool in resectable lesions (low grade brain tumour, AVM, cavernoma) located in eloquent area of the brain, in particular related with the pre-operative planning. The identification of standardised tasks (to locate eloquent areas) and continuing to accumulate evidence correlating different modalities is required.

**Keywords:** Epilepsy; pain; microelectrode recording; fMRI.

## 8B06

### Statistical Mapping of the Subthalamic Region from Diffusion Tensor Magnetic Resonance Imaging

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**Objective:** This study is dedicated to the segmentation of the anatomical structures included in the subthalamic region, using DT-MRI and a modified clustering algorithm.

**Material and methods:** The DT-MRI acquisition was obtained in a healthy normal volunteer (age 36 years). The data was generated on a Siemens Magnetom Symphony 1.5 Tesla with a diffusion-weighted single-shot echo-planar sequence. The data consisted in 29 axial contiguous slices of 3 mm thickness covering the region of interest with 1.5 mm overlapping. The voxel size was  $1.64 \times 1.64 \times 1.5$  mm. The whole procedure was implemented on MATLAB 6.5 program (The Mathworks Inc., Natick, MA). Both subthalamic regions were clustered separately using the modified k-means algorithm with 4 a priori specifications: (1) the number of clusters was set to  $n = 5$ , (2) the distance metric was defined as a linear combination of the voxel distance and the tensor distance, (3) the  $n$  centroid locations were initialized randomly on  $n$  voxels of the volume of interest, although imposing a minimum distance between them and (4) a convergence criterion, i.e. no change of the centroid position between 2 iterations.

**Results:** Distinctive clusters were identified for (1) Pyramidal Tract, (2), Cerebrospinal Fluid, (3) Substantia Nigra, (4) STN Red Nucleus Forel Fields. The clustered subthalamic regions were matched with the corresponding T2-weighted sequence. The coordinates of the vectors of principal diffusion for each cluster were obtained.

**Conclusion:** Our preliminary results were consistent with structures identifiable on T2-weighted MRI, such as the red nucleus and the substantia nigra. STN itself could not be identified as a separate cluster, but its position could be deduced by the identification of the substantia nigra cluster. The current segmentation accuracy was limited for the most part by the image resolution and the probable significant fiber-crossing existing in the subthalamic region.

**Keyword:** Parkinson's disease.

## 8B07

### Neuronavigation: The Kiel Experience 10 Years – 1222 Patients

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**Objectives:** To Evaluate the Usefulness of Neuronavigation in a Clinical Neurosurgical Routine Setting.

**Methods:** Data collection of operations on 1222 patients over a period of ten years from 1994 to 2003 in a prospective manner and retrospective analysis of clinical results.

**Results:** Patients age ranged from 6 months to 90 years (mean 51 years). The procedures included brain tumor localization to facilitate tumor resection ( $n = 984$ ), tumors in the sella/suprasellar region operated via transsphenoidal or transcranial approach ( $n = 55$ ) as well as other skull base lesions (71), cysts, abscesses or hydrocephalus ( $n = 30$ ). Endoscopic instruments were included into the operation in 16 cases, functional brain mapping for surgery on lesions in eloquent brain areas in awake patients were performed in 67 cases.

The benefits of image guided surgery include facilitating the appropriate surgical approach, providing additional identification of surrounding normal structures and therefore enabling the surgeon to better delineate the surgical lesion. This has been thought to improve quality of surgery, allowing for more aggressive yet still minimally risky surgery providing better outcome. Incorporation of functional data provided by functional MRI and/or neurophysiological/neuropsychological monitoring in the awake patient additionally allows for identification of eloquent brain areas during surgery.

*Conclusions:* Since the major disadvantage of this technique is so-called "brain shift" resulting in intraoperative inaccuracy, neuronavigation has been shown to be most useful for operations on clearly delineated lesions (e.g. metastasis, cavernomas), those adjacent to eloquent cortical brain areas and skull base tumors.

The experiences, pitfalls, learning curves using three different systems (a mechanical arm system as well as optical systems with passive and active markers) will be presented, together with examples of specific applications of neuronavigation.

*Keyword:* Neuronavigation.

## 8B08

### Verification of MRI-Based Fiber Tracking of the Pyramidal Tract during Neurosurgical Procedures

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*Objective:* To validate the findings of the MRI-based fiber tracking of the cortico-spinal tract.

*Method:* With the diffusion weighted magnetic resonance imaging (DWI) it is possible to detect fiber tracts. An algorithm was used to display the pyramidal tract. During two meningioma resections the result of this fiber tracking of the cortico-spinal tract was integrated in an usual neuronavigation system (BrainLab). The position of the tracked fibers were identified during surgery and these spots were stimulated with the Ojemian cortex stimulator.

*Results:* In both cases there were contralateral limbs movements evoked by stimulation of these places according to the result of the fiber tracking.

*Conclusion:* The DWI calculated position of the tracked fibers of the cortico-spinal tract seem to match proper with the intraoperatively successfully stimulated positions. If this localization by DWI will turn out reliable in further investigations the integration of this data in neuronavigation may make surgeries along the pyramidal tract safer.

*Keywords:* Neuronavigation; fiber tracking.

## 8B09

### Evaluation of Brain Shift during Functional Neurosurgery by Vectorgraphic Analysis

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*Objectives:* Stereotactic surgery is based on a reproduceable high degree of accuracy in definition and localizing of intracranial targets as well as placement of surgical tools. Brain shift can influence it's accuracy significantly. Former studies were designed to evaluate the "total clinically relevant error" comprising errors associated with imaging, target selection, vector definition and the mechanical errors of stereotactic frames, without any consideration of dynamic intracranial changes including brain shift. And up to now, exact and reproducible models for determination of the magnitudes of the shift in the brain especially in the basal ganglia have not been established.

*Materials/methods:* In this study we performed a vectorgraphic brain shift analysis in a patient with Parkinson's disease, in whom electrodes were implanted initially in the Nc. subthalamicus (STN) of both sides and in whom electrode displacement occurred because of shift of central brain structures during surgery.

*Results:* Using a deformation field analysis of pre- and post-operative 3D-MR images (vectorgraphic analysis) an intraoperative brain movement of 13 millimetres near the brain surface and of two millimetres even in the region of STN could be documented in an excellent way. After following electrode-repositioning, we achieved efficient stimulation effects, which confirmed the suspicion of shift problem as the reason of electrode displacement.

*Conclusion:* The results of our study deliver an answer about the dimension of intraoperative brain shift during stereotactic procedures. To guarantee a safe stereotactic procedure and to prevent any undesirable side effects it's worth to minimize the loss of CSF by the use of fibrin glue or bone wax to re-close the bore hole during surgery, by shortening the procedure and by finishing the surgery in case of suspicion of electrode displacement. Until now no other study could demonstrate intraoperative brain shift with this grade of accuracy.

*Keywords:* Parkinson's disease; microelectrode recording; brain shift.

## 8B10

### Diffusion Tensor Imaging for Structural Analysis of White Matter Tracts in Brain Lesions

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*Objectives:* To evaluate the structural organization of communicating fibres in Brain tumor patients for surgical planning.

*Materials/methods:* 15 Patients with intraaxial lesions were studied prior to surgical intervention for intraaxial lesions. These lesions were located adjacent or within the motor area as well as the brainstem. Diffusion Tensor Imaging (DTI) was performed in a 1.5 Tesla MRI Unit. A semiautomated method for delineating the specific cortical areas was employed, which enabled the identification of white matter tract origin. From these origins the fibres are automatically detected.

*Results:* For patients with lesions adjacent to motor areas the white matter tract displacement was well delineated, few seeds were necessary to obtain a valid result, displaying the whole length of the cortico-spinal tract. The visualization modul displayed either colour-coded source slices, or overlaid grayscale sources (T1WI, and T2WI). The latter enabled more intuitive analyses of the data.

For patients with lesions extending into the motor areas white matter tracts were not delineated as well. It was remarkable, that more seeds were necessary to reach a continuous tracking of the white matter tracts (from cortex to brainstem).

Combined with functional anatomical studies, these studies sustained our clinical decision making.

**Conclusion:** Previously focussing on normal anatomical knowledge, functional studies and intraoperative electrophysiology, pre-surgical assessment as to the potential risks of surgery in eloquent areas underestimated the problem of cutting the subcortical connections. Thus these imaging modality already provides valuable information to augment surgical planning. Nevertheless there remain some shortcoming, such as the visualization of smaller connecting fibres as well as whether fibres traverse the lesion perimeter, thus providing incomplete information as to the resectability of a lesion.

More work is needed to enhance this imaging technology in regards to reliability and resolution.

**Keywords:** Neuronavigation; white matter tracts.

## 9A11

### Comparison of the Effect of Electrical Stimulation in the Nucleus Accumbens, the Mediodorsal Thalamic Nucleus and the Bed Nucleus of the Stria Terminalis on Compulsive Behaviour in Rats

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**Objectives:** A major disadvantage of electrical stimulation in the anterior limbs of the internal capsule in patients with obsessive-compulsive disorder (OCD) is the high energy consumption of the electrical current needed to obtain a good clinical outcome. 'Schedule-induced polydipsia' is a rat model for compulsions in patients with OCD. The aim of the present study is to compare in those rats the efficacy (percentage decrease in compulsive behaviour versus energy consumption) of electrical stimulation in the nucleus accumbens (nacc), the mediodorsal thalamic nucleus (md) and the bed nucleus of the stria terminalis (bst).

**Materials/methods:** Food pellets administered each minute induced excessive drinking in rats. Animals were included when drinking 8 ml/30 min or more during the last of 25 preoperative test sessions. They were randomly divided into four groups: electrode implanted in the 1) nacc (n=7), 2) md (n=8) or 3) bst (n=8), or 4) a sham-operated control group (n=7). Postoperatively, each rat of group 1, 2 and 3 was randomly tested in the model using either constant current monophasic rectangular pulses with a frequency of 2 Hz and 100 Hz, each at an amplitude of 0.1, 0.2, 0.3, 0.4 and 0.5 mA, or without stimulation. The pulse width remained fixed at 0.05 ms. Group 4 was tested 11 times without stimulation. Each day the rats were tested in random order. The electrode position was histologically verified.

**Results:** A first analysis indicated that high frequency stimulation decreased water intake in the first 3 groups, in a stimulation amplitude-dependent manner, with the highest efficacy in the bst.

In contrast, low frequency stimulation had no effect on drinking in the 'schedule-induced polydipsia' model.

**Conclusion:** The bst thus might serve as a potential target for electrical stimulation in OCD in humans. However, animal models for OCD have their limitations.

**Keywords:** Psychiatric indications; deep brain stimulation.

## 9A12

### Capsulotomy in Anxiety Disorders

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**Objectives:** Capsulotomy is a neurosurgical treatment for refractory obsessive-compulsive disorder (OCD) but is also, even more rarely, used for other anxiety disorders. The evidence for the efficacy of capsulotomy is limited.

**Methods:** We studied two groups of patients. First, 26 patients that had undergone bilateral thermocapsulotomy for anxiety disorders other than OCD (anxiety study) and the second ongoing study included 26 OCD patients that underwent gamma- or themocapsulotomy (OCD study). Patients were followed-up in mean 13 years post-op in the anxiety study and in mean 10 years post-op in the OCD study. Methods included rating scales of symptoms and global functioning, neuropsychological assessment, MRI scans and a personality inventory. Ratings were done by psychiatrists not involved in patient selection and postoperative treatment.

**Results:** In the anxiety study, the reduction in anxiety ratings was significant at long-term, 67% of the patients having a  $\geq 50\%$  anxiety rating reduction. Seven patients, however, were rated as having significant adverse events in terms of frontal lobe functioning, most prominent symptoms being apathy and dysexecutive behavior. Neuropsychological performance was significantly worse in these patients. Seizures and weight-gain were also reported. In a quantitative MRI analysis we were not able to confirm the findings by Lippitz *et al.* that a particular right-sided lesion was required for response.

Preliminary findings from the 17 first patients in the ongoing OCD study will be presented. The anti-obsessive effect was significant, the Y-BOCS dropped from 34 preoperatively to 18 at long-term follow-up. One patient was severely disinhibited post-operatively, two had persistent urinary incontinence and three patients had executive problems.

**Conclusions:** Capsulotomy was effective in treating both anxiety and obsessive-compulsive symptoms in the two studies presented here. In both studies, across diagnoses and surgical technique, there was a higher than expected rate of serious adverse events. Persistent apathy and executive problems were the main adverse events but more rarely, urinary incontinence, seizures and disinhibition were reported.

We therefore suggest that, if used, capsulotomy should only be performed at specialized centers with greatest caution and that it is crucial to continue to study the safety aspects of the procedure.

**Keyword:** Psychiatric indications.

## 9A13

### Electrical Stimulation of Inferior Thalamic Peduncle in Major Depression and Obsessive Compulsive Disorder

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**Objective:** To determine the effect of chronic electrical stimulation (ES) of the Inferior Thalamic Peduncle (ITP), a fiber tract that links non-specific thalamic nuclei with medial orbitofrontal cortex, in the control of major depression (MDD) and obsessive compulsive disorder (OCD)

**Patients and methods:** One-49 years old female with 23 years history of recurrent MDD, the last episode started 5 years before and was resistant to pharmacological and electroconvulsant therapies, with Hamilton Scale score from 33 to 38 and one 21 years old male with 15 years history of OCD characterized by agoraphobia and compulsive writing of his symptoms, resistant to pharmacological and cognitive therapy with score of 37 in Y-BOCS were selected for the study. Both patients were totally incapacitated by their symptoms. Prior surgery a complete neuropsychological evaluation was performed. Electrodes (DBS 3389 by Medtronic) were stereotactically implanted in ITP ( $x = 5.0$  mm,  $z = AC-PC$  level,  $y = 5.0$  mm behind AC) and their correct position confirmed by MRI and electrophysiologically by the evoked recruiting responses. ES parameters: 130 Hz, 0.45 ms, 2.5 to 4.5 V, bipolar and continuous. Psychiatric and neuropsychological evaluations have been repeated every 3 months.

**Results:** Hamilton Scale score decreased 30 points from the beginning and has remained so for 15 months in the MDD patient who is OFF medication. Preoperative abnormal scores in Wisconsin Card Sorting Test (WCST), praxias and verbal and non-verbal memory tests normalized. Y-BOCS scale score decreased 20 points and has remained so for 9 months in the OCD patient, with an improvement in WCST performance from 2 to 6 categories and number of errors decreased from 100 to 34. No adverse effects have been reported.

**Conclusion:** ES of ITP is a promising treatment to control MDD and OCD.

**Keywords:** Psychiatric indications; thalamo-orbitofrontal system; major depression; obsessive-compulsive disorders; electrical stimulation.

## 9A14

### **MRI Guided Capsulotomy for Refractory Obsessive-Compulsive Disorder: Results and Complications of 68 Cases**

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**Objectives:** To assess the efficacy and complication of magnetic resonance imaging-guided capsulotomy for treatment of refractory obsessive-compulsive disorder (OCD).

**Materials/methods:** 68 patients with obsessive-compulsive disorder who were intractable to medications, psychotherapy as well as behavior therapy which provided by experienced psychiatrists received bilateral anterior internal capsulotomy. Patients underwent Yale-Brown rating scale (Y-BOCS) and Hamilton anxiety rating scale (HAMA) as well as Hamilton depression rating scale (HAMD) as pre-operative and post-operative evaluations. 12 of 68 cases received a PET scan pre-op and post-op respectively for evaluation of capsulotomy induced changes of brain metabolism. The targets of anterior limbs of internal capsulum were determined under high resolution MRI and lesions were made by radiofrequency as 80°C 60 seconds. Intraoperative macroelectrode recording and stimulation were applied.

**Results:** 68 patients were followed up from 4 months to 51 months (mean 26.5 months): 35/68 (51.5%) cases were OCD symptoms free, 20/68 (29.4%) cases were significant improved (symptoms improved more than 50%), 13/68 (19.3%) remained mild or not improved. Meanwhile, scores of Y-BOCS, HAMA, HAMD also decreased significantly. Temporary side effect such as urinary incontinence, memory complaints and confusion were seen in most patients. As a severe complications of capsulotomy, 6 case (8.8%) experienced personality changes postoperatively, it including: apathy, dysexecutive behavior, inactive and lack of interest, poor judgment.

**Conclusion:** MRI guided capsulotomy demonstrated substantial benefit for 80%. Compare to those of previous studies of surgical treatment, capsulotomy has more effect for refractory OCD, but the adverse consequences of capsulotomy must be highly paid attention.

**Keyword:** Psychosurgery; obsessive-compulsive disorder; capsulotomy.

## 9B11

### **Real-Time 3-D Ultrasound Neuronavigation System (Sonowand-Mison). Experience with 114 Cases**

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**Objective and importance:** Three dimensional (3-D) ultrasound has recently emerged as an alternative intraoperative imaging modality used for neuronavigation. The system offers a real-time upgraded image of the operative zone. This paper summarizes one year clinical experience of using intraoperative 3-D ultrasound integrated into neuronavigation (SONOWAND-MISON) for guidance in neurosurgical interventions, specially in brain tumor resection.

**Methods:** Between January 2003 and December 2003, 114 patients were operated in our department with the help of the ultrasound-based neuronavigation system. Eighty-eight patients had brain tumors, 4 intracerebral hematomas, and 2 had brain abscess. The system was used for frameless biopsy in 8 cases. The SONOWAND-MISON<sup>®</sup> 3-D ultrasound neuronavigation technology presented with the combination of ultrasound 3-D acquisition and navigation. Ninety-four craniotomies were performed using full integrated neuronavigation – associating conventional navigation and real-time ultrasound imaging – and 10 using only the ultrasound application.

**Results:** The surgical duration was with no significant difference when using the system comparative to standard neurosurgical operations. It has improved the craniotomies design which also was better adjusted. It has allowed a more safe and functional protective approaches in eloquent areas minimizing the brain dissection. The resection control was improved using the 3-D ultrasound control intraoperatively with a better hemostasis. Upgrading the map many times during the intervention enabled us to reduce the significance of brain shift.

**Conclusion:** Intraoperative 3-D ultrasound seems to provide a time- and cost-effective way to update high quality 3-D maps used in neuronavigation being an alternative for the intraoperative MRI.

**Keywords:** Neuronavigation; intraoperative 3-D ultrasound.

**9B12****In Vivo Determination of the Accuracy of Stereotactically Implanted I-125-Seeds Using Intra-Operative X-Ray Imaging**

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*Objectives:* In stereotactic guided interstitial therapy of brain tumors I-125-seeds are implanted at pre-calculated positions. The aim of this study is to determine the degree of spatial accuracy of implanted seeds achieved in our hospital and to analyze the dosimetric consequences of possible misalignments.

*Methods:* From all patients treated in our hospital during 6/1994 and 2/2002 for gliomas and brain metastases 37 patients (with 65 implanted catheters and 157 seeds) have been selected randomly. Archived intra-operative x-ray images have been digitized and analyzed using in-house software for stereotactic treatment verification (STV-X). The target point accuracy has been determined from the planned coordinates of the target points and the measured coordinates of the implanted catheters. The change in target dose and dose to brain has been quantified with the treatment planning software (STP3) for dose calculation using the measured and originally planned seed positions.

*Results:* The mean error in x, y and z is  $-0.1, 0.3$  and  $0.2$  mm with standard deviations of 1.1, 1.2 and 1.4 mm. The resulting spatial accuracy of the implanted catheters is  $0.2 \text{ mm} \pm 0.9 \text{ mm}$ . Only random and no systematic errors were observed (t-test). Tests of the factors diagnosis, location, target volume, catheter length showed no significant influence on the accuracy. Analysis of the influence of positioning errors on the target dose and dose conformity showed that spatial target point errors less than 1.5 mm has only minor influence on the quality of the treatment. For errors greater than 1.5 mm we found in 60% of the cases dose deviations of more than 5%.

*Conclusion:* The results establish standards for quality assurance in stereotactic interstitial therapy. The determined high accuracy requirement for the target point of 1.5 mm indicates the need for postoperative dosimetry.

*Keywords:* Radiosurgery; interstitial therapy.

**9B13****Targeting the Vim Nucleus by Direct MRI Visualization**

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*Objective:* To demonstrate the imaging technique and anatomical correlations that enable recognition of the Vim nucleus of the thalamus using clinical high-field MRI.

*Methods:* Patients selected for stereotactic thalamic surgery (either thalamic stimulation or thalamotomy) had a pre-operative MRI performed on a 3T GE MR system. A modified spin-echo protocol was selected to produce fine axial slices throughout the upper midbrain and basal ganglia up to the level of the lateral ventricles.

The images were processed using a computer workstation to allow fusion with stereotactic computerized tomography (CT) and multiplanar reformatting for surgical planning.

*Results:* The thalamus, capsula interna, pallidum, AC, and PC, were clearly outlined. The Vim was consistently delineated as a hypo-intense band coronally crossing the ventral-lateral mass of the thalamus, with a typically elongated triangular shape. The images were correlated with anatomical slices of the Schatellbrand and Bailey map. The anatomical substrate of the particular magnetic characteristics of the Vim will be discussed. A clinical case of bilateral Vim stimulation will be shown.

*Conclusion:* We demonstrate that the Vim nucleus of the thalamus can be targeted by direct visualization using clinical high-field MRI. Direct targeting of the Vim greatly enhances the probability of obtaining successful results in stereotactic procedures, as has been previously shown for other popular functional targets such as the pallidum and subthalamic nucleus.

*Keywords:* Stereotactic targeting; Vim; MRI.

**9B14****Cerebral Lesions Located in Functional Critical Areas. Preoperative Assessment and Extended Use of Cortical Stimulation**

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During surgical resection of lesions placed in critical cerebral areas like language, motor and somatosensory cortex, the functional and structural preservation of such areas is crucial. By now, neuronavigation has a consolidated role in the anatomical orientation inside the brain. Consequently we are looking today for accurate functional information of the area involved by surgery. The accuracy of preoperative analysis, which could be useful during surgery, is still lacking and we still need cortical mapping.

*Material and methods:* We present a series of 97 consecutive cases of lesions located in functional critical areas, 24 in language cortex and 74 in central area. All cases of the latter group underwent registration of cortical evoked responses and motor potentials (Curry; Neuroscan-USA). The functional information have been loaded in the navigator (Stealth Station, Sofamor Danek-USA). During surgery we compared the coincidence of preoperative and intraoperative data with cortical mapping. We evaluated these data also with reference to topographical, volumetrical and istological peculiarity of the lesions. In particular, we have performed a study in a subgroup of patients underwent to a preoperative neurophysiological evaluation and, afterwards, to a resection of the lesion in motor-sensory area. The relationship between functional postoperative status and location of the lesion has been evaluated. It was recognised that lateral displacement of function is a worse prognostic factor.

*Results:* We have obtained cortical recordings in 72 cases (97.3%). During surgery we found a coincidence equal or less than 15 mm in 43% of cases. The better results have been obtained in patients with limited structural deformation, compatible with predictable areas of positive cortical stimulation. In cases with major anatomical deformity the coincidence has been very poor. In our series there was no mortality and the morbidity one month after surgery was 7%.

*Conclusion:* The preoperative functional information available from studies of motor and somatosensory cortex are still limited for surgical purposes even if this method is still in progress. Particularly interesting is anyway the possibility of having functional indicative data also in cases with major anatomical alteration. Up to now cortical mapping still remains resolute in selected cases.

*Keywords:* Neuronavigation; direct cortical stimulation; awake patient; brain mapping.

## P001

### Uncommon Movement Disorders – Unusual Approach to Neurosurgical Correction

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*Objective:* Different injuries of the human brain and spinal cord sometimes are followed by uncommon movement disorders (“philogenetic zoo”). An unusual neurosurgical approach is needed in these unusual conditions. We present our experience in neurosurgical correction of uncommon movement disorders (MD) or MD in unusual cases.

*Materials and methods:* CASE 1. Severe posttraumatic and post-encephalitic torsion dystonia with pain syndrome in neck, arms and legs – 1) bilateral DBS of GPi (Kinetra); 2) bilateral SCS on the lumbar level (Synergy). The result – disappearance of torsion painful spasms in cervical, thoracic, arm and hand muscles, disappearance of pain syndrome in legs, restoration of self-service and mobility; CASE 2 and CASE 3. Severe spastic paraparesis after ischemic injury (1) and siringomyelia (2) – combination of selective posterior rhizotomy (bilateral L1-S1) with epidural spinal cord stimulation (SCS) on the lumbar level (Itrel3). The results – relief of painful spasticity in legs and feet, restoration of the ability to stand (CASES 2, 3) and walk without assistance (Case 2); CASE 4. Severe posttraumatic bilateral intention-ballistic hyperkinesias in arms and hands – bilateral DBS of VIM. The result – bilateral decrease of hyperkinesias and improvement of self-service; CASE 5. Ischemic stroke of the spinal cord on C3-C6-level followed by hypotonic tetraparesis – epidural SCS on the lumbar level with changeable frequency (Mattrix). The results – low frequent SCS in early stage (2–3 months) followed by restoration of active movements in arms, increasing of muscle tone in legs and feet to the spastic level. The replacement of low frequent SCS by high frequent SCS (after the spasticity have began to disturb the rehabilitation process) allowed to decrease the spasticity and partly to restore active movements in legs by 8 month after the stroke.

*Conclusion:* The uncommon movement disorders demand the above-mentioned neurosurgical approaches for its correction.

*Keywords:* Dystonia; spasticity; pain; dystonia; DBS; SCS.

## P002

### Recurrence of Dystonia after Discontinuation of Chronic Deep Brain Stimulation

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*Objective:* Chronic deep brain stimulation (DBS) for medically refractory dystonia has been recognized as a valuable treatment

option only recently. The full effect of DBS may appear only after months, but in contrast to Parkinson’s Disease it is unknown how dystonic symptoms recur after discontinuation of chronic DBS.

*Methods:* In this prospective study we enclosed 8 patients with segmental or generalized dystonia who underwent pallidal (7 patients) or thalamic (1 patient) chronic DBS. Mean age at surgery was 47.9 years, there were 4 men and 4 women. The time course of the appearance of dystonic symptoms has been assessed at 5/–2 months post-operatively according to the Burke-Fahn-Marsden (BFM) Dystonia Scale immediately and at 4 hours after switching off DBS.

*Results:* Seven patients benefitted from chronic DBS, while one patient had no improvement. After discontinuation of DBS, dystonic symptoms recurred within minutes in 3 patients. In one of these patients, further worsening of dystonia was observed over the next four hours. In the other 4 patients dystonic symptoms only gradually returned to baseline at 4 hours. The dystonic symptoms which reappeared early after discontinuation of DBS were primarily phasic, while those which worsened gradually were the tonic components.

*Conclusions:* Discontinuation of chronic DBS in patients with dystonia has a differential impact on the time course of the reappearance of phasic and tonic dystonic movements. These findings indicate that the effect of DBS on dystonic symptoms are mediated via different pathophysiological processes.

*Keywords:* Dystonia; deep brain stimulation.

## P003

### Limits and Errors of the Neuronavigation System in Intracranial Pathology Neurosurgical Treatment

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*Object:* The introducing of neuronavigation systems in neurosurgical practice seems to be a real advantage to achieve higher precision and accuracy in operative procedures. It is known, the main profit of the image-guidance systems is the 2D and 3D visualization of the anatomical structures and possibility of the virtual instrument movement on computer monitor during the operation. However, there are situations when the system is breaking down and the accuracy of reality to virtuality projection is not acceptable by neurosurgeon.

*Material:* There were analyzed 90 operations with the neuronavigation system carried out in Department of Neurosurgery and Pediatric Neurosurgery PMU, Szczecin PL from 2001 to 2003. All the patients were operated due to primary and metastatic brain tumors and arteriovenous matformation. The patient registration to the system was supported on the preoperative MRI scanning (layer thickness less than 2 mm) and to the head anatomical points.

*Methods:* There were estimated MRI-, patient-, neurosurgeon-dependent factors influencing on final accuracy of neuronavigation system, the value of brain shift, the dura and the brain surface movement in craniotomy, the brain shift because of tumor and its histopathology. Finally, the role of lumbar puncture during the operation was estimated to minimize brain shift and to improve the tumor removal.

*Results:* In analyzed series the final neuronavigation system accuracy was 1.2 mm, the area (circle) of 2 mm the best accuracy contained 55% of skull and brain volume and 65% of tumors was behind this area. The dura shift hesitated 3–4 mm and brain surface shift was from 4 to 25 mm. The lumbar puncture carried out in 70% patient increased brain collapse in craniotomy especially in oedematogenous tumors.

*Conclusion:* The main role in the patient registration takes part the accuracy of preoperative MRI scanning, very important

is a neurosurgeon precision in registration procedure. During the operation it is necessary the verification all parameters of the brain shift. The most important is confirmed using intraoperative sonography or MRI. The lumbar puncture seems to be very useful in normalization of intraoperative brain shift.

*Keyword:* Neuronavigation.

## P004

### Outcome of Unilateral Stereotactic Ablative Surgery for Parkinson's Disease using Direct Depicting of Basal Ganglia and Individual Anatomical Landmarks

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*Objectives:* The assessment of late results of treatment of the patients with Parkinson's disease by thalamotomy and pallidotomy.

*Material and method:* Between December 2000 and May 2003 343 patients with Parkinson's disease were treated in our department. Stereotactical surgical intervention was performed on patients of highly intensified movement signs and of ineffective conservative treatment. When tremor dominated electrocoagulation of nucleus ventralis intermedius of the thalamus (Vim) was performed (118 cases). However when rigidity or intensified levodopa-induced dyskinesias connected with bradykinesia were noticed the internal globus pallidus (GPi) was destroyed (225 cases). Setting targets was made after MRI IR and CT full volumetric image fusion and by the use of direct visualisation of thalamus, globus pallidus and their relationship to the individual anatomical landmarks (internal capsule, third ventricle and optic tract). Moreover the position of the target was verified in relation to midcommissural point and by the use of computer Schaltenbrand and Wahren brain atlas (BrainLab's@Target v.1.17). Surgeries were performed in local anaesthesia checking functional position of the target by the means of macrostimulation. The patients were examined, always in "off"-drug condition, before surgery, on the 5<sup>th</sup> day after surgery and at least 1 year after operation basing on total Unified Parkinson's Disease Rating Scale (UPDRS) and its parts, Schwab and England Activities of Daily Living Scale (S&E). The stage of the disease was estimated basing on Hoehn and Yahr Scale (H&Y).

*Results:* According to total UPDRS on the 5<sup>th</sup> day after thalamotomy the improvement was 50%, according to tremor score of UPDRS – 68.3%, according to H&Y scale – 1.8 degrees and according to S&E scale – 22 points. The time "off" decreased of 68%.

Immediately after pallidotomy the improvement was 44% according to total-UPDRS, 1.7 degrees according to H&Y scale and 25 points in S&E scale. The time "off" decreased of 45% and dyskinesias of 77%. The authors intend to show the evaluation of the outcome received at least 1 year after the surgery.

*Conclusions:* Adequate selection of the patients for thalamotomy and pallidotomy determine good results of surgical intervention in Parkinson's disease. In some cases verifying the position of the target based on direct visualisation of thalamus or globus pallidus can improve accuracy of target localisation and results of treatment of the patients with Parkinson's disease.

## P005

### LINAC Based Radiosurgery of Intracranial Arteriovenous Malformations

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*Objectives:* Surgery is the treatment of choice for brain AVMs, but radiosurgery and embolization has been accepted as an alternative treatment. Embolization can completely obliterate the lesion or reduce the size of the malformation as a preoperative or pre-radiosurgery measure. We will describe the overall experience of radiosurgery alone and with embolization in the treatment of large complex and deeply located AVMs.

*Methods:* During the period from 1991 to 2002, 68 patients; 48 males and 20 females, ranging in an age from 8–63 years with brain AVM, were treated by Endo-vascular technique followed by Linac Radiosurgery to obliterate the residual nidus. Endovascular treatment has been performed by means of super selective techniques and intra-nidal injection of NBCA.

*Results:* The follow-up clinical, MRI and angiographic studies demonstrated:

1. Total obliteration of the residual AVM in 28 patients (2 to 3 years follow-up).
2. Regression of the residual nidus in 16 patients.
3. No change in 6 patients.
4. Others are in short follow-up.
5. No additional neurological deficits were encountered in any case after the treatment.

*Conclusions:* Radiosurgery is an effective alternative and safe procedure in the management of surgically difficult and deep seated AVMs and also after incomplete embolization.

*Keywords:* Linac; radiosurgery; malformations; arteriovenous.

## P006

### Surgical Treatment of Movement Disorders – Early Experiences in Saudi Arabia

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*Objectives:* There have been several developments, which have contributed to the renaissance of functional Neurosurgery. Ablative surgery and deep brain stimulation for the Parkinson Disease and other movement disorders can be performed in the thalamus, the pallidum and the subthalamic nucleus. Presently unilateral pallidotomy is probably the most widely practised procedure for advanced stage of Parkinson's disease.

*Methods:* Since the inception of the functional Stereotactic programme in 2002 at Riyadh Armed Forces Hospital we have performed 27 successful lesioning in 24 patients for Parkinson's disease, levodopa induced dyskinesias, tremors, dystonia and essential tremors. We use RM frame rigidly fixed to patient's head under local anesthetic. Coordinates of targets for functional stereotactic surgery are determined by extrapolation and the x, y, z co-

ordinates are defined. Image fusion of MRI with CT using STP 4 workstation is done and the patient is transferred to OR. RM frame with aiming bow in place a burr hole is placed and a probe introduced to slowly stimulate the target and on confirming the target. Radiofrequency lesioning is performed using N50 Leibinger Lesion generator. Throughout the procedure a neurological assessment is carried out by the neurologist and patients participation is also encouraged.

*Results:* Immediate post-operative improvement was noticed in all these patients. Three, six and twelve monthly follow-up using Unified Parkinson Disease Rating Scale (UPDRS) showed substantial improvement in motor off, motor on, activities of daily living off and activities of daily living on. The most dramatic effect was seen on dyskinesia with substantial reduction in contralateral dyskinesia and some in the ipsilateral dyskinesia.

*Conclusions:* Lesioning as a surgical option for movement disorder treatment remains a viable option with the improvement in imaging techniques and image guidance especially in developing countries where DBS is an affordable and close monitoring and programming difficult to carry out. Whereas unilateral lesioning does impair motor responses to levodopa, it does not allow for post-operative reduction in daily levodopa dose. Long-term results of unilateral lesioning have yet to be evaluated by us.

This is our limited early experience with a small number of patients and we will discuss our shortcomings and plans for the future including lesioning the subthalamic nucleus.

*Keywords:* Thalamotomy; pallidotomy; lesioning; dystonia; dyskinesia.

## P007

### Surgery of Parkinson's Disease: Retrospective Results of Early Results

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*Objectives:* Retrospective evaluation of the safety and efficacy of different surgical procedures in patients with advanced Parkinson's disease (PD).

*Methods:* Using diagnostic criteria and evaluations outlined in the Core Assessment Programme in Transplantations (CAPSIT) protocol, we revised twenty-three patients with advanced idiopathic PD who had been operated in the period between March 1998 till October 2002. Thalamotomy was done in 5 cases and pallidotomy was done in 5 cases. Deep brain stimulation was done in the remaining 13 patients. Thalamic stimulation was in 4 cases, pallidal stimulation was done in 4 cases and sub thalamic nucleus (STN) stimulation was done in the remaining 5 patients. Assessments conducted in the "practically defined off" and "best on" states at baseline and at 1 and 6 months

postoperatively included Unified Parkinson's Disease Rating Scale (UPDRS) parts II, III, and IV and timed motor testing as outlined in CAPSIT.

*Results:* Thalamotomy and thalamic stimulation was very effective in controlling the tremors with complete discontinuation of their antiparkinsonian drugs. Pallidotomy or pallidal stimulation was able to improve the rigidity and bradykinesia or drug induced dyskinesias, we were able to reduce the antiparkinsonian drugs reducing their side effects.

*Conclusion:* Deep brain stimulation is very effective in controlling the cardinal symptoms of Parkinson's disease with reduction of the doses of the antiparkinsonian drugs and improvement of the drug-induced side effects.

*Keywords:* Parkinson's disease; surgery; thalamotomy; pallidotomy; deep brain stimulation.

## P008

### Deep Brain Stimulation: Initial Experience in Malaysian Patients

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*Objective:* To develop a functional neurosurgery programme at Sunway Medical Centre, Petaling Jaya, Malaysia, for implantation of deep brain stimulators (DBS) in patients with advanced Parkinson's disease.

*Methods:* A strict protocol was designed for selection and pre-operative assessment of potential patients. Criteria for surgery were functional impairment which could not be managed with best medical therapy, and levodopa-induced dyskinesia. Surgical candidates were selected after assessment by an expert panel which comprised in-house and external neurologists and neurosurgeons with interest in movement disorders. All patients had subthalamic nucleus as the selected target for implantation. Stereotactic surgery was performed using the Leksell frame. Target localisation was based on anatomical coordinates, Schaltenbrand-Wahren brain atlas and stereotactic MRI guidance. Confirmation of target was done with microelectrode recording using LeadPoint Micro-Electrode Recording system. Final confirmation of target localisation was performed with Macro Stimulation.

*Results:* DBS surgery was performed on eight patients between February and December 2003. A total of 15 leads were implanted. There was no serious surgical complication. Four patients had previous procedures done elsewhere: unilateral pallidotomy (Patients #2 and #3), bilateral pallidotomy (Patient #6) and bilateral DBS (Patient #7). Six patients showed satisfactory improvement in medication dosage and motor function using the Unified Parkinson's Disease Rating Scale (UPDRS Items 5-31). Two patients (#6 and #7) who had operation in December 2003 have residual problems. Patient #6 has persistence of coarse flapping unilateral tremor. Patient #7, who had re-implantation on one side, has asymmetric functioning which led to problems with programming which are currently being addressed.

*Conclusions:* These early results have been very encouraging and provide a stimulus for expanding our programme.

*Keywords:* Parkinson's disease; microelectrode recording; deep brain stimulation; Malaysia.

**P009****Stealthstation Neuronavigation for Planning Micro-electrode Trajectories**

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*Objectives:* Hemorrhage during microelectrode recording in the human brain is well recognized. The authors describe a method of neuronavigation that enables direct visualization of the proposed microelectrode trajectory and thus avoidance of subdural, sulcal and periventricular vessels.

*Materials/methods:* Twenty-five Parkinsonian patients presenting for bilateral subthalamic nucleus (STN) deep brain stimulation (DBS) were prospectively followed. Each had pre-operative MRI localization of their STN. Images were transferred to the StealthStation Neuronavigation computer (Medtronic, Minneapolis, MN) in the operating room. Sequences for visualizing the STN were merged with thin cut axial post-gadolinium T1 weighted images through the entire head and stereotactic frame. Framelink 4.1 software was then used to plan individual microelectrode trajectories. Patients had pre-operative and four month post-operative UPDRS motor measurements. Routine post-operative CT scans were performed prior to discharge. Hemorrhagic complications were defined as new post-operative clinical deficits due to hemorrhage.

*Results:* In this small cohort, no patient had any hemorrhagic complications. Four months post-operatively, UPDRS motor scores on medications were significantly improved by 62% with stimulation "on" compared to "off".

*Conclusion:* This study was designed to demonstrate the feasibility of utilizing StealthStation neuronavigation to plan micro-electrode trajectories during DBS surgery. Potential sulcal and periventricular vessel penetration by the microelectrode (and its guide tubes) were visualized pre-operatively and avoided. Avoiding these vessels will theoretically help to reduce the hemorrhagic complications associated with microelectrode use. A larger series is being followed to confirm this.

*Keywords:* Microelectrode recording; Parkinson's disease.

**P010****Microrecordings-Based STN Stimulation in Parkinson's Disease**

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*Objectives:* Our results with microelectrodes recording-based STN stimulation in a group of 13 Parkinson's Disease (PD) patients with a FU of 6 months are presented, focusing on motor and daily life activities, and changes in need of medication.

*Material and methods:* A group of 21 PD patients have been operated up to date, 13 with a FU of 6 months. The mean age was 63 yrs (43–73), with dyskinesias and motor fluctuations in 95 of cases. The Leksell frame and CT-MR imaging fusion software were used (Medtronic Framelink). Microelectrode recordings were obtained with a microdrive along the tracks to the STN looking for evidence of subthalamic activity and processed with Leadpoint

(Medtronic). Macrostimulation followed looking for evidence of tremor/rigidity changes and absence of side-effects.

*Results:* A 63% time increase in the ON period and a 53% reduction in the OFF period, and a decrease of 83% in dyskinesias and dystonia were observed. At 6 mos FU, UPDRS II scale shows a 25% decrease in the OFF-M/OFF-S state, and 16% in the ON/ON state. UPDRS III scale shows an 8%, 50%, 15% and 44% reduction in the OFF/OFF, OFF/ON, ON/OFF and ON/ON states respectively. The need for L-Dopa intake dropped a 47%.

*Conclusion:* Microrecordings are a valuable tool for precise target localization but are troublesome and time-consuming. The reduction in motor off periods, dyskinesias, dystonia and motor fluctuations leads to a better quality of life.

*Keywords:* Parkinson's disease; microelectrode recording; subthalamic stimulation.

**P011****Hardware Infections Following Deep Brain Stimulation**V. Visser-Vandewalle<sup>1</sup>, Y. Temel<sup>1</sup>, L. Ackermans<sup>1</sup>, H. Celik<sup>2</sup>, T. van de Kar<sup>1</sup>, G. H. Walenkamp<sup>1</sup><sup>1</sup> University Hospital Maastricht, The Netherlands<sup>2</sup> University of Maastricht, The Netherlands

*Objective:* To report on our experience with hardware-related infections following deep brain stimulation (DBS).

*Material/methods:* This is the retrospective chart review of the experience gained in a two-centre, single-surgeon study of 108 consecutive DBS cases, operated upon between 1996 and 2002. In all patients the minimum follow-up was six months. In all patients the electrodes were fixed in the burr hole with acrylic cement (Antibiotic Simplex; Howmedica, Ireland), and 106 underwent internalisation with implantation of a pulse generator, at a second stage.

*Results:* In total 178 electrodes were implanted with a mean follow-up of 42.6 months and a cumulative follow-up of 367.7 patient-years. Four patients (3.8%) developed an infection related to the DBS-hardware. All four were initially treated with antibiotics. Two patients (with a bilateral STN DBS for PD) eventually required additional surgical therapy. In the two patients one of the two pulse generators (Itrel II in pt 1, Itrel III in pt 2, Medtronic) and extension cables were removed, with the electrode left in situ. In patient 1, a new pulse generator was implanted after 2 months. In patient 2, because of persistent necrosis of the skin covering the burr hole, a microsurgical free-tissue transfer was performed. After graciloplasty, the vessels of the m. gracilis were anastomosed end to end to the a. and v. temporalis superficialis. One month later, a new extension cable and pulse generator were implanted.

*Conclusion:* Infections due to DBS-hardware can result in considerable morbidity. Conservative treatment with intravenous administration of antibiotics may be successful. In other cases, temporal removal of pulse generators and extension cables might be necessary. In our experience, the electrodes never had to be removed, even if there was a persistent skin necrosis with evident infection of the wound covering the site of electrode implantation.

*Keywords:* Parkinson's disease; infection.

**P012****A Simple Intraoperative Chart for Stereotactic Surgery for Movement Disorders in Developing Nation**

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*Objectives:* To date, various approaches has been used, such as radiological, anatomic, physiological or all three to precisely locate the target within the human brain in the stereotactic surgery of movement disorders. Various sites had been identified as a possible site for different types of movement disorders such as ventral intermediate nucleus (VIM), subthalamic nucleus (STN) and pallidothalamic system. In order to precisely documenting the procedure being performed and accurately localizing the target area, we propose a simple intraoperative chart comprising brief clinical information of the subject/patient, radiological investigation, target area for the treatment of particular movement disorders and multiple selected target points in association with neurophysiological parameters, schematic topographic representation and patient complaints or symptoms during the procedure.

*Methods:* Based on our clinical experience in performing movement disorder surgery and literature research pertaining to this, we derive an intraoperative chart for stereotactic movement disorder surgery.

*Results:* An intraoperative chart for movement disorder surgery is invented and proposed for clinical use.

*Conclusion:* This documentation will provide a useful clinical documentation of the procedure being performed and assist the surgeon to accurately locate the desired target area for various movement disorders.

*Keywords:* Intraoperative chart; movement disorder.

**P013****Deep Brain Stimulation for High Stage of Parkinson's Disease**

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*Objective:* To present preliminary results of deep brain stimulation (DBS) of the subthalamic nucleus (STN) in the high stage for Parkinson's disease (PD).

*Methods:* The bilateral DBS STN has been performed in three cases of PD with akinesia. In all cases the preoperative OFF-medication condition corresponded to the fifth stage of the Hoehn & Yahr scale. Clinical examinations have been lead in 1, 3 and 6 months postoperatively in the OFF-medication condition with ON-stimulation.

*Results:* Improvement on scales UPDRS II, III, Schwab & England end PDQ-39 was observed at two from three patients. They have improved up to the fourth stage on the Hoehn & Yahr scale. The third patient had severe vegetative disorders, urinary disturbances, the depression and mental and emotional frustrations. This 70 old years patient has received the positive result on all scales [H&Y – 4] in the first month. After that she has shown the deterioration in akinesia and rigidity and marked increase in UPDRS II & III. She has decreased of daily-living activity on

Schwab & England scale and quality of life on PDQ-39. The stage of Parkinson's disease returned to the fifth stage.

*Conclusions:* The bilateral DBS STN is an effective neurosurgical method even for the high stage of PD. It improves the quality of life and the gerontological nursing. Precise criteria are necessary for selection of patients for surgical treatment in high stage of PD. If patient has severe vegetative disorders, urinary disturbances, the depression, mental and emotional frustrations, it's the certificate of development of the terminal stage. Probably, appearance of such symptoms in these cases can be a comparative contraindication for the neuromodulation.

*Keywords:* Parkinson's disease; deep brain stimulation.

**P014****Treatment Tactic Selection for Patients with Cranial Neuralgias (Fundamentals of Pre-Operative Planning)**

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*Objectives:* The goal of this work is to show the substantiation of indications for microvascular decompression (MVD) and fundamentals of pre-operative planning that is the key moment in achieving treatments success.

*Methods:* 1. Evaluation of complaints and neurological status of the patient with use of standardized questionnaires. Diagnosis of "classic" neuralgia shouldn't call any doubts. 2. MRI on high-resolution systems with contrast intensifying (GAD 3D SPRG) allows to eliminate others reasons of neuralgia (tumor, malformation, MS) and reveal degree of contact of the nerve root and vascular till 100% in cases of arterial contact and till 80% in cases of venous contact. In cases where is present just root and vascular contact it is possible to continue medicament treatment (effectiveness till 70%), but in cases where root deformation is approved effective is MVD only. 3. EMG is an important indirect tag of the fact of rough root compression (deformation), especially in cases of clinical tags of portions V2 and V3 trigeminal nerve suffering. Compression of sensory fibers of these portions almost always is accompanied with compression of moving portion of the nerve, which leads to increase of latent period of masseter reflex.

*Results:* Keeping these diagnostic steps allows legibly prognosticate operation plan and define zone of root compression which must be revealed during operation. Keeping microsurgical technology and principle of non-retractor surgery, compression zone verification corresponding to clinical manifestation, neuro-visualization data and neuro-physiology allows achieving almost 100% result at absence of neurological fallout.

*Conclusion:* MVD in cases of cranial neuralgias is patogenetically reasonable operation, allowing achieve stable and complete result of pain regress at absence of neurological fallout. Extremely low level of operational complications at precise keeping "Jannetta technology" makes MVD attractive operation both for the surgeon and for patient.

*Keywords:* Pain; microvascular decompression; cranial neuralgias; preoperative planning.

**P015****Intraoperative Electrocoagulation (ECoG) in Temporal and Extratemporal Epilepsy Surgery**

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**Objectives:** The value of intraoperative ECoG in epilepsy surgery (especially in temporal lobe epilepsy-TLE surgery) remains unclear. Some authors emphasize the importance of pre- and post-resection ECoG in guiding the extent of temporal lobe resections; others advocate a standard operation.

**Materials/methods:** We performed both pre and postresection ECoG in 10 consecutive patients with Mesial Temporal Sclerosis, who underwent either temporal resection or selective amygdalo-hippocampectomy and in 5 patients who underwent extratemporal lesionectomy. The recordings were obtained using either a grid over the lateral temporal surface, sub temporal strips and depth electrodes placed in the head and body of the hippocampus, or a grid over the extratemporal epileptogenic area.

**Results:** All patients had spikes recorded from mesial or lateral contacts. If the sharp waves were recorded outside the borders of the planned anteromedial temporal resection, the resection was modified to include the anterior part of the superior temporal gyrus and the posterior hippocampus. This occurred in 5 of the 10 patients with TLE. Intraoperative recording did not alter our surgical planning in the other 5. In the first 4 patients with extra temporal focus, the lesion was removed along with the surrounding brain tissue under ECoG guidance. The fifth patient underwent first a right craniotomy for placement of subdural electrodes. After that, he was subjected to 5-day intracranial monitoring with video telemetry. Then we proceeded to cortical resection according to the presurgical electrocorticographical data. In this particular patient, it was found that the epileptogenic area was extended well beyond the borders of the epileptogenic lesion.

**Conclusion:** During follow up all patients have remained in Engel's Grade I. On the basis of specific and clear criteria, we advocate the use of intraoperative corticography, which may be a useful tool to obtain excellent surgical results with the minimum resection.

**Keywords:** Epilepsy; microelectrode recording; intraoperative electrocorticography.

**P016****Trigeminal Neuralgia Treated by Percutaneous Radiofrequency Rhizotomy**

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**Objectives:** Radiofrequency thermocoagulation for trigeminal neuralgia is still the initial and useful surgical intervention for patients with drug resistant and drug intolerant patients.

**Methods:** We analyse the results obtained by percutaneous radiofrequency technique for trigeminal neuralgia. Clinical material consists of 200 cases observed over a period of 7 years. Idiopathic drug refractory neuralgia was seen in 184 cases,

whereas MS and post-traumatic causes only accounted for 4 and 10 cases respectively. Neuroleptanalgesia comprised of short acting barbiturate during the needle insertion and approach to foramen ovale was made using standard technique described with the aid of anatomical landmarks and radiological guidance. Lesion time was 60–120 seconds and temperature varied between 60°–90°.

**Results:** Analysis of the results showed good outcome in 92 patients with permanent relief. 36 patients required re-interventions. 19 patients continued to have symptoms even after re-intervention and were considered for other modalities. Bad penetration was seen in 3 cases. Our complication included sensory loss of cornea in 6 cases, anaesthesia dolorosa in 8 cases, coagulation of motor root of fifth nerve in 2 cases and damage to the oculomotor nerve in one case. We will compare our results with those of major reports in the literature and mention all limitations and shortcomings, especially when treating elderly patients.

**Conclusions:** Thermocoagulation for trigeminal neuralgia is a safe and effective procedure in vast majority of patients and should be first line of surgical intervention for this condition. It is minimally invasive and very cost effective.

**Keywords:** Neuralgia; radiofrequency; thermocoagulation; trigeminal.

**P017****Study of Functional Improvement in Staged Bilateral Subthalamic Nuclei Deep Brain Stimulation in Parkinson's Disease**

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**Aim:** To study the discrepancy in motor effects and functional improvement in unilateral STN DBS compared with subsequent bilateral STN DBS in Parkinson's patient.

**Patients and methods:** Patients of idiopathic Parkinson's disease underwent staged operations of bilateral STN DBS were recruited. Unified Parkinson's Disease Rating Scale (UPDRS) (Motor score, dyskinesia score, ADL), waking time diary (On, On Dyskinesia, Off) and L-DOPA equivalent dose at Pre-Op, Post-unilateral DBS and Post-bilateral DBS were recorded and analysed.

**Results:** Between 1998 and 2002, eight patients with idiopathic PD underwent staged bilateral STN DBS were studied. Improvement in motor score (Off: from 54.4/–19.4 to 42.5/–17.9) and ADL score (Off: from 32.1/–9.1 to 20.8/–12.3) after unilateral DBS were observed in most of the patients after unilateral STN DBS. However, this was not followed with reduction in dyskinesia (87.5%) and L-DOPA dosage (from 1087 mg/day to 1340 mg/day). With the interference of On-dyskinesia, the On-waking time after unilateral STN DBS remained short (37.5% of 16 hours waking time). Meaningful improvement in ADL and On-waking time were observed only after bilateral STN DBS.

**Conclusion:** Unilateral STN DBS produced significant contralateral motor improvement; however, this was not translated into functional improvement because of imbalance in L-DOPA requirement and dyskinesia threshold between two sides of the body. Bilateral STN DBS produced overall motor and functional improvement.

**Keywords:** Parkinson's disease; staged STN DBS.

**P018****Vagus Nerve Stimulation in Refractory Epilepsy**

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*Objectives:* Since neuromodulation by electric stimulation of different brain structures is a mean of controlling seizures in so-called intractable epilepsy, the goal of this study is to present the results of intermittent vagal stimulation in a serie of medically and surgically resistant epileptic patients.

*Material and methods:* A serie of 33 patients presenting several seizure types (ranging from SPS, CPS with or without secondary generalization to atonic crisis) submitted to chronic intermittent left vagal stimulation is here described. All patients were pharmacologically refractory despite multiple trials and appropriate anticonvulsivant plasma levels. Petients were either considered inoperable or had already undergone surgery (lesionectomy or callosotomy). Before surgery they were studied by pertinent brain MR and PET-scanning and routine and continuous EEG. For stimulation an helical platinum electrode arround the left vagus at or above the omohyoid muscle was used. The leads were tunnelled through a subcutaneous pocket in the subclavicular area and connected to a pulse generator (NCP).

*Results:* All but 5 patients showed a significant clinical improvement after a follow-up period of 4 months to 8 years, consisting in supression of seizures or decrease in their frequency to a lesser seizure intensity and a better subjective individual performance or social integration. Side-effects are mild and transitory, occurring only when stimulation was on: hoarseness, dysphonia, coughing or local paresthesias. Neither gastrointestinal nor cardiovascular complications were registered.

*Conclusions:* Vagal stimulation is a harmless and safe method of improving seizure outcome and life quality in otherwise intractable epileptic patients.

*Keywords:* Epilepsy; vagal nerve stimulation.

**P019****STN-Target in PD: Our Experience by Intraoperative Neurophysiological Monitoring and Stereotactic IRM**

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*Objectives:* We compare the neurophysiological and neuroradiological target to DBS in STN in PD.

*Methods:* Since May 2002 we have implanted 28 electrodes in 14 patients with PD; in all cases the target was STN. In all cases the pre-operative planning was performed with IRM.

Intra-operative neurophysiological monitoring was performed with multichannel microrecording (3–5) of spontaneous nuclear activity. When the neurophysiological target was performed, microstimulation was carried out through the same electrode to assessed effectiveness of the stimulation and to avoid collateral effects.

*Results:* In all cases the neurophysiological target was identified and the microstimulation was neurological effective.

*Conclusions:* In our experience the neurophysiological monitoring is important to identify the correct position of the electrode to DBS in PD.

*Keywords:* Microelectrode recording; Parkinson's disease.

**P020****MRI Imaged Fronto-Pontine Tract Changes Following Bilateral Anterior Capsulotomy**

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*Objectives:* The authors present a series of five patients with fronto-pontine tract MRI changes following anterior capsulotomy. The role of fronto-pontine tract in the pathogenesis of major depression (MD) and obsessive-compulsive disease (OCD) is reviewed.

*Materials/methods:* In a two-year period, five patients were surgically treated with capsulotomy at University of British Columbia. Four of them had MD and one had OCD. All patients had post-operative MRI done between three and eighteen months after surgery.

*Results:* The follow-up MRI showed fronto-pontine tract changes as well as the expected postoperative fronto-thalamic tract changes in all patients.

*Conclusion:* The mechanism by which capsulotomy improves MD or OCD is not entirely understood. The authors review the potential role of fronto-pontine tract in the pathophysiology of MD and OCD.

*Keywords:* Psychiatric indications; anterior capsulotomy; fronto-pontine tract; major depression; obsessive-compulsive disease.

**P021****DBS in Chronic Neuropathic Pain**

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*Background:* Neuropathic pain (NP) is considered most resistant among other chronic pain syndromes. Within the last decade DBS has been successfully performed for treating severe NP. The aim of this paper is to present preliminary results of DBS in cases of central NP.

*Material and methods:* The authors report 4 cases (2 female and 2 men; aged 32–65) with an average 4.5-year history of severe intractable central NP. Therapy with analgetics (including morphine) gave poor effect. Case 1: phantom limb pain syndrome (exarticulation of the hip, sarcoma), Case 2: NP of the left arm (traumatic neuroma, n. radialis), Case 3: FBSS transformed into CRPS type II, and Case 4: CRPS type I according to generalized rheumatoid polyarthritis. Severity of NP was assessed by visual analog scale (VAS, 10 1) for 2 weeks – 1 month before surgery with a 5-year follow-up.

Case 1 – DBS of VC- and CE-nucleoli of thalamus. Case 2 – DBS of VC-nucleolus of thalamus. In case 3 and 4 we performed unilateral DBS of periaqueductal gray.

**Results:** Positive effect in the early postoperative period was observed in all cases. In the 2 of them (1, 2) excellent results were marked – intensity of NP has decreased from 9–10 points to 0–3 points according to VAS. In the other 2 cases (3, 4) the results are good (reduction of pain syndrome from 10 to 5–6 points) and moderate (from 9 up to 6 points). In all cases analgetics were reduced or fully abolished. An improvement of quality of life was marked in all cases. Follow-up demonstrated stable positive effect in all patients. There were no complications.

**Conclusions:** DBS of sensory and nonspecific nuclei of thalamus and periaqueductal gray may be a method of choice for treatment of intractable NP.

**Keywords:** Pain; DBS; neuropathic pain; phantom limb pain; periaqueductal gray; CE; VC.

## P022

### **BIS Guided Anaesthesia with Propofol and Remifentanyl Target-Controlled Infusion (TCI) for Deep Brain Stimulation in Parkinson's Disease**

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**Objectives:** BIS guided anaesthesia with both propofol and remifentanyl TCI have been suggested for clinical assessment in neurosurgery. In PD surgery, clinical control with iterative awakenings optimises the electrode implantation. Among patients in off-drug condition, per operative respiratory complications can impose to maintain a tracheal intubation throughout surgery. The endotracheal tube cuff inflation done with an alkalinized lidocaine solution provides a sustained local analgesia during awake period. The goal of this study was to validate an anaesthetic protocol for patients with PD treated by bilateral subthalamic nucleus (STN) stimulation.

**Materials and methods:** Prospectively 15 patients scheduled for PD surgery under general anesthesia with iterative awakenings were studied. Propofol and remifentanyl were administrated with Infusion Toolbox software (Schnider and Minto models). Depth of anaesthesia was monitored with BIS between 40 to 60; the cuff of the endotracheal tube was inflated with lidocaine 40 mg (2 ml) and NaHCO<sub>3</sub>.

**Results:** STN electrophysiological recording were available during anaesthesia. TCI effect site concentration varied from 1 to 3 µg/ml for propofol and 1 to 3 ng/ml for remifentanyl. Iterative awakenings were obtained in less than 15 min (after targeting 0 for propofol and remifentanyl) without coughing, bucking or desaturation (SPO<sub>2</sub> > 97%).

**Conclusion:** This anaesthetic protocol provides security and patient comfort during a long lasting surgery (>6 hours); therefore it doesn't disrupt electrophysiological recording as well as clinical evaluation considering that the best predictors of postoperative clinical outcome are the occurrence of dyskinesias provoked by stimulation during the operation.

**Keyword:** Parkinson's disease.

## P023

### **Anatomy/MRI Comparative Study of the Normal Hippocampal Volume**

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**Introduction:** The atrophy of the hippocampal complex (HC), a hallmark of Mesial Temporal Sclerosis, is usually defined by side to side Magnetic Resonance Imaging (MRI) volume comparison, once the reference values of the normal HC volumetry are contradictory and lack anatomical validation. However, an anatomical study previously done by the authors showed that the normal HC volume is larger than the one estimated by MRI. The aim of the present study is to compare, on the same population, the normal HC volume calculated by MRI and by anatomical technique.

**Material and method:** Twenty normal HC specimen from male and female adult human brains were studied. 1) MRI study: HC T1 ponderated serial imaging perpendicular to the great axis; volume calculation from the HC areas outlined on the cuts; 2) Anatomical study: serial cutting (in cryomicrotome) and volume calculation from digitised cuts similar to the MRI study; 3) Comparison of MRI and anatomical results, and HC dynamic 3-D image visualisation. In both MRI and anatomical studies, the contour tracing included the entire cornu ammonis, dentate gyrus and subiculum, but not the fimbria.

**Results and conclusions:** The values of the HC normal volume calculated by MRI and by anatomical technique were 3.9 ± 0.6 cc and 4.1 ± 0.9 cc, respectively. These values reflect the higher accuracy of the anatomical technique to measure the HC volume in detail. Nevertheless, the absence of significant differences between MRI and anatomical global results shows that MRI-based HC volume calculation is reliable, once the correct outline criteria are used. The anatomical dynamic 3-D visualization suggests the existence of regional HC volume variations not detected on MRI, that deserve further investigation.

## P024

### **Treatment of Kinetic Tremor Due to Cerebellar Herniation and Torsion of Cerebellar Outflow Pathways by Petrosal Reconstruction**

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**Objective:** Kinetic tremor due to lesions of the cerebellum and the cerebellothalamic pathways are a therapeutic challenge. There are no treatment options usually to repair the primary structural deficit. This is the first study to report causal treatment of kinetic tremor taking into account preoperative functional imaging.

**Methods:** Videographic and both structural and functional imaging studies were performed in a 42-year-old man who

was referred with right-sided kinetic tremor. Six months earlier, a glomus jugulare tumor was removed via a right petrosectomy. At the time of the referral, the patient suffered also from gait ataxia, dysarthria, nystagm and a peripheral facial palsy.

*Results:* MRI studies revealed a herniation of the right cerebellum into the bony deficit after the petrosectomy, accompanied by torsion of the cerebellar outflow pathways. Functional MRI demonstrated the herniated cerebellar tissue to be functionally intact. Transfemoral angiography showed no compromise of blood flow in the superior cerebellar artery. The patient then underwent a lateral suboccipital craniotomy with reposition of the herniation and plastic reconstruction of the petrosal bone. Apart from the facial palsy, the deficits improved within days, and the tremor disappeared almost completely.

*Conclusion:* Functional imaging is useful in decision-making to plan surgical repair after petrosectomy. In the rare case, kinetic tremor can be cured by reconstruction of the posterior fossa.

*Keyword:* Tremor.

## P025

### The Value of Microdoppler in Stereotactic Brain Biopsy

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*Objective:* To analyse the value of intraoperative microdoppler in stereotactic brain biopsy (SBB). So far, only one study reported about the use of microdoppler in stereotactic brain biopsy.

*Material and methods:* Between 1998 and 2003, 154 SBB were performed in 152 patients (80 males, 72 females, mean age: 59 years). All operations were performed using a ZD-frame and a multiplanar computertomography-guided trajectory planning system (Leibinger, SPP). A 16 MHz microdoppler probe (diameter 1 mm, DWL) was used in all cases to explore the area of biopsy before tissue specimen were taken out. Serial biopsies (mean 6 samples) were taken with the Sedan side cutting canula (n = 145) or with the small forceps (n = 9). We evaluated the number of intraoperative detectable vessel signals by microdoppler, intraoperative bleedings and bleedings detected by postoperative CT (performed in all cases). We compared our results with the bleeding related complications as reported in the recent literature.

*Results:* A conclusive histopathological diagnosis was achieved in 149/152 patients (98%). A re-biopsy had to be undertaken in 2 cases. In 95 biopsies (62%), no vessel could be detected by microdoppler. In the remainder, arterial signals were detected in 22 (14%), venous signals in 35 cases (23%). Detection of vessel signals led to a change of the biopsy site in all cases within the same trajectory. Biopsy related bleedings were detected in 4 cases (each with vessel signals in doppler) (2.6%). The overall biopsy related morbidity was 0.7% (n = 1), the mortality was 0.

*Conclusions:* Despite the overall relatively high security of SBB, microdoppler may lead to an additional reduction of the risk for a biopsy related bleeding with additional little expense.

*Keywords:* Microdoppler; biopsy.

## P026

### Frameless Fractionated Stereotactic Radiotherapy for Benign Brain Tumor

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*Purpose:* To evaluate the role of LINAC-based frameless fractionated stereotactic radiotherapy (FFSRT) in the management of benign brain tumors, we reviewed clinical responses, radiographic responses, and neurological deficits in patients treated at our institution.

*Methods and materials:* Between March 1996 and March 2002, 36 patients were treated with FFSRT. There were 14 male and 22 female patients. The median age was 48 years (range, 15 ~ 74 years). Pathologic diagnoses included pituitary adenomas (12 patients), craniopharyngiomas (5 patients), meningiomas (10 patients), and acoustic neurinomas (9 patients). Twenty-five patients had undergone prior resection. Eleven patients received FFSRT as the initial treatment. At least one clinical symptom presented at the time of FFSRT in 35 patients and cranial neuropathy was seen in 28 patients. The median tumor volume was 4.8 cm<sup>3</sup> (range, 0.6 ~ 16.2 cm<sup>3</sup>). FFSRT, using the P-reference system, was given 3 ~ 6 Gy/fraction, up to 25 ~ 35 Gy/5 ~ 10 fractions, depending upon the location and volume of tumors. The mean prescription isodose was 85 ~ 90% with a 3 mm-safety margin. The median clinical and imaging follow-up periods were 31 months (range, 2 ~ 74 months) and 21 months (range, 4 ~ 56 months), respectively.

*Results:* According to follow-up images, the tumor volume was reduced in 17 cases (52%) at a median of 13 months (range, 4 ~ 44 months), arrested growth in 13 cases (39%), and increased in size in 3 cases (9%). Among 17 responsive patients, 7 patients showed complete response. Clinical improvement was seen in 13 patients (37%), conditions stabilized in 16 patients (46%) and 6 patients (17%) were worsened. No one suffered from late complications after FFSRT.

*Conclusions:* LINAC-based FFSRT is considered a safe and effective treatment method for benign brain tumors. But additional studies are needed with large numbers of patients and relatively long duration of follow-up to determine the exact role or effect of FFSRT. Furthermore, a more detailed treatment plan and appropriate decision on radiation dose are necessary to obtain a high rate of local control and a low rate of complication.

*Keyword:* Radiosurgery.

## P027

### Antiepileptic Effect of High Frequency Stimulation of Bilateral Subthalamic Nucleus in a Case of Intractable Bilateral Frontal Lobe Epilepsy

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*Introduction:* Previously, it was proven that the nigral system modulates neuronal excitability in animal models of epilepsy. We introduce an experience with high-frequency stimulation (HFS) of the subthalamic nucleus (STN) in a patient with intractable epileptic seizures.

*Case:* A 23-year-old female with intractable bilateral frontal lobe epilepsy caused by cortical dysplasia underwent implantation with a permanent electrode in both STN and was chronically stimulated. To date, we have followed up this patient for 8 months postoperatively. HFS of the both STN induced a significant reduction (by 60%) in the number and severity of seizures as well as a decrease of the numbers of interictal spikes (40.9%). The effect was more prominent for seizures occurring during sleep (85.7%) than for those occurred during the day (40%) or in a cluster (33.3%). In addition, consistent improvement in both motor and cognitive functions was suggested.

*Conclusion:* To our knowledge, it is the first case of STN deep brain stimulation (DBS) for a control of intractable epilepsy in Korea. We think that HFS of the STN may hold significant future potential as a treatment for epilepsy, similar to its established role in the treatment of Parkinson's disease.

*Keyword:* Epilepsy.

## P028

### Long Term Follow-Up Results of LINC Radiosurgery for 283 Cases of Cerebral Lesions

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*Objective:* To study the long term follow-up results of LINC radiosurgery for cerebral lesions.

*Methods:* Two hundred and eighty-three patients with cerebral tumor or cerebral vascular malformation treated using linear accelerator radiosurgery had been followed up for 1 to 8 years (average 2.05 years).

*Results:* The tumors or cerebral vascular malformation was showed disappearance in 92 cases, decrease in size in 98 cases, unchanged in size in 65 case and increase in size 28 cases. Among these cases, necrosis of lesions was found in 99 cases, cystic change in 19 cases, circumscribed enhancement in 73 cases, gliosis in 20 cases, transient swelling in 23 cases, and brain edema in 28 cases.

*Conclusion:* LINC radiosurgery for small cerebral tumor and cerebral vascular malformation are safe and effective with edema as the major complication.

*Keywords:* Radiosurgery; brain neoplasms.

## P029

### The Method for Subthalamic Nucleus Targeting in Deep Brain Stimulation

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*Objective:* To describe the technical approach of subthalamic nucleus targeting in deep brain stimulation (DBS) in Parkinson's disease (PD).

*Methods:* Thirty patients with medically intractable PD underwent unilateral subthalamic (19 case) or bilateral subthalamic (11 case) stimulation. The anatomic target coordinates were calculated by a combination of direct and indirect MRI neuroimaging. Microelectrode recording was performed.

*Results:* The STN was visible on T2-weighted imaging sequences. The STN extension and boundaries were identified by

a microelectrode recording of the neuronal electrical activity. Macrostimulation via the final DBS electrode was then used primarily to establish the treatment effect and side effect profile for postoperative stimulation.

*Conclusion:* In our experience, direct MRI targeting is accurate method and microelectrode recording and macrostimulation are helpful targeting adjunct.

*Keywords:* Parkinson's disease; microelectrode recording.

## P030

### Dystonia Secondary to Brainstem Lesions

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*Objective:* To investigate dystonic movement disorders following brainstem lesions without evidence of morphological damage of the basal ganglia or the thalamus. Secondary dystonia is well known subsequent to lesions of the basal ganglia or the thalamus. Neuroradiological and pathological findings in patients with acquired dystonia most often show involvement of the caudate, striatum or the sensorimotor thalamus. There is evidence, however, that also brainstem dysfunction may be associated with dystonia. While electrophysiological abnormalities have been convincingly demonstrated, little is known about pathoanatomical correlations.

*Methods:* Over a period of 10 years, we have identified dystonia disorders in four patients with brainstem lesions. Multiplanar studies were performed with a 1.5 Tesla MR scanner using standardized T1-, T2- and proton weighted sequences. There was no evidence of morphological damage of the basal ganglia or the thalamus. Coincident occurrence of idiopathic dystonia was ruled out by clinical findings.

*Results:* Pontomesencephalic hemorrhage was demonstrated in three patients and the fourth patient suffered from diffuse axonal injury secondary to severe craniocerebral trauma. All four patients had persistent clinical signs of brainstem dysfunction. MR imaging revealed tegmental pontomesencephalic lesions whereas no structural changes were found in the basal ganglia or the diencephalon. Dystonia developed with a delay of one to 14 months, at a mean of 6 months. The patients mean age at occurrence of the brainstem lesion was 36 years (range 4–56 years). Two patients presented with hemidystonia combined with cervical dystonia, one patient had segmental dystonia, and one generalized dystonia. Three patients also suffered from postural or kinetic tremor. Dystonia was persistent in three patients, and improved gradually in one. There was little response to medical treatment. One patient with hemidystonia combined with cervical dystonia improved after thalamotomy.

*Conclusions:* Pontomesencephalic lesions due to hemorrhage or trauma may cause secondary dystonia. Since these lesions are often associated with fatal outcome, the occurrence of dystonia developing only with a delay is a rare clinical manifestation. The phenomenology of secondary dystonia due to brainstem lesions is similar to that of dystonia caused by basal ganglia or thalamic lesions, but it is more often associated with tremors.

*Keyword:* Dystonia.

**P032****LINAC Radiosurgery For Cerebral Arteriovenous Malformation**

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*Objective:* To evaluate the effected by LINAC radiosurgery for arteriovenous malformation.

*Method:* From June, 1994 to October, 2003, the 58 patients with cerebral arteriovenous malformation were treated by LINAC radiosurgery. Among 58 patients, 44 cases were arteriovenous malformation (AVM), 14 cases were cavernous malformation. AVM were classified according to the Spetzler-Matin grading system: 10 were grade  $\ddagger$ T, 16 were grade  $\ddagger$ UC10 were grade  $\ddagger$ VC8 were grade  $\ddagger$ W. Symptoms at presentation included prior hemorrhage in 12 patients, headache in 28 patients and seizures in 18 patients. 39 cases were treated by LINAC radiosurgery alone, 3 cases with reside AVM were treated by LINAC radiosurgery after intracranial hematoma was removed. In 8 selected patients with the larger AVM, embolization procedures were performed in an attempt to reduce the AVM size prio to radiosurgery.

*Results:* All the patients followed up ranged from 12–60 months, mean 33.5 17.6 months. The peripheral dose ranged from 17.0 Gy to 30.0 Gy in AVM, the mean dose is 23.0 3.7 Gy. Complete obliteration of AVM were 28 cases, partial obliteration 14 cases, no obliteration were 2 cases.

*Conclusion:* Obliteration rate of AVM relationship from dose of LINAC radiosurgery and AVM volume. More larger of dose of X-Knife, more higher rate of obliteration in larger AVM. The LINAC radiosurgery successfully obliterates carefully selected AVM of the brain. The LINAC radiosurgery is an effective and safe method for AVM. LINAC radiosurgery combining embolization or surgery treated larger grade  $\ddagger$ V to grade  $\ddagger$ W AVM.

*Keywords:* Radiosurgery; cerebral arteriovenous malformation; LINAC radiosurgery.

**P033****Subthalamic Nucleus Stimulation for Parkinson's Disease**

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*Objective:* The objective of the study presented here was to describe the technical approach and to assess the efficacy and safety of deep brain stimulation of the subthalamic nucleus for Parkinson's disease (PD).

*Methods:* Fifty and two patients with medically intractable PD underwent surgical treatment of STN stimulators between January 2000 and December 2003 in Changhai hospital, Shanghai, Simultaneous unilateral implanting was performed in 21 cases, bilateral implanting was performed in 31 cases. All implans were the products of Medtronic., Inc. The target was identified by a combination of MRI neuroimaging and microelectrode recording during operation. We compared scores on the motor portion of the Unified Parkinson's disease rating scale (UPDRS) when the stimulation was turned on or off.

*Results:* All patients followed up range 6–36 months, mean followed up 11.3 months. Improvement of the UPDRS motor scores was 45.2% when the stimulation was turned on and 20.7% when the stimulation was turned off without any undesirable side effects.

*Conclusion:* Our finding showed that the stimulation of subthalamic nucleus results significant control of the motor symptoms of the patients. The subthalamic nucleus (STN) is a target in the surgical treatment of Parkinson's disease (PD). STN stimulation is the ability to reduce the dosage of dopaminergic medications.

*Keywords:* Parkinson's disease; microelectrode recording; subthalamic nucleus; stimulation.

**P034****Neuronavigation and Stereotaxy in Neurosurgical Practice**

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*Objectives:* This study analyzes 3 years experience of neuronavigation in neurosurgical practice.

*Materials/methods:* Since 2000 neuronavigation and since 2002 – stereotaxy were used as standard options in brain surgery. Formerly Zeiss SMN neuronavigation system was used, but since September 2002 – Medtronic Stealth Station Treon neuronavigation system with Mach 4.1 software. Preoperative planning was done with Siemens Symphony 1.5 Tesla MRI scanning. All operations were performed with Carl Zeiss OPMI 200 NC4 microscope and CUSA Excell ultrasound aspirator. For stereotactic biopsies ZD stereotactic frame (Stryker-Leibinger) with Frame Link Mach 4.1 software was used 238 operations on 208 patients have been performed 190 patients (91%) were tumour patients. Male/female ratio was 90/118. Stereotactic biopsies were performed in 16 patients, mostly in disputable cases. For stereotactic coordinate calculation Siemens Somatom CT scanning was used, freely fused with MRI scans when necessary. In 18 patients more than one lesion was extirpated by help of neuronavigation.

*Results:* All neuronavigation and stereotaxy procedures were done technically successfully. Mean neuronavigation accuracy was 0.62–1.76 mm, stereotaxy accuracy – 0.39–1.3 mm. No lethality was encountered in connection with equipment itself. In brain tumour patients 40% were gliomas, 13% – metastases. Stereotactic biopsy proved most useful in brain lymphoma cases guiding patients to important tumour disappearance after irradiation therapy.

*Conclusions:* Frame and frameless surgery is useful in deep seated and small subcortical lesions and both neuronavigation and stereotaxy improve the quality of brain tumor surgery.

*Keyword:* Neuronavigation.

**P035****Bilateral Subthalamic Nucleus Stimulation in Pathologically Proven Dementia with Lewy Bodies. A Case Report**

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**Objective:** To outline the effect of Subthalamic stimulation (STN-DBS) in-patients with Parkinson's Disease and dementia.

**Methods:** A 74 year-old advanced PD patient underwent STN-DBS. Pre-surgical neuropsychological performance, phonetic and semantic verbal fluency were normal. Three months after STN-DBS the patient showed disappearance of motor fluctuations and dyskinesias. An improvement in the activities of daily living score and a 70% reduction in dopaminergic medication were achieved. Neuropsychological assessment did not evidence any cognitive change. On the ensuing two years, motor performance and dopaminergic medication remained stable. Shortly later, the patient developed mild depressive symptoms and diurnal somnolence. At three years follow-up, the patient presented fluctuating spatial and temporal disorientation, impaired verbal learning, apraxia and visual agnosia. Psychotic symptoms, such as hallucinations, paranoid ideation and aggressiveness appeared, with little response to several atypical anti-psychotic drugs. Motor status, however, remained almost unchanged. Stimulators were switched-off during one month to rule out a relation between cognitive and behavioural changes and STN-DBS. Motor condition deteriorated and mental status did not change. Four years after surgery the patient died from a bronchopneumonia.

**Results:** The brain pathologic findings showed changes typical of PD. In addition, abundant Lewy bodies were found in the locus coeruleus, amygdalar complex and several cortical areas. The electrode tips were placed within the STN, but were surrounded by an inflammatory reaction to foreign body with T-type lymphocytes and multinucleated giant cells. The pathological diagnosis was Lewy body dementia, limbic type.

This is the first case of pathologically proven dementia with Lewy bodies and STN-DBS. In PD patients with normal cognitive performance before surgery, STN-DBS may improve motor symptoms even after the appearance of dementia.

**Conclusions:** Although the long-term effects of STN-DBS on cognition are not well established, this case report suggests the development of dementia in this patient was due to the progression of the neurodegenerative process rather than to a direct effect of STN-DBS. Inflammation in the STN seems to differ to the gliosis around the electrodes found in previous publications.

**Keywords:** Parkinson's disease; microelectrode recording; dementia with lewy bodies.

### P036

#### Investigation of Brain RF-Lesion Size by Finite Element Simulations

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**Objectives:** Radiofrequency (RF) lesioning is a method in which malfunctioning tissue is coagulated using heat generated by an electric current. In neurosurgery it is used to e.g. treat symptoms of Parkinson's disease or to alleviate severe chronic pain. The aim of this study was to investigate the influence on lesion size from the thermal and electrical conductivity of the tissue, the blood perfusion and the preset lesioning temperature.

**Material and method:** An axi-symmetrical model of a temperature controlled brain electrode with a radius of 0.5 mm and

a tip length of 4 mm (Elekta Instrument AB, Sweden) was implemented using equations for steady current and time-dependent conduction of heat in a finite element program (FEMLAB, Comsol AB, Sweden). Simulations were carried out in order to investigate the influence on lesion size from thermal and electrical conductivity of surrounding homogeneous tissue as well as the microvascular perfusion and the preset lesioning temperature. These parameters were varied and their impact was analysed using factorial design and quadratic regression analysis.

**Results:** Lesion size increased with increased preset temperature and thermal conductivity. Increased blood perfusion reduced the size. The impacts from thermal conductivity and blood perfusion were greater with increased preset temperature. Electric conductivity had no apparent effect on the lesion development and can be neglected in this case.

**Conclusion:** This study shows that knowledge of thermal conductivity of the tissue and blood perfusion at the lesion site is important in order to predict the resulting size of the lesion. This will result in better control of the RF-lesioning procedure and may form the base for future pre-operative planning systems.

**Keywords:** Parkinson's disease; RF-lesioning; computer simulation.

### P037

#### Male-Pattern Baldness May Increase the Risk of Wound Complications Following DBS Surgery

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**Objective:** To determine whether male pattern baldness is associated with an increased risk of wound infection or scalp erosion in Parkinson's disease (PD) patients undergoing deep brain stimulation surgery.

**Methods:** Retrospective chart review of 184 DBS device implants performed in 89 PD patients by one surgeon (RLA) at a single institution from February 1998 to August 2003. Sixty-one implants were performed in 32 women, 69 implants in 35 non-bald men, and 54 implants in 22 bald men.

**Results:** Nine devices (4.9%) became infected and were explanted. An additional four devices (2.1%) caused scalp erosion requiring surgical revision. A total of 11 patients (12.4%) suffered a wound complication (two patients suffered two separate infections). Ten men (17.5%) and one woman (3.1%) suffered at least one wound complication ( $P < 0.05$ , Chi-Squared Analysis). Six bald patients (27.3%) and five non-bald patients (7.4%) suffered wound complications ( $P < 0.025$ , Chi-Squared Analysis). Four bald males (18.2%) and three non-bald males (8.3%) suffered wound complications ( $P > 0.05$ , Chi-Squared Analysis). Both patients who suffered multiple infections were bald; one was also diabetic. All of the infections were successfully treated. No patient suffered a serious complication related to the infection or re-implantation surgery.

**Conclusion:** Male patients are at increased risk of developing wound infections or scalp erosions following DBS surgery for Parkinson's disease. This increased risk may be due to male-pattern baldness, which has been associated with microvascular insufficiency of the frontal scalp.

**Keyword:** Deep brain stimulation.

**P038****Unilateral Holmes Tremor Clearly Responsive to CSF Release in a Patient with an Ischemic Midbrain Lesion and Associated Chronic Hydrocephalic Ventricle Enlargement**

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*Objective:* To describe a case of a 58 years old man with a sudden onset of unilateral tremor and headaches caused by a midbrain lesion, which affects the substantia nigra as well as the cerebellothalamic pathway. The patient also showed clinical and radiological signs of a communicating chronic hydrocephalus. He was severely handicapped by the tremor, which had resting, postural and intention components.

*Methods:* The patient was extensively clinically and electrophysiologically examined. Furthermore, CCT, MRI, MRI-perfusion, DAT-Scan and IBZM-SPECT was done. The patient had a temporary CSF drainage, then a ventriculoperitoneal shunt and after 6 month a stereotactic implantation of an electrode in the contralateral VIM.

*Results:* CCT showed an enlargement of all cerebral ventricles. In MRI, a small ischemic lesion between the red nucleus and substantia nigra could be seen. There was no change of cerebral perfusion measurement detectable in perfusion sensitive MRI. In DAT scan and IBZM-SPECT Parkinson's disease, as well as multiple system atrophy could be ruled out as a cause for the tremor. In EMG, the tremor could be described as a 4-5 HZ resting, intention and postural agonist-antagonist tremor. After temporary CSF drainage, the tremor was completely suppressed for several days. After VP-Shunting, it was suppressed for 6 months without any additional medication. Afterwards, the tremor came back and had to be treated by VIM stimulation, which suppressed the tremor completely and permanently.

*Conclusions:* We describe a rare case of an association of a Holmes tremor with an hydrocephalus. The tremor, as well as the therapeutic effects are well documented. Other causes for the tremor, such as Parkinson's disease or MSA could be ruled out. This case is very interesting and different pathophysiological aspects are to be discussed.

*Keywords:* Rubral tremor; communicating chronic hydrocephalus; perfusion weight MRI; DBS; VIM.

**P039****Reappearance of Tremor after Discontinuation of Subthalamic Deep Brain Stimulation in Parkinson's Disease: Objective Assessment of Amplitude and Frequency**

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*Objective:* After discontinuation of STN DBS, there is a sequential pattern of return of parkinsonian symptoms with a fast reappearance of tremor. This suggests that STN DBS may act by different mechanisms on parkinsonian symptoms. To quantify the

time course of the reappearance of tremor amplitude and frequency after discontinuation of STN DBS in Parkinson's disease (PD), using a computerized 3D ultrasound-based measuring method combined with surface electromyography of forearm muscles.

*Methods:* Seven patients (mean age  $67.1 \pm 4.6$  years) suffering from idiopathic PD were evaluated in medication off state 4-14 months after chronic bilateral STN DBS. Tremor amplitude and frequency were measured at baseline and at 0.5, 1, 2, 3, 4, 5, 10, 15, 20, 25 and 30 minutes after discontinuation of STN DBS. In addition, after switching DBS on, the mean latency the disappearance of tremor was determined.

*Results:* After discontinuation of STN DBS tremor rapidly reappears with a mean latency of 7.1 seconds ( $\pm 1.2$ ). Disappearance of tremor after switching DBS on was even faster at a mean latency of 3.7 seconds ( $\pm 1.1$ ). In three patients, a significant change of tremor frequency within two seconds after switching DBS on was found.

Tremor amplitude quickly increased after discontinuation of STN DBS, reaching a maximum amplitude after 2 minutes ( $29.6 \text{ mm} \pm 8.1$ ), compared to baseline: ( $1.8 \text{ mm} \pm 0.8$ ). In the sequel, tremor amplitude gradually dropped to a mean level of  $22.4 \text{ mm} (\pm 7.1)$  10 minutes after switching STN DBS off and remained stable during the following 20 minutes of DBS discontinuation.

*Conclusion:* After discontinuation of STN DBS in PD, tremor reappeared rapidly within seconds, reaching a maximum amplitude after 2-3 minutes of discontinuation, and in some patients STN DBS almost immediately changed tremor frequency. These findings support the hypothesis, that DBS acts by direct interference with the basal ganglia loops involved in tremor.

*Keywords:* Parkinson's disease; tremor.

**P040****AWIGS – A New Stereotactic Workspace**

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*Introduction:* Stereotactic surgery consists of vast and different surgical strategies like biopsy, DBS, radiosurgery and tissue implantation. Stereotactic imaging is mostly performed outside the OR. In our dept. the internationally first installation of the advanced workspace for image guided surgery (AWIGS) (Fa. Maquet, Rastatt, Germany) took place end 2001.

*Material and methods:* A high speed helical computed tomograph scanner in combination with a row based computer driven operation table was installed in Dec. 2001. The system combines all possibilities of a modern operation table including intraoperative imaging without patients transfer. Imaging can be performed under sterile conditions at any surgical step. From 1/02 until 12/03 80 stereotactic procedures for biopsies, drainage of abscesses and hematomas, deep brain stimulation and radiosurgery were performed. Intraoperative imaging was utilized 160 times. Image processing is additionally performed on the advantage windows workstation. It provides high quality angiographic and image fusion data, utilizing all imaging modalities such as MRI, PET.

*Results:* AWIGS is a highly effective and time saving intraoperative imaging system giving all necessary information about the individual brain or spine at any moment of surgery. The content on information is far beyond of intraoperative imaging techniques until now.

*Keywords:* History of stereotaxy; radiosurgery; dystonia; neurotransplantation; Parkinson's disease; surgical operation system.

**P041****Stereotactic Body Radiation Therapy: Transfer of Stereotactic Treatment Concepts beyond the Brain**

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*Objectives:* Presentation of treatment concept and clinical applications of stereotactic body radiation therapy (SBRT).

*Background:* Non-invasive stereotactic body radiation therapy (SBRT, also commonly referred to as extracranial stereotactic radiation therapy or extracranial radioablation) is a recent conceptual development defining prescription and delivery of large single radiation doses (radiosurgery) or a limited numbers of radiation fractions (hypofractionated radiation therapy) to small target volumes within major visceral organs such as lung and liver as well as malignant lesions in adrenal glands, vertebral bodies or paraspinal tumors. Requirements for SBRT include advanced non-invasive patient immobilization techniques, means to address target motion second to breathing, image-guided radiation therapy (IGRT) and sophisticated radiation treatment planning and delivery technology typically derived from systems commonly used for Linear accelerator based brain radiosurgery.

*Summary:* This presentation will summarize the current clinical experience and documented outcomes following SBRT. Knowledge about single dose or short course stereotactic radiation treatment options outside the brain may enhance the arsenal of available multi-modality treatment options for patients with primary and metastatic malignant diseases, especially since these new treatment capabilities become more readily available.

*Keywords:* Radiosurgery; history of stereotaxy; body stereotaxy.

**P042****Minimally Invasive Awake Craniotomy Guided by Steiner-Lindquist Stereotactic System**A. Bekar<sup>1</sup>, H. Bilgin<sup>2</sup>, G. Korfali<sup>2</sup>, H. Kocaeli<sup>1</sup>, O. Taskapilioglu<sup>1</sup>, E. Korfali<sup>1</sup><sup>1</sup> Department of Neurosurgery, Bursa, Turkey<sup>2</sup> Department of Anesthesiology, Uludag University School of Medicine, Bursa, Turkey

*Objective:* Awake craniotomy is a useful and reliable method for continuous intraoperative neurologic examination which allows for maximal lesion resection with acceptable postoperative neurologic deficit in eloquent regions of the brain.

*Patients and method:* Between January 2000 and January 2004, 27 patients underwent Steiner-Lindquist stereotactic laser guided awake craniotomy for resection of various mass lesions in eloquent brain. The presenting symptoms of the patients were seizure in 16 (59.2%), hemiparesis in 8 (29.6%), headache in 2 (7.4%) and dysphasia in 1 (3.7%). Eloquent areas was determined by functional MRI. The goal of the surgery was the maximal tumor resection and surgery was stopped at the onset of intraoperative neurologic deficit.

*Results:* The hospital stay ranged from 1 to 8 days (mean,  $3.6 \pm 2.1$  days). Lesion size ranged from 9 to 50 mm (mean,  $23 \pm 0.97$  mm). Histopathological diagnosis of the lesions were glial tumors in 14 (51.8%) cases, metastasis in 7 (25.9%) cases, meningioma in 2 (7.4%) cases, cavernous angioma in 2 (7.4%) cases and gliosis in 2 (7.4%) cases. Three (11.1%) patients experienced transient worsening of their neurological deficits.

*Conclusion:* Awake craniotomy guided by Steiner-Lindquist stereotactic laser system is an effective method for minimal invasive

resection of the lesions at the eloquent brain. Tumor resection until the onset of neurological deficit allows not only for maximal removal but also a good functional recovery and short hospital stay.

*Keywords:* Epilepsy; history of stereotaxy; awake craniotomy.

**P043****Confirmation of DBS Electrode Placement by Fusion of Intraoperative Fluoroscopic and Preoperative MR Images**

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*Objectives:* Deep brain stimulation (DBS) is an increasingly useful treatment in a variety of movement disorders, including Parkinson's disease, essential tremor, and dystonia. Confirmation of DBS electrode position following surgery is an important goal for the surgeon. This has been difficult to obtain, owing to the artifact created by the leads in the postoperative MRI. We have devised a localization paradigm involving the fusion of preoperative 3D MR images with intraoperative stereotactic fluoroscopic image data. We now have data from 150 patients who have undergone this pre-/intra-operative localization procedure.

*Materials and methods:* Preoperatively, a Leksell stereotactic frame is fixed to the patient and a series of six MR imaging sequences are obtained for volumetric analysis and surgical planning. In the operating room, the Leksell stereotactic arc system is attached to the frame and coordinates are set according to the preoperative plan. Following placement of the DBS electrode(s), the arc system is removed and the X-ray localizer box is positioned. Fluoroscopy is then used to obtain AP and lateral films that are scanned into the Surgiplan software and merged with the preoperative MR images using the fiducial markers of the Leksell system.

*Results:* In this series of 150 patients, location of each contact of the DBS electrode could be more precisely determined by our fusion technique than by direct postoperative MRI. The procedure obviates the distortion in the MR image commonly seen once the leads are in place. The fusion technique is bidirectional: The MR targeting information can be superimposed on the fluoroscopic image or the fluoroscopic image may be superimposed on the MR image. Interpretation of contact location takes place immediately in the OR, allowing confirmation of lead placement, ensuring that the leads are directed to the appropriate target.

*Conclusions:* We believe this imaging technique provides enhanced precision in determining electrode position and that this precision translates into a reduced risk of complications and better overall patient outcome. In addition, we are now beginning to use a frameless localization system, reducing overall operative time and further reducing patient risk.

*Keywords:* Parkinson's disease; dystonia; electrode positioning.

**P044****Thalamotomy in Movement Disorders**

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*Objectives:* Parkinson disease is a very disabling movement disorder. Surgical and medical treatment has been advocated for the former and other movement disorders like dystonia too. Patients

with unsuccessful medical treatment or drug side effects should be considered to surgical management. Thalamotomy (VIM) was proposed to the patients included at the present work.

**Methods and materials:** Three patients with parkinson disease and one with pos encephalitic dystonia were included in the study. All patients had more than 5 years with medical treatment and side effects like dyskinesias because of drugs.

The CRW (radionics) stereotactic frame, OWL radiofrequency system, Tasker Electrode and the SYTEC2000 (CT scan) enclosed the equipment for the procedures. Unified Parkinson Disease Rating Scale score to all patients pre an pos surgical were applied. The chosen target at 5 mm in front of the posterior commissure and 13–14 mm lateral to the third ventricular wall in all cases received two radiofrequency lesions with 75 celsius degree during 60 seconds.

Patients remained awake during stimulation (1–2 volts//50–100 hertz) and lesioning for neurological examination.

**Results:**

UPDRS	Patients			
	#1	#2	#3	#4
Pre Surgical	25	139	127	48
Pos 3 months	09	100	94	30
Pos 12 months	12	105	100	31
Pos 24 months	12	107	100	33

**Conclusion:** Thalamotomy is a good and safe surgical procedure to certain patients with parkinson disease and other movement disorders. Even patients get a good outcome the first three months moderate improvement remain two year after the procedure. Comparison between ablative, augmentative and restorative techniques should be done.

**Keywords:** Parkinson's disease; dystonia; movement disorders.

## P045

### Electrical Stimulation of Prelemniscal Radiations in Advanced Parkinson's Disease

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**Objective:** To determine if bilateral electrical stimulation (ES) of the Prelemniscal Radiations (Raprl) control all symptoms of Parkinson's Disease (PD) without causing undesirable effects and to outline the target location and extension through imaging and electrophysiological studies.

**Material and methods:** Five patients in Hoehn-Yahr (HY) stage I underwent bilateral stereotactic electrodes implantation (3387 DBS by Medtronic) in Raprl guided by ventriculography, as well as stereotactically oriented 1.5 T MRI to confirm their position. Transoperative microelectrode recordings and microstimulation were used to explore the targeted area. Patients were evaluated OFF medication before surgery and ON stimulation 3, 6, 9, and 12 months after the onset of chronic ES (130 Hz, 90–130  $\mu$ s, 1.0 to 3.0 V) through different PD scales: HY, UPDRS, and NYPDS with emphasis in determining the severity of symptoms in each one of the extremities independently. Results were statistically evaluated through non-parametric Walloon's test.

**Results:** The simple insertion of the electrode decreased or abolished tremor and rigidity in contralateral extremities in all cases. In contrast to STN microelectrode recordings disclosed scattered neuronal spikes in the target area organized in rhythmic bursts and

microstimulation above 5.0 V, 130 Hz, 450  $\mu$ s induced contralateral paresthesias and diplopia. Analysis of MRI sections fused with anatomical sections of the Schaltenbrand-Wahren stereotactic atlas revealed electrodes were always posterior to STN and lateral to red nucleus. Chronic ES significantly improved scores of HY ( $p < 0.001$ ), UPDRS ( $p < 0.01$ ) and NYPDS ( $p < 0.001$ ). Improvement of tremor and rigidity ( $p < 0.001$ ) had a higher degree of significance than that of bradykinesia ( $p < 0.01$ ).

**Conclusion:** Raprl is an effective target to treat all symptoms of PD, anatomically and physiologically different to STN as it is relatively acellular and located closer to the lemniscal fibers and III nerve.

**Keywords:** Parkinson's disease; microelectrode recording; electrical stimulation; subthalamus; prelemniscal radiations.

## P046

### Cost Analysis of Radiofrequency Trigeminal Neurolysis

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**Objectives:** Trigeminal neuralgia is a disease that consist of excruciating paroxysm of pain in the lips, gums, cheek or chin and very rarely. Medical treatment is the first choice others include vascular decompression, surgical rizothomy, chemical injections (glycerol, alcohol, fenol etc), radiofrequency pulsed and no pulsed neurolysis and recently radiosurgery. Trigeminal Radiofrequency is proposed for patients with drug side effects and older patients in order to analyze expenses.

**Methods and materials:** Twelve patients with Trigeminal neuralgia were included in the study, nine men and three women. Patients treatment included drugs like, carbamazepine, gabapentin, Nsaids and codeine. All patients had more than seven years suffering Trigeminal neuralgia and three patients have had neurovascular decompression. Patients were admitted to the study because side effects or no pain control. Average expenses per month for each patient 496200 Colombian pesos (183.7 dlls) and no pain control was achieved must cases. Radiofrequency lesion with OWL Diros equipment and Trigeminal electrode were done with 90 celsius degree and 90 seconds. Outcome and expenses per month and year are analysed during 2 years. No complications were registered during neither after the procedure. The average cost of the procedure including equipment use, drugs, radiology suit and medical honorary is \$2430000 Colombian pesos (900 dlls)

**Results:**

Patient	Expenses	
	After 6 months	24 months
1	65 dlls	77 dlls
2	69 dlls	40 dlls
3	65 dlls	77 dlls
4	23 dlls	17 dlls
5	4 dlls	4 dlls
6	81 dlls	23 dlls
7	73 dlls	23 dlls
8	4 dlls	4 dlls
9	73 dlls	23 dlls
10	40 dlls	4 dlls
11	40 dlls	17 dlls
12	4 dlls	4 dlls

*Conclusion:* Pain control is good and patients are not exposed to side effects drugs because less drug or any is needed. Even other technologies are available the cost increases preclude sometime their use in undeveloped countries.

Radiofrequency thermal lesion are not expensive procedures and very effective in operated patients and not operated patients.

*Keyword:* Pain.

## P047

### Interactions between Implantable Pulse Generator and Host Tissues in Parkinson's Disease with New Microscopical Analysis

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*Objectives:* To elucidate the histopathological interactions between Implantable Pulse Generator (IPG) and the host subcutaneous pouch tissue in patients with deep brain stimulation implant for Parkinson's disease.

*Materials/methods:* In three patients suffering from severe Parkinson's disease after removal of the depleted IPG a biopsy of the superior part of the fibrous capsule was carried out; the specimens were analysed at scanning electron microscope and at light microscope. The mean duration of the implant was 3 years; all IPG worked in monopolar stimulation. Moreover a microscopic study of the IPG surface was performed.

*Results:* Testing the structural features of the IPG surface at low magnification, it was possible to observe a lot of grooves regularly displaced along all the stimulator's surface. At high magnification it was possible to view some microfractures among the grooves described before, probably due to the fusion and cooling industrial processes. Testing the human tissue at light microscopic examination it was possible to distinguish a granular inflammatory chronic process from a lamellar one. At scanning electron microscope we can well distinguish the apposition of many collagenic layers constituting the tickness of the capsule. Moreover, performing a microanalysis along the surface in contact with the IPG, it wasn't possible to highlight any metallic non-ionic inclusion along the surface in contact with the IPG.

*Conclusion:* No particular histological alterations have been revealed in the fibrous capsule; the electric activity of the IPG did not show influence on the tissues come into contact with the implant.

*Keyword:* Parkinson's disease.

## P049

### Objective Clinical Evaluation of Tremor in Patients with DBS

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Tremor is a symptom characterized by regular rhythmical oscillation of a body part. Most tremors are periodic although fluctuations in amplitude and frequency impose a technical and precise approach. We have centered our efforts in assessing resting and action tremor by applying objective methods in patients with DBS in on-off conditions. It is based on the spectral analysis of signals derived from the hand and arm movement of patients with the finger pointing to certain patterns draw on the screen of a computer. The pattern of movements analyzed consisted in obtaining the non-intentional component features of the patient's tremor calculated from the departure of the signal performed from an ideal trajectory. A pattern consisted in a trajectory draw on a screen that the patient has to repeat as perfect as possible and permit to identify the direction of the movement. Patterns were classified in: static, kinetic, and dynamic. Twenty four patients were selected by the neurologist: sixteen patients with parkinsonian tremor and 8 with essential tremor. This type of analysis helped in discerning between resting and essential tremor patients before being checked by the neurologist that later confirmed the diagnostic. This technique allowed to record differences in patients with DBS and to evaluate tremor by objective methods.

*Keywords:* Tremor; DBS; computer tremor evaluation.

## P050

### Characterization and Correction of Geometric Distortions in Stereotactic MRI on Dedicated Phantom: Application to the Bilateral Subthalamic Stimulation in Parkinson Disease (PD)

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*Purpose:* Chronic high-frequency stimulation of the subthalamic nucleus (STN) has been shown to be an effective method for treating medically refractory idiopathic PD. MRI in stereotactic conditions is used by many teams to perform pre-operative targeting of the STN. Usually, T2 weighted images are used to visualize the STN. However, distortions on MR images have been described which could diminished the precision of MRI targeting. The goal of this study is to analyse and correct these geometric distortions.

*Material and methods:* A dedicated phantom of known geometry was used. We calculated existing shifts between measured points and theoretically defined points on the same T1 and T2 weighted sequences used to target the STN in PD patients. A shifting volume was built to correct the phantom images and images acquired pre-operatively in 13 patients with PD. A quantitative study of the correction was carried out on the phantom images and acquisitions done in patients. To quantify the quality of distortions corrections in patients, we have segmented the lateral ventricles and calculated the overlap of the T1/T2 not corrected and T1/T2 corrected segmentation.

*Results:* For the T1 weighted acquisition, the shifts were found inferior to the pixel. T2 weighted acquisitions, however presented significant distortions in all the volume with maximum value equal to 3.81 mm and 2.19 mm respectively in frequency encoding and slice selection directions. After correction, the distortions were considerably reduced and inferior to the pixel size. Results on acquisitions in patients showed an average overlap of 93.95% after correction instead of 76% before.

*Conclusion:* Our study shows that significant distortions can be observed on T2 weighted images used to visualize the STN. These distortions can be corrected using an appropriate software.

*Keywords:* Parkinson's disease; deep brain stimulation.

## P051

### Comparison of Atlas- and Magnetic Resonance Imaging-Based Stereotactic Targeting of the Subthalamic Nucleus in the Surgical Treatment of Parkinson's Disease

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*Objective:* To assess the variability of the subthalamic nucleus (STN) size, orientation and target coordinates from direct visualization of the STN on high-resolution magnetic resonance (MR) images. Additionally, the authors assessed the validity of using a direct anatomical method for functional neurosurgery by comparing target coordinates in the dorso-lateral STN obtained using MR imaging with those determined using an atlas.

*Methods:* Sixty-six patients with Parkinson's disease, who were treated with lesioning or deep brain stimulation of STN, were included in this study. The STN was visualized directly on high-resolution MR images acquired in both the axial and coronal planes. The STN size and orientation in both planes was recorded, as were the coordinates of the dorso-lateral STN (DL-STN) target in relation to the anterior-posterior commissural (AC-PC) line. The same STN target was defined in the Schaltenbrand atlas and in addition normalised atlas-based coordinates in proportion to the patient's AC-PC dimension was calculated. Magnetic resonance imaging-based STN target coordinates were statistically compared with the corresponding atlas-based coordinates.

*Results:* Marked variation of STN size and orientation was observed. A significant difference was demonstrated on comparing left and right sided x ( $p < 0.001$ ) and y ( $p < 0.002$ ) coordinates. The comparison between MR-imaging based and atlas-derived target coordinates demonstrated a significant difference in all directions (x, y and z) except the left y coordinate; and a distance error of  $1.9 \pm 0.8$  mm. No significant correlation was observed between the MR-imaging based coordinates and the length of the AC-PC. Our results further predicted that the first electrophysiological tract directed to the atlas-based coordinate would localise the MR-based DLI-STN in only 45% cases.

*Conclusions:* This study demonstrates that substantial individual variability of STN size, orientation and target coordinates exists; as does a significant difference between target coordinates obtained by direct visual targeting on MR images and those obtained by indirect targeting based on atlases.

*Keywords:* Parkinson's disease; stereotactic surgery; subthalamic nucleus; anatomical variability; magnetic resonance imaging.

## P052

### Early and Late Histopathological Changes Following Deep Brain Stimulation – Correlation with Microlesional Effect

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The clinical efficacy of deep brain stimulation (DBS) in treating tremor and other movement disorders is well established. Numerous patients develop a postoperative microlesional effect of variable degree and duration. Histological studies of this effect do not exist. Publications in the literature report autopsy findings obtained long after electrode placement. The study presented here describes the autopsy findings in a patient who died of pulmonary embolism eight weeks after electrode placement on the right side. Two years before this intervention the patient had undergone electrode implantation into the ventrointermediate (VIM) nucleus on the contralateral side. The histopathological examination of the patient's brain demonstrated the known long-term damage (mild gliosis) associated with chronic DBS as well as early reactive changes consisting of pronounced microglial activation and perifocal edema. These early abnormalities are assumed to represent the histological correlate underlying the well-known microlesional effect produced by electrode implantation.

In conclusion, the case presented here suggests that the early changes associated with DBS are more pronounced than has hitherto been reported. While so far only marginal gliosis has been described, our findings demonstrate that tissue changes occur in an area of least 5-mm diameter around the electrode track.

*Keywords:* Parkinson's disease; histopathology.

## P053

### Dermatomal Stimulation to Identify Spinal Rootlets in DREZ Surgery

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*Objectives:* To identify intraoperatively the level of spinal cord correlating with the area of a patient's pain, using dermatomal stimulation. Evoked responses were recorded from spinal rootlets in a fashion similar to that used with peripheral nerve stimulation of Blaine *et al.* (1985).

*Methods:* The patient was a 52 year old male with a complex regional pain syndrome type 1. The clinically defined painful area extended mainly over T10/L1 on one side. This was confirmed preoperatively, and in theatre paired neuroline surface electrodes were applied to the skin over sequential dermatomes from T9 to L2, for stimulation. Recording was via paired stainless steel hooks held under groups of spinal rootlets at each site studied while stimulation was applied to pairs of electrodes at each root level. Amplitude of responses was monitored and maximal response for each recording site determined.

*Results:* Responses were easily obtained with minimal averaging. 61 mA stimuli gave responses up to 2 mV peak to peak, lesser or absent responses being seen from more distant roots. This clearly identified the cord in the region of the proximal margin of his pain: the distal margin could not be defined until the operative site was extended: this then became clear. Lesioning of the substantia gelatinosa of the spinal cord was then performed over the relevant segmental levels.

*Conclusions:* Dermatomal sep recording from spinal roots proved of value in defining the spinal segmental levels intraoperatively, assisting the surgeon in placing the DREZ lesion correctly. There was appropriate sensory loss and pain relief though some vascular conus damage occurred.

*Keywords:* Pain; DREZ; dermatomal evoked potentials.

**P054****Diagnosis and Management of the Elderly in Stereotactic Neurosurgery**

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*Objective:* In the near future, elderly patients are going to constitute an increase proportion of the population. Therefore the medical community has to deal with a new group of patients with cerebral lesions. Little is known in the literature about the histology of those lesions and how to handle patients.

*Method:* We retrospectively analysed all patients aged 65 to 90 years which underwent stereotactic biopsy or radiosurgery at our clinic between 1997 and 2001 (433 patients). Datas from our own digital files were aligned with the written records and missed datas such as management, duration of hospital stay and survival were included. Afterwards datas were analysed with a statistical computer program.

*Result:* The majority of patients had a WHO III or IV glial tumor (40%) and most of them received radiation therapy (55%), whereas for patients with a low Karnowsky index a symptomatic therapy was chosen. The decision for radiation therapy was significantly ( $p < 0.005$ ) dependent on the Karnowsky index and not on the age of the patient. Patients with metastasis made up 21% of the study group, but therapy was quite manifold: 32% received interstitial irradiation, 31% radiosurgery, 17% radiation therapy, 2% resection and 16% supportive therapy because of a low Karnowsky index. The third group consist of patients with intercranial lymphomas (9%) which received either radiation and/or chemotherapy or a supportive therapy. Because of a low hospital stay which in our patient group was an average of 5.8 days, a rapid assessment for further therapy was guaranted which is accompanied with a quick return of the elderly to his habitation. Because of the minor surgical trauma, stereotactic neurosurgery is a very useful method in patients with concomitant diseases.

*Conclusion:* Our datas indicate a great variety of diagnoses for intercranial lesions in the elderly. Management depends significantly on the performance of the patients (Karnowsky index) and not on the age. Refusing an invasive diagnostic for an adequate therapy because of an advanced age is therefore not recommended in our opinion.

*Keywords:* Radiosurgery; brain tumor; elderly; biopsy.

**P055****Anatomical Stereotactic Localization of Active Contacts in Bilateral Subthalamic Nucleus Stimulation for Parkinson's Disease**

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*Objectives:* To determine the localization of active contacts in patients with Parkinson's disease (PD) and bilateral subthalamic nucleus (STN) deep brain stimulation (DBS).

*Materials/methods:* Sixteen STN electrodes were analyzed in 9 PD patients with STN DBS (mean age 62.4 years; 7 men, 2 women; mean disease duration 16.6 years; mean UPDRS sub-scale III change with stimulators on at 4 months 49.8%). Con-

tacts are labeled 0, 1, 2 and 3 from distal to proximal (Medtronic Model 3389) and measure 1.5 mm; 0.5 mm between contacts. Contact 1 was aimed at the electrophysiological center of STN, determined by intraoperative microelectrode recording. Pre-operative MRI and post-operative CT of the brain were fused using Medtronic STEALTH Framelink IV software and the coordinates for the tip of the electrodes were determined. The coordinates for the center of each contact were derived from these results. The coordinates for contact 1 were compared with the original target to determine surgical accuracy and bias. Active contacts in each electrode (contact 2 in 12 electrodes, contact 3 in 3 electrodes, contact 1 in 1 electrode) were measured to the midcommisural point (MC) and the electrophysiological center of STN.

*Results:* Absolute change (units = mm) after comparing planned target coordinates vs. actual localization of contact 1 (accuracy):  $x = 1.0$  (range: 0.2–2.7),  $y = 1.4$  (0.5–2.5),  $z = 1.9$  (0.2–4.1). Vector change (bias):  $x = 1.0$  (medial),  $y = 1.1$  (posterior),  $z = 1.9$  mm (inferior). Distance of active contacts to MC: 12.8 lateral (SD = 1.4); 3.8 posterior (SD = 1.3); 3.3 inferior (SD = 2.0). Distance of active contacts to electrophysiological center of STN: 0.4 medial (SD = 0.9); 0.1 posterior (SD = 1.2); 0.05 superior (SD = 1.5).

*Conclusion:* The electrophysiological center of STN may be the optimal site of stimulation for PD. A surgical bias towards deeper placement of electrodes along the originally planned trajectory may explain why contact 2 is most frequently selected as the active contact in this series of patients.

*Keywords:* Parkinson's disease; microelectrode recording.

**P056****Stereotactic Aspiration of Brain Abscesses: Experience in Six Cases**

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*Introduction:* There is growing evidence that stereotactic aspiration should be considered the gold standard for the treatment of brain abscesses.

*Methods:* Between 1998 and 2003 six patients with an intracerebral abscess were treated according to a fix protocol: 1. Stereotactic drainage of the abscess with repeated installation and aspiration of isotone 0.9% NaCl. 2. Catheter implantation and installation of 5 mg Gentamicin (1 ml Refobacin L). 3. For 3 to 5 days daily lavage of the abscess cavity with 0.9% NaCl, followed by 5 mg Gentamicin installation. 4. Antibiotic regime: perioperative – broad spectrum antibiotics, postoperative – antibiotics according to the aspirated material for at least six weeks.

*Results:* Patients (aged between 10 to 68 years) were followed by clinical examination and repeated CCT or MRI. The location of the abscesses were in eloquent areas causing severe neurological deficits: 2 × left central region, 1 × right central, 2 × right parietal, 1 × multiple abscesses occipital left. All patients showed an immediate neurological improvement after surgery, with complete neurological recovery in most cases after weeks. One patient with immunosuppressive therapy due to Morbus Boeck had to be operated 3 weeks after stereotactic aspiration with open removal of the abscess membrane (all probes were sterile). No significant morbidity was observed in any of the surgical procedures.

*Conclusion:* Stereotactic aspiration of brain abscess according to the described protocol is an effective treatment modality with low morbidity and mortality.

*Keywords:* Brain abscesses; stereotactic aspiration.

## P057

### Safety and Long-Term Efficacy of Non-Microelectrode Guided Deep Brain Stimulation of the Subthalamic Nucleus in Advanced Parkinson's Disease

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*Objective:* To evaluate long-term clinical response and side effects of STN-DBS following non-microelectrode (MER) guided stereotactic lead implantation.

*Methods and material:* 69 consecutive PD patients (mean age at surgery: 60/-10 yr mean disease duration: 15/-5 yr) have been followed for up to 3 years. Stereotactic implantation of quadripolar electrodes was performed using stereotactic CT, image fusion of non-stereotactic MRI, computerized 3D-multipolar treatment planning, intraoperative macrostimulation, and teleradiography.

*Results:* Stimulation (monopolar in 99% of the patients, stimulation parameters:  $3.1 \pm 0.6$  V,  $80.7 \pm 26.0$  ms,  $147.1 \pm 21.0$  Hz) reduced statistically significant the following items: (i) OFF-motor symptoms by 61% (UPDRS scale), (ii) dyskinesias by some 75% on the dyskinesia rating scale, and the L-Dopa equivalent dose by 44% of the pre-surgical dosage. ON-symptoms were not significantly altered. While the reduction of OFF-motor symptoms remained stable over the observation period of up to 3 years an overall small increase of symptom severity most probably reflected the progression of the underlying disease. No intracranial haemorrhage was observed. Main surgery-or device related complications included infection of lead or pulse generator (4 patients), one electrode dislocation and 2 electrode fractures, none of which resulted in permanent morbidity. The most common therapy-related side-effects were dysarthrophonia, abulia and an average weight gain of 7.3 kg in the first year following surgery.

*Conclusions:* If microelectrode recording (MER) is an indispensable prerequisite for precise stereotactic implantation of DBS electrodes is still under debate. Theoretically, MER seems to be essential to identify STN boundaries. The here presented data demonstrated that good and stable clinical results of STN stimulation can be obtained without the application of MER minimizing the risk of intracranial haemorrhage.

*Keyword:* Parkinson's disease.

## P058

### A New MRI-Localizer Box Enabling Stereotactic Surgery in Quadrupeds

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*Objectives:* The objective of our study is to construct an apparatus for localization of stereotactic coordinates by MRI, imaging equipment in relation to known animal stereotactic frames comprised of a pair of steel bars held in spaced parallel relation to each other by a cross bar. The design of the apparatus also has to take in to account, that quadrupeds in general have skulls with a cylindrical geometry as opposed to humans and primates that have skulls with a spherical geometry.

*Methods:* The apparatus is designed as a box of nonmagnetic, radio lucent Plexiglas with removable side plates that contain embedded fiducial markers. The localizer box will be fixed to the head of the experimental animal (pigs in our case) before stereotactic MRI. The animal is then fitted into to the stereotactic frame with the localizer box still connected to the skull, making sure that the position of the brain in relation to the localizer box is the same during the stereotactic MR and during the following surgery. Before surgery the side plates with fiducial markers are removed to ensure good surgical access to the calvarium of the experimental animal. The localizer box prototype was tested with a water phantom in a General Electric 3 Tesla Sigma Excite System with Twin Speed Gradients. Following a 3-plane localizer, one coronal T1-weighted Inversion Prepared 3D-gradient echo sequence (TR = 15 ms, TI = 450 ms, TE = 2.8 ms, 20 flip angle, 4 NEX) was acquired.

*Results:* The test scans showed sharp delineation of the fiducial markers that allowed registration in the Elekta Surgiplan system.

*Conclusion:* We have devised an apparatus that allow stereotactic MRI scanning of quadrupeds. The digital MRI datasets can subsequently be transferred to computerized surgical planning systems for exact determination of stereotactic coordinates.

*Keywords:* Neuronavigation; Parkinson's disease; microelectrode recording; neurotransplantation; experimental stereotactic surgery.

## P059

### ECoG Helps to Spare the Hippocampus in Mesial Temporal-Lobe-Resection

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*Introduction:* In epilepsysurgery as opposed to general neurosurgery an epileptogenic focus instead of only the lesion is resected to achieve seizure control. In Temporal-Lobe-Resection (TLR), this approach has led to the so called "tailored resection". Patients with symptomatic mesial Temporal Lobe Epilepsy (TLE) together with ipsilateral high neuropsychological functions bear a high risk of memory loss (e.g. spatial and episodic memory) if hippocampal structures are resected. To decide whether these can

be spared, we perform an intraoperative ECoG on the surface of the intact hippocampus following previous lesionectomy.

**Methods:** Standard diagnostic methods used at our centre are high resolution MRI and Video-EEG-monitoring. Neuropsychological assessments (e.g. Wada-testing) and functional MRI are applied in addition. Between 1999 and 2002 we operated 36 patients using the above mentioned approach.

**Results:** 33 of 36 patients between 4 and 59 years of age were followed up after a period of 6 months up to 2 years. Seizure control, according to the Engel classification class 1, could be achieved in a total of 27 (76%); according to Engel's class 2 (almost seizure free) in 5 (15%) patients.

**Conclusion:** ECoG is a highly sensitive and less invasive diagnostic tool to find out whether the hippocampus is part of the epileptic focus. Patients with symptomatic mesial TLE where we could reduce the extent of the mesial resection using ECoG showed a postoperative outcome of 76% seizure control.

**Keywords:** Epilepsy; ECoG; TLE; hippocampus.

## P060

### Outcome of Ablative and Neurostimulation Thalamic and Pallidal Procedures for Movement Disorders

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**Purpose:** To assess the early results in treating movement disorders in patients with Parkinson Disease (PD) or Multiple Sclerosis (MS) by either thalamotomy, pallidotomy or pallidal stimulation. To evaluate the efficacy of CT-MRI fusion and microrecordings-macrostimulation guided surgery in optimizing the outcome.

**Patients and methods:** Since the service establishment in September 2002, 16 patients were treated for movement disorders. Fourteen PD patients suffered from either tremor, bradykinesia or levodopa induced dyskinesias, while 2 suffered from tremor secondary to MS. Prior to surgery, all patients, were evaluated by a multidisciplinary group of neurosurgeons, neurologists, neurophysiologists and neuropsychiatrists. In PD patients, presurgical evaluation included neurological examination, the UPDRS III, the S&E and PDQ-39 scales, while the disease was staged with the H&Y scale. The MS patients were evaluated using the Expanded Disability Status Scale (EDSS) and the Fahn-Tolosa scale.

Targeting was performed after stereotactic CT and MRI fusion with the StereoPlan (Radionics Inc, Burlington, MA, USA), by direct target visualization, confirmed by geometrical coordinates and the Schaltenbrand atlas. In the PD patients, 5 underwent unilateral pallidotomy, 3 unilateral and 6 bilateral pallidal stimulation. The 2 patients with MS related tremor were treated with thermo-electro-coagulation at the Vim.

**Results:** All PD patients showed significant improvement in the UPDRS III, the S&E, PDQ-39 and H&Y scales and a reduction in medication was achieved. This has persisted so

far in subsequent follow up examinations (1–15 months). The multiple sclerosis patients also exhibited marked improvement in their kinetic state.

**Conclusions:** Judicious selection of either thalamotomy, pallidotomy or pallidal stimulation, determine good results of surgical intervention in PD symptoms and tremor secondary to MS. When image fusion is available, direct target visualization, which is confirmed intraoperatively by microrecordings and macrostimulation, can improve the accuracy of target localization and the results of treatment, offering satisfactory surgical outcome.

**Keywords:** Parkinson's disease; fusion.

## P061

### A Modified CT-MRI Fusion Protocol Increases Targeting Accuracy and Reduces Microrecordings Time in Pallidal Surgery

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**Purpose:** CT-MRI fusion merges stereotactic CT with MRI images, preserving their advantages. We present our experience with a modified CT-MRI fusion protocol in the treatment of movement disorders.

**Patients and methods:** In 2003 we treated 14 patients with medically intractable PD. In order to enhance the accuracy of fusion and reduce the number of electrodes insertion for microrecordings, we utilized a special MRI sequence (T1 Wref/fMRI). This allows excellent anatomical definition of the basal ganglia, depicts very clearly the distribution of all infarcted areas (lacunae) within the thalamus and globus pallidus, and hence provides a pattern that assists in a) more accurate visual identification of the precise GPi target, b) interpreting intra-patient variations in microrecordings and c) reducing the number of trajectories and time required for microrecordings. Targeting was performed on fused images (StereoPlan, Radionics Inc, Burlington, MA, USA) by direct target visualization and confirmed with standard geometrical coordinates and the Schaltenbrand atlas. The appropriate axial T1 images were correlated with T1 Wref/fMRI images, allowing very accurate recognition of the intended target point within the GPi.

**Results:** Five patients underwent unilateral pallidotomy, 3 unilateral and 6 bilateral pallidal stimulation. In 20 procedures (8 unilateral and 6 bilateral), 33 microrecordings trajectories were utilized (1,65 trajectories/procedure, 2,35 trajectories/patient). The efficacy of targeting was proven by symptoms elimination, medication reduction and UPDRS-III score improvement, achieved in all patients. No complications were noted.

**Conclusions:** CT-MRI fusion assisted by this special MRI sequence, improves accuracy in surgery for movement disorders. The sequence used in our study allowed more accurate visual identification of the precise CPi target and in interpreting variations in microrecording results which otherwise would require additional microrecordings.

**Keywords:** Parkinson's disease; fusion.

**P062****Motor Cortex Stimulation: Electrode Placement by Correlation of fMRI, Cortical Stimulation, Phase Reversal and Neuronavigation**

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*Objectives:* The medical control of deafferentation pain is often unsatisfactory. In the early 90ies chronic motor cortex stimulation was found to be a possible alternative for pain relief. Nevertheless little is known about the modes of action and the determination of the correct stimulation point is crucial as the pain relief is a long-term result. We present a combination of fMRI, cortical stimulation, phase reversal and neuronavigation which provides an accurate placement of the electrode.

*Materials:* In this study 5 patients were treated. Preoperative a functional MRI was made including standard motor and somatosensory paradigm. With the help of a navigation system the anatomical as well as the resulting functional data can be indicated on the patient for exact placing of the stimulation electrode. Furthermore direct bipolar cortical stimulation and the phase reversal of the medianus or tibialis SEP were used to localize motoric response and the central sulcus. Finally the stimulated points and the contacts of the electrodes were registered by an ultrasonic system. Thus the exact position of the electrode contacts in relation to the motor cortex and the previous functional MRI can be determined. This provides an easier control of the stimulation parameter in the follow up.

*Results and conclusion:* 4 of 5 patients gained a pain relief higher than 75%. The combination of different localization methods is time intensive but provides the highest possible accuracy concerning electrode positioning.

*Keywords:* Pain; neuronavigation.

**P063****Deep Brain Stimulation of the Internal Globus Pallidus in Primary Generalized Dystonia**

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*Objectives:* To evaluate the safety of the surgical procedure of electrodes implantation and the efficacy of bilateral pallidal stimulation on motor impairment and functional disability according to Burke-Fahn-Marsden dystonia rating scale, in a group of patients with primary generalized dystonia.

*Materials/methods:* Retrospective evaluation of 9 adult patients with primary generalized dystonia treated with bilateral pallidal stimulation in the postero-ventral part (GPi). Quadripolar electrodes (Medtronic) were bilaterally implanted under general anesthesia in stereotactic conditions with MRI and electrophysiological guidance. The final position of the electrodes was checked postoperatively on MRI with the aid of FrameLink™ 4.0, Medtronic software before the Kinetra pulse generator implantation. The effect of chronic bilateral stimulation on motor impairment

and functional disability at 6 months postoperatively was compared to 3 months preoperatively state.

*Results:* There were 9 patients (4 female/5 male), aged  $33 \pm 12$  years (mean  $\pm$  SD). Duration of the disease of  $20 \pm 8$  years, with a follow up  $>6$  months. On the Burke-Fahn-Marsden scale, dystonia score was  $47.2 \pm 20$  preoperatively and  $21.7 \pm 16$  postoperatively ( $p < .005$ ) with a mean percentage of improvement of  $53 \pm 12$ . Disability score was  $11.14 \pm 5.5$  preoperatively and  $6.5 \pm 5.5$  postoperatively ( $p < .004$ ) with a mean percentage of improvement of  $37.6 \pm 30$ . No surgical complications or permanent adverse effects were observed at 6 months.

*Conclusions:* This study allowed to evaluate the GPi targeting technique by stereotactic MRI and the interest of the electrophysiological recording in the procedure. In addition, the clinical results observed among these patients show that it is possible to obtain a good clinical effect in the generalized dystonia of the adult by bilateral chronic stimulation of GPi and, that these results are homogeneous with those already presented for the whole of the multicentric national study SPiDY.

*Keywords:* Dystonia; microelectrode recording; magnetic resonance.

**P064****The Results of the Treatment by the Stereotactic Thalamotomy of Essential Tremor, Post-Traumatic Tremor, Post-Apoplectic Tremor, Post-Inflammatory Tremor and the Tremor in Case of SM**

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*Objectives:* The purpose of this study is to present the results of the stereotactic thalamotomy in the cases of the tremor as a main symptom of disease. There are presented complications of the stereotactic thalamotomies, too.

*Materials and methods:* From July 1999 were performed 55 stereotactic thalamotomies on 45 patients of highly intensified of tremor (when the tremor was a main symptom of disease) and ineffective pharmacological treatment. 42 thalamotomies on the 34 patients with the essential tremor (76.4%), 7 thalamotomies on the 6 patients with the post-traumatic tremor (12.7%), 1 thalamotomy on the 1 patient with the post-inflammatory tremor (1.8%), 1 thalamotomy on the 1 patient with SM (1.8%), 4 thalamotomies on the 3 patients with the post-apoplectic tremor (7.3%).

Setting target (Vim) was made after MRI and CT fusion and by the use of computer Schaltenbrandt and Wahren brain atlas (Brain Lab's@Target v.1.17). Moreover, in each case the position of the target on fused MRI-IR images was directly verified. Surgeries were performed in local anaesthesia checking functional position of the target by the means of macrostimulations. The patients were always examined before and after surgery basing on clinical tremor scale, Karnofsky scale, tablet test.

*Results:* An improvement was recorded in all patients with the different kinds of tremor treated by stereotactic thalamotomy  $\geq 90\%$ .

*Conclusions:* Verifying the position of the target based on direct visualisation of thalamus can improve accuracy of the target localisation and results of the treatment different kinds of the tremor. Stereotactic thalamotomy is a safe and effective procedure.

*Keywords:* Tremor; stereotactic thalamotomy.

**P065****Autotransplants of Carotid Body Cell Aggregates Increases the Number of Striatal Dopaminergic Cells in MPTP-Monkeys**

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*Objective:* To investigate whether the number of striatal dopaminergic cells is increased in MPTP-monkeys treated with striatal autotransplants of carotid body cells aggregates (CBCA).

*Background:* Intracerebral lentiviral delivery of GDNF to MPTP-monkeys elicits an increased number of striatal dopaminergic neurons. Carotid body cells contain a large amount of GDNF, and MPTP-monkeys grafted with CBCA show a marked improvement of parkinsonism.

*Design/methods:* Six monkeys (*Macaca fascicularis*) were divided into 3 groups: Group I (2 intact animals), group II (2 untreated MPTP-monkeys) and group III (2 MPTP-monkeys with unilateral striatal transplant of CBCA). Monkeys were rendered parkinsonian by systemic administration of MPTP. Autotransplants of CBCA were performed by injecting 14–16 CBCA into the posterior putamen. Six months later, monkeys were transcardially perfused to obtain sections of the striatum, which were processed for TH/GAD/DAT immunoreactivity. Counts of striatal TH-ir cells and double immunofluorescence were also performed.

*Results:* Transplants of CBCA markedly improved parkinsonism and induced a robust dopaminergic innervation of the striatum. Striatal TH-ir cells were observed in all groups and preferentially distributed in the dorsolateral striatum. A greater number of TH-ir neurons were seen in group II with respect to group I. The number of TH-ir cells was significantly enhanced in the striatum of group III relative to groups I-II. The number of TH-ir neurons in the grafted striatum of group III was larger than in the non-grafted striatum. About 85% of the striatal TH-ir cells also expressed GAD while only 12% of these cells expressed DAT, indicating that striatal TH-ir neurons are striatal neurons.

*Conclusions:* There is an augmentation of the number of TH-ir striatal neurons in MPTP-monkeys. Striatal grafts of CBCA markedly enhanced this increase. These TH-ir neurons also expressed GAD indicating their striatal origin and might have partially contributed to the recovery of parkinsonism and the dopaminergic striatal innervation observed in the grafted animals.

*Keywords:* Neurotransplantation; Parkinson's disease.

**P066****A Universal Non-Invasive Reference Frame for CT-MR-SPECT-PET Image Fusion, Computer-Assisted Neurosurgery, Frameless Stereotactic Brain Tumor Biopsy and Radiotherapy – Experiences with 450 Patients**

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*Objective:* To apply the universal SIP-Lab Innsbruck frame attached to the VBH vacuum mouthpiece for a unified, multidisciplinary diagnosis and therapy by allowing image fusion

of CT/MR/SPECT/PET, and fixation for radiotherapy and neurosurgery. We report our clinical experiences with this new device in various disciplines in a total of 450 patients.

*Materials and methods:* The VBH mouthpiece is an individualized vacuum dental-cast, which is attached to the upper palate by underpressure. For immobilization of the patient's head the VBH mouthpiece (MP) is secured to a base plate by hydraulic arms. The frame contains multimodal markers and provides external reference points for image fusion, computer aided surgery and radiotherapy. The diagnostic scans are performed with the VBH mouthpiece. Image-fusion is based on reference points on the frame. Biopsy is performed with frameless stereotactic navigation. If a surgical intervention is necessary, the image guided surgery relies on the fiducials on the frame, thus necessitating another additional scan. For radiotherapy the patient is repositioned with the original VBH mouthpiece, thus necessitating the fabrication of a mask. For follow-up subsequent image acquisitions are performed with the frame.

*Results:* The VBH head holder was successfully used for fractionated radiotherapy, brachytherapy, SPECT acquisition and computer assisted surgery in a total of 450 patients. The VBH head holder offered rigid, accurate, and reproducible fixation and accurate external reference points for image to image and image to patient registration.

*Conclusion:* Application of the mouthpiece is an important step towards unified, multidisciplinary diagnosis and therapy by allowing image fusion of CT/MR/SPECT/PET, use of imaging data for neurosurgical interventions and radiotherapy.

*Keywords:* Neuronavigation; epilepsy; image fusion; registration.

**P067****Frameless Stereotactic Puncture of the Trigeminal Ganglion for Radiofrequency Ablation**

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*Purpose:* The therapeutic approach to puncture the gasserian ganglion in drug resistant trigeminal nerve related pain is crucial. Our objective was to develop a method which is secure, precise, reproducible and minimal invasive.

*Method:* The patient's head is fixed in the non-invasive VBH head holder and scanned in a CT. The VBH head holder permits rigid fixation of the head by using an individualized dental cast attached to the upper jaw by vacuum. Following 3D-CT-scanning, a 3D-reconstruction of the head, the skull and the mouthpiece is created on a workstation. The puncture is simulated in the absence of the patient on the Treon navigation system (Medtronic, USA): the head holder only is repositioned and the reference points on the VBH mouthpiece are registered to the 3D-data set. The virtual foramen ovale is determined with the navigation system. During simulation, frameless stereotaxy permits to follow the needle position (= probe) on the monitor in real-time in various reformatted CT planes. Thus the optimal access path can be determined. Once it is found, the targeting device is locked in the aligned position. For the intervention, the patient's head is precisely repositioned in the VBH head holder and the puncture needle is advanced through the preset target device towards the gasserian ganglion. Thereafter, controlled thermocoagulation of the gasserian ganglion is performed.

*Results:* The gasserian ganglion could easily be reached through the foramen ovale in all 15 cases performed so far, typically at the first attempt.

*Conclusion:* The use of 3D-computer-assisted navigation allows for an exact placement of the puncture needle and seems to be especially valuable for patients with abnormal anatomy. A similar method can be used for obtaining biopsies, placing foramen ovale electrodes and puncturing tumors for interstitial brachytherapy.

*Keywords:* Trigeminal neuralgia; frameless stereotaxy; pain.

## P068

### Spinal Cord Stimulation for Treatment of Chronic Non-Malignant Pain

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*Introduction:* Since the implantation of the first system for spinal cord stimulation (SCS) in 1967, the SCS-technology has undergone an enormous development and has been utilized increasingly as a longterm treatment for patients with chronic non-malignant pain syndromes.

*Clinical material and methods:* During a 3 years period (1999–2001) 42 patients with chronic, mainly neuropathic pain underwent implantation of SCS. The indications were post-discotomy-syndrom (15 patients), post-traumatic pain (11), reflex sympathetic dystrophy (4), phantom limb pain (4), stump pain (3), low back pain (3), post-traumatic intercostal neuralgia (1) and polyneuropathia (1). Follow-up of our retrospective study ranged from 24 to 58 months, with an average of 42 months. The patients were followed up by the VAS (Visual Analog Scale), level of activity and subjective assessment of the quality of life.

*Results:* Preoperatively all patients had a VAS below 6. The degree of pain relief by the last follow-up was rated as very good in 36% (15), good relief in 45% (19), moderate relief in 14% (6) and poor relief in 5% (2). Only 40% (17) classified themselves as “passive and withdrawn” against 93% (39) preoperatively, 86% (36) reported an improvement of quality of life.

*Conclusion:* We conclude from this retrospective analysis that spinal cord stimulation is efficacious, comfortable and deemed safe for the treatment of chronic non-malignant, mainly neuropathic pain syndromes. The success is critically dependent on the selection of patients based on extensive interdisciplinary diagnosis and exploration of conventional therapies.

*Keywords:* Pain; trigeminal neuralgia.

## P070

### Deep Brain Stimulation (DBS) in the Treatment of Parkinson's Disease: Benefits Outweigh Side Effects and Complications

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*Background:* DBS has mostly replaced irreversible stereotactic coagulations in the treatment of advanced Parkinson's disease. This study was undertaken for evaluating the benefits of the DBS of the subthalamic nucleus (STN) as compared with its risks and side effects.

*Patients and methods:* 31 consecutive parkinsonian patients treated since the year 2001 with bilateral STN-DBS were prospectively followed-up. The effects on Parkinsonian symptoms were studied with repeated UPDRS evaluations in stable medical condition by our neurologist (TH) preoperatively, and thereafter one month and one year after the operation, twice at each visit as blinded to the stimulator status (on/off).

*Results:* One patient died of postoperative pulmonary embolism. Another patient contracted a subacute intracerebral haemorrhage, the net effect being slight permanent worsening in spite of successful STN-DBS therapy later on. Other complications and side effects were clearly minor and temporary, resolving spontaneously during the first postoperative weeks. Superficial skin or wound infection necessitated removal of the implanted material during the follow-up in four patients: in one of them from one side followed by a successful STN-tomy later on, and reimplantation of a new impulse generator after antibiotic treatment in another one.

At one year examination UPDRS motor symptom scores with stimulator on were improved from the preoperative  $34.2 \pm 15.6$  to  $24 \pm 14.8$ , ADL scores from  $20.4 \pm 6.1$  to  $16.8 \pm 8.3$ , and dyskinesia scores from  $5 \pm 2.6$  (max. value 13) to  $2.2 \pm 2.5$  ( $n = 27$ ). All these changes were statistically significant.

*Conclusions:* A majority of Parkinsonian patients experience a significant and long lasting relief of their motor symptoms and improvement in ADL functions. Serious complications are quite rare, the benefits outweighing untoward effects.

*Keywords:* Parkinson's disease; DBS.

## P071

### Low-Cost Quantitative Tremor Assessment Method Precisely Detects Tremor Characteristic Changes during VIM Deep Brain Stimulation

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*Introduction:* Deep brain stimulation (DBS) of thalamic VIM nucleus effectively reduces tremor amplitude in patients with Essential Tremor (ET). However, in order to objectively assess the benefits and correctly adjust the stimulator to its optimal settings, quantitative tremor analysis (QTA) might be favourable. So far, only expensive and sophisticated methods exist to accurately quantify tremor parameters. We present a low-cost method of quantitative tremor assessment.

*Objective:* To quantitatively assess DBS benefits in ET patients.

*Methods:* 5 patients with ET (mean age  $67 \pm 6$  years, 4 men; disease duration  $19.2 \pm 5.4$  years) with bilateral (4 cases) and unilateral (1 case) subthalamic VIM nucleus stimulator were evaluated during both on and off stimulation. QTA was performed by means of power spectral analysis of spiral drawing on a graphic digitizing tablet. Autospectra for displacement, velocity and accel-

eration in 4–8 Hz frequency band were calculated and dominant tremor frequency was determined. Additionally, clinical tremor rating scale (CTRS) and visual assessment of spiral drawing were performed.

**Results:** In all patients, during VIM stimulation there was a significant improvement in both CTRS and visual rating of spiral drawing ( $p < 0.05$ , Wilcoxon test). Autospectra of drawing displacement (D) signal calculated during VIM stimulation showed reduction of both maximum ( $2.07 \pm 1.9$  vs.  $0.53 \pm 0.4$  mm<sup>2</sup>/Hz,  $p < 0.01$ ) and mean ( $0.37 \pm 0.3$  vs.  $0.19 \pm 0.1$  mm<sup>2</sup>/Hz;  $p < 0.01$  Wilcoxon test) power spectral density value as well as decline in  $D_{(\max)} * D_{(\text{mean})}$  coefficient ( $1.19 \pm 1.9$  vs.  $0.15 \pm 0.2$ ,  $p < 0.01$ ). VIM stimulation, however, did not affect the main tremor frequency component ( $5.05 \pm 0.4$  vs.  $4.93 \pm 0.8$  Hz,  $p > 0.05$ ).

**Conclusions:** Our method using graphic digitizing tablet might prove helpful when used for precise tuning of VIM stimulators and possibly represent a low-cost alternative for not-easily available accelerometers. Validation studies, however, are needed to compare accuracy of presented method with gold-standard devices.

**Keywords:** Parkinson's disease; neuronavigation; tremor recording and analysis.

## P072

### A Novel Method for Broken DBS Electrode Replacement

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**Introduction:** Deep brain stimulation (dbs) is an effective therapy for different forms of movement disorders and medicamentous refractory pain syndromes. Most complications of the therapy form are hardware related and are easy treated unless a broken lead is the cause. A free hand electrode exchange is possible but not recommended by us. A new stereotactic procedure is mostly the only solution to exchange a broken lead. We developed a new method to replace a broken electrode.

**Material and methods:** From 1997 until end of 2003 236 dbs electrodes were implanted in 127 patients for different indications. Patients age ranged from 13 to 75 years. Four electrodes broke functionally. The resistance in two electrodes were higher than 4500 Ohm without any visible fracture. In two cases the electrode were damaged surgically in cases of infections. In one case the electrode got exchanged stereotactically. In three cases a spinal epidural lead exchanger from medtronic got abused. The lead exchanger got slipped over the broken electrode under fluoroscopic control and the electrodes were changed easily. The position of the new electrode was controlled by intraoperative computed tomography and image fusion with the original planning ct, the position of the broken electrode and the new electrode.

**Results:** In all four cases the electrodes got exchanged absolutely accurate by stereotactic means. Operation time could be reduced to 40 minutes and the procedure can be performed under general anesthesia.

**Conclusion:** We could demonstrate that our described method for electrode replacement is safe and easy to be performed. The method should be restricted to patients with optimal stimulation results. Other patients should be treated by a new stereotactic procedure.

**Keywords:** History of stereotaxy; Parkinson's disease; dystonia; deep brain stimulation; electrode fracture; lead fracture; electrode replacement.

## P073

### Long Term Follow-Up of Bilateral STN Stimulation in Advanced Parkinson's Disease

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**Objectives:** In recent years bilateral stimulation of subthalamic nucleus/STN BDS/is thought to be the best stereotactic target in controlling akinetic-hiperkinetic form of PD when off and severe levodopa-indecuce dyskinesia when on. Especially young PD patients without cognitive and mood disturbances are the best candidates for bilateral STN DBS. The aim of this study is to evaluate the effectiveness of bilateral STB BDS in young PD patients.

**Methods:** 4 patients with akinetic-rigid idiopathic PD form were included in the study. There were 2 women and 2 men. Evaluations using UPDRS, Schwab and England scale, Hoehn and Yahr scale, motor test/stand-walk-sit test and rapid movements between two points/were performed before surgery in on and off states and after bilateral implantation at 3 months, 1 and 2 years.

**Results:** In off drug state stimulation on, the total motor score of the UPDRS compared to preoperative off drug state was improved by 58% at 2 years. The parkinsonian tremor/items 20–21/was improved by 77%, rigidity/item 22 UPDRS/by 49% and bradykinesia/items 23–26/by 56%. Also axial symptoms/items 13–14–15 UPDRS/gait and postural stability/items 29–30 UPDRS/showed good improvement by 58% with bilateral chronic STN stimulation in off drug phases when stimulation on. Duration of dyskinesia and severity of dyskinesia/items 32–33 UPDRS/showed dramatic improvement with STN BDS. The daily dose of levodopa dropped from 1290/–345 mg to 367/–197 mg at 2 years. The side effects related to surgery and stimulation were mild and reversible.

**Conclusion:** Bilateral DBS STN is the best method of controlling motor symptoms in off state in severe PD patients and enables dramatic reduction in the daily dose of levodopa.

**Keywords:** Parkinson's disease; deep brain stimulation nucleus subthalamicus.

## P074

### Pallidotomy Successfully Abates Persistent Hemichorea Due to Bleeding from a Basal Ganglia Cavernoma

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**Background and objective:** Acute hemichorea (Hemiballismus) usually results from a vascular insult to the contralateral subthalamic nucleus (of Luys). However it is well known that also pathological events in other areas of the contralateral basal ganglia

may cause the syndrome. Although classically addressed by thalamotomy, the close resemblance of this movement disorder to the L-dopa-induced dyskinesias that respond well to postero-ventral pallidotomy prompted us to select the latter to the treatment of a patient with hemichorea of vascular origin.

*Patient and method:* A 68 year-old hypertensive woman was admitted with a severe left hemichorea which developed acutely 6 weeks before admission. The condition did not respond to 10 mg daily of haloperidol. A Brain MRI revealed a haemorrhagic lesion in the right putamen compatible with the diagnosis of cavernoma. A stereotactic right postero-ventral pallidotomy with microelectrode guidance was performed.

*Results:* The hemichorea abated immediately after the procedure and did not reappear during the follow up period extending now to 3 years. Intraoperative recording showed that mean firing rates were low and firing was very irregular in the globus pallidus as compared with the recording in off-state parkinsonian patients.

*Conclusions:* Vascular lesions in the basal ganglia with contralateral persistent chorea can be successfully treated with stereotactic pallidotomy.

A video clip of the patient before and after surgery and the intraoperative neuronal recording will be presented.

## P075

### Stereotactic Procedures. Goals Achievement and Pitfalls

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*Objectives:* Brain biopsy and other stereotactic procedures have evolved over the last decades. Most recently the morbidity and mortality decreased radically with increase in successful histopathological diagnosis. It gives the possibility of applications of appropriate treatment, especially in malignant brain tumours cases. The aim of the study was to evaluate early results of stereotactic procedures, reasons of their complications and failures. Between December 2000 and February 2004 at Department of Neurosurgery Silesian Medical University (Katowice, Poland) 114 stereotactic procedures were performed, based on the system of stereotactic planning and treatment Brain-Lab equipped with automatic CT/MR image fusion software.

*Material/methods:* Material consist 76 stereotactic biopsies, where after having obtained histopathological diagnosis, appropriate treatment procedures were introduced (HDR after loading Ir 192 brachytherapy – 36 patients, LINAC based radiosurgery – 10, fractionated irradiation – 17, and another methods – 1). In 3 cases samples obtained from the biopsy were not diagnostic. 32 patients have the catheter implanted into the remnant tumor, or into its bed, in order to perform postoperative brachytherapy. Three patients underwent stereotactic evacuation of intracerebral haematoma and in 3 cases stereotactic craniotomy have been performed.

*Results:* Desired goal had been achieved in 97.3% of procedures. Important complications and technical problems were: sei-

zures during surgery – 3, bleeding after biopsy – 1 (angioma with intracerebral chronic haematoma), accidental slipping out of implanted catheter – 1 and displacement of stereotactic frame during biopsy – 1. There was no peri-operative mortality. Morbidity in our group equals 1.8%.

*Conclusions:* 1. Our observation indicates that stereotactic procedures provide valuable histological diagnosis with low complication rate. 2. Presence of histopathologist on the operation room provides high level of biopsy's efficiency.

*Keywords:* Radiosurgery; stereotaxy; brachytherapy; brain tumour; image fusion.

## P076

### Late Outcome of Gliomas Treatment with Various Strategies. The Role of Stereotactic Methods

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*Objectives:* One of the basic goals that should be adopted after taking the decision to operate a patient with malignant CNS tumour is to provide him with a good comfort of life and neurological state after the surgery. The aim of the study was to evaluate results of treatment of primary gliomas employing three different algorithm's of multimodal treatment.

*Material/methods:* Material consist 198 patients with primary glioma treated in Neurosurgical department of Medical University of Silesia in period 1999-march 2003. Three schema of treatment was introduced: surgical evacuation and external radiotherapy (group S, n = 117, low grade 21, high grade 79), surgical evacuation and stereotactic brachytherapy (group BRT n = 45, low grade 18, high grade 82), stereotactic biopsy and brachytherapy and/or radiosurgery and/or fractionated irradiation (group SB, n = 36, low grade 28, high grade 72).

Statistic analyses of status of patients in KS on admission, after procedure, at the end of hospitalization and during long-term observation, and survival time in groups S, BRT, and SB were conducted. We distinguished subgroups of tumors, concerning histological type and localization.

*Results:* Only statistic significant comparisons are mentioned below. Status of patients on admission in KS depended on histological type of tumour and on grade in WHO classification. Survival time is longest in patients with "lobar" tumours and in BRT group. Survival time is shortest in patients with tumours crossing midline and in SB group.

It is a little surprise, that status of patients at the end of hospitalisation and in long-term follow-up is the best in patients in BRT group.

*Conclusions:* 1. In our opinion gross and gently total surgical removal of the glioma (if possible) and immediate internal and/or external x-ray therapy gives the best effect in glioma management. 2. Stereotactic x-ray methods (radiosurgery, brachytherapy) are safe and well tolerated by patients with primary gliomas.

*Keywords:* Radiosurgery; glioma; brachytherapy; late outcome; stereotaxy.

**P077****Simulation of DBS Electrode and Basal Ganglia Suggests Mechanism of Clinical Benefit**

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*Objective:* Although the clinical benefit of DBS in a number of movement disorders has been repeatedly demonstrated, the mechanism by which such benefit is achieved has remained elusive. A computational approach is taken here toward understanding the dynamic effects on the circuitry of the basal ganglia that the DBS electrode may have.

*Methods:* Models of thousands of biophysically based single cells and dendritic processing within a simplified basal ganglia circuit were created. The circuit was modified by changes in the substantia nigra cells consistent with those found in Parkinson's Disease. A detailed model of the typical four-contact DBS electrode (Medtronic) was then made to interact with the simulated cells of the model subthalamic nucleus (STN). Comparison was made between the output spike rates and regularity within the thalamic cells of the model in these two circumstances.

*Results:* Although only based at this point on the standard direct/indirect pathway schematic, diversified cell responses were appreciated within each nuclear population of cells. Moreover, cells displayed spike rates very similar to those seen in microelectrode recordings from PD patients, between 40 Hz and 90 Hz. In addition, the thalamic cells in the model showed a more irregular bursting pattern in approximately 5–10% of the simulated cells. Interestingly, they were often cycling at about 5 Hz, based on a moving window spike rate analysis. Importantly, with the STN DBS electrode added, the same cells in the thalamic component showed no bursting, but rather a far more regular pattern at the same or slightly higher spike rate.

*Conclusion:* Using a moderately detailed computational modeling approach, the findings of simulated cells in the PD circuit thalamus suggest that the effect of a DBS electrode is in minimizing irregularities and burst-type activity even up to two synapses downstream.

*Keywords:* Parkinson's disease; dystonia; DBS.

**P078****The Role of the Stereotactic Biopsy in a Properly Treatment of the Brain Tumors**J. Furtak<sup>1</sup>, M. Harat<sup>1</sup>, T. Szyberg<sup>2</sup><sup>1</sup> Department of Neurosurgery, Military Hospital, Bydgoszcz, Poland<sup>2</sup> Department of Pathology, Military Hospital, Bydgoszcz, Poland

*Objective:* The purpose of this study was to analyse the role of the stereotactic biopsy in an effective treatment of the brain tumors. The stereotactic serial biopsy obtains tissue material from brain tumor to achieve correct diagnosis. The correct diagnosis lets us treat properly the patient.

*Materials and methods:* 615 stereotactic serial biopsies were performed in our department since 1996. Since 2001 biopsies have been performed based on CT/MRI fusion. After diagnosis patients underwent whole brain radiotherapy, brachytherapy, chemotherapy or operation.

*Results:* In our series of 615 biopsies, glioblastoma multiforme was diagnosed in 213 cases (34.6), high-grade glioma

in 133 cases (21.6), low-grade glioma in 157 cases (25.5) metastases in 53 cases (8.6), lymphoma in 23 cases (3.7). The following methods of treatment were applied: WBRT in 342 cases (55.6), brachytherapy in 320 cases (52), chemotherapy in 45 cases (7.3), operation in 38 cases (6.2). Complications of biopsy occurred in 21 patients (3.4): haemorrhage in 13 patients (2/1), death in 2 patients (0.32), neurological deficits in 3 patients (0.49), seizure during biopsy in 4 patients (0.65), respiratory failure in 1 patient (0.16). After introduction CT/MRI fusion in 2001 complications occurred only in 8 cases (1.3).

*Conclusions:* The stereotactic biopsy of brain tumors is a minimal invasive and an effective method to obtain tissue material from brain tumor. CT/MRI fusion decreases number of complications.

*Keyword:* Stereotactic biopsy.

**4A06****Intrapatamenal infusion of glial cell line-derived neurotrophic factor in Parkinson's disease: Towards a potential neuroprotective and neurorestorative therapy**Nikunj K. Patel<sup>1</sup>, Gary R. Hotton<sup>2</sup>, Puneet Plaha<sup>1</sup>, Martin Bunnage<sup>1</sup>, David J. Brooks<sup>2</sup>, Clive N. Svendsen<sup>3</sup>, Peter Heywood<sup>1</sup>, Steven S. Gill<sup>1</sup><sup>1</sup> Frenchay Hospital, Institute of Neurosciences, Bristol BS16 1LE, UK<sup>2</sup> MRC Clinical Sciences Center and Division of Neuroscience, Faculty of Medicine, Imperial College, Hammersmith Hospital, London W6, UK<sup>3</sup> The Waisman Center Stem Cell Research Program and Departments of Neurology and Anatomy, 1500 Highland Avenue, University of Wisconsin-Madison, Madison, WI, 53705, USA

Glial cell line-derived neurotrophic factor (GDNF) promotes recovery of the injured nigrostriatal dopamine system and improves motor function in both rodent and non-human primate models of Parkinson's disease (PD). The only previous clinical study of GDNF utilized an intraventricular route of administration, however, this was unsuccessful, attributed to poor parenchymal penetration. The neuroprotective and neurorestorative properties of GDNF seen in preclinical studies suggest that trophic factors may play an important role in treating PD, and intraparenchymal infusion of GDNF may represent a new treatment option.

In a phase I study, 5 PD patients with a previous good response to levodopa underwent unilateral or bilateral insertion of cannulae into the posterior putamen through which human recombinant GDNF has been chronically infused via indwelling pumps. Clinical evaluations were based on the Core Assessment Program for Intracerebral Transplantations (CAPIT), a validated protocol for evaluating surgical treatments of idiopathic PD. All patients were evaluated on the Unified Parkinson's Disease Rating Scale (UPDRS) and underwent timed motor tests at baseline and after 3, 6, 12, 18 and 24 months. The impact of GDNF infusion on quality of life was assessed using validated quality of life questionnaires: the 39-item Parkinson's Disease Questionnaire PDQ-39 and the 36-item Medical Outcomes Study short form health survey SF-36 and were used before surgery and after 3, 6, 12, 18 and 24

months. Neuropsychological outcomes were assessed once before surgery and then at 12 and 24 months after surgery.  $^{18}\text{F}$ -dopa PET assessments were performed pre-operatively and postoperatively at 6 monthly intervals for 2 years.

After 2 years, there were no serious clinical side effects, a 57% improvement in the off-medication UPDRS motor subscore ( $P < 0.0005$ ) and a 63% improvement in the activities of daily living subscore ( $p < 0.002$ ). Health-related quality of life measures (PDQ-39 and SF-36) showed general improvement over time, with the overall scores tending towards levels expected in a control population. Neuropsychological assessment results indicated, both

at one and two years, no significant detrimental effects of GDNF infusion on cognition; and at 2 years showed some evidence of an improvement in verbal anterograde memory.  $^{18}\text{F}$ -dopa PET scans showed a 60% increase in posterior putaminal uptake ( $p < 0.01$ ).

Chronic infusion of GDNF into the posterior putamen for 2 years is safe and results in a sustained improvement of parkinsonian symptoms and quality of life; and is accompanied by a significant increase in  $^{18}\text{F}$ -dopa uptake. GDNF may represent a potential neuroprotective and neurorestorative therapy for PD.

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