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ПРЕДГОВОР

Минимално инвазивната неврохирургия навлиза бързо в съвременната клинична практика в световен мащаб. Въпреки трудностите, които страната ни изпитва по пътя към пазарна икономика, Българската неврохирургия полага усилия да не изостава от съвремнния прогрес в тази област. Първата по рода си конференция по минимално инвазивна неврохирургия и интраоперативно образно водене, организирана от Българското Неврохирургично Дружество се състоя в курорта „Златни пясъци" край Варна на 5-7 Юни 2003 година. Нашата цел беше да представим съвременното състояние на въвеждане в страната и българския опит с модерни минимално инвазивни неврохирургични и невроизобразителни методики, акцентуирайки върху интердисциплинарното сътрудничество, особено със съвременната компютърно асистирана невроренгенология. Водещи в световен мащаб фирми и поканени от тях международно известни експерти ни запознаха с някои от най-новите разработки в тази област.

Неделима част от научната проява беше съвместният Българо-Германски симпозиум „Образно водена ендоскопия - симулация и клинично приложение в минимално инвазивната неврохирургия". Той беше спонсориран от фондация „Александър фон Хумболдт", Бон, Германия и представляваше етапна оценка на извършената до момента работа по този съвместен проект между университетските неврохирургични клиники в София и Мюнстер. Тази чудесна съвместна инициатива на българската и германската неврохирургия представлява шанс сътрудничеството да прерастне в бъдеща традиция на периодични съвместни прояви на двете научни дружества.

Настоящият брой от списание „Българска Неврохирургия" съдържа подбрани материали от конференцията и поднася информация, която, надяваме се, ще стимулира по-широкото въвеждане на съвременните компютърни технологии в ежедневната неврохирургична практика и ще спомогне за по-доброто лечение на нашите пациенти.

Доц. д-р М. Маринов, дм,
Редактор на броя

PREFACE

Minimally invasive neurosurgery is a rapidly evolving discipline and innovations in this field are introduced worldwide quickly in the clinical practice. In spite of numerous difficulties in our transition to market economy Bulgarian neurosurgery is trying to keep up with these innovations. The First Meeting on Minimally Invasive Neurosurgery and Image Guidance was held in Golden Sands Resort, Varna - Bulgaria from June 5-7, 2003, organized by The Bulgarian Society of Neurosurgery. Our purpose was to present the current state of application of innovative minimally invasive neurosurgical and neuroimaging techniques in our country and to enhance interdisciplinary cooperation especially with computer assisted neuroradiology. On the other hand, neurosurgical experts and representatives of world-leading companies provided us with overview of some of the latest technical and clinical developments in the field.

An integral part of this meeting was the Bulgarian-German Symposium „Image guided endoscopy - simulation and clinical application in minimally invasive neurosurgery". It was supported by the „Alexander von Humboldt" Foundation, Bonn, Germany and represented an interim seminar on the progress we have achieved working on this joint research project of the University Neurosurgical Clinics in Sofia and Muenster. This cooperation is a positive validation for both Bulgarian and German neurosurgery and we regard this as an excellent opportunity to set up a future tradition for joint activities of both neurosurgical societies.

The present issue of the journal „Bulgarian Neurosurgery" contains selected materials from the meeting and thus provides a source of information that will stimulate more widespread acceptance of modern computer assisted technologies in our daily neurosurgical practice and will help us to improve the care of our patients.

M. Marinov, MD, PhD,
Issue Editor

BULGARIAN-GERMAN NEUROSURGICAL RESEARCH COOPERATION FOR CEREBROPROTECTIVE MEASURES WITH THE SUPPORT OF ALEXANDER VON HUMBOLDT FOUNDATION

Prof. Dr. H. Wassmann
Head of the Neurosurgical Department, University Clinic, Muenster, Germany

БЪЛГАРСКО-ГЕРМАНСКО НЕВРОХИРУРГИЧНО НАУЧНО СЪТРУДНИЧЕСТВО В ОБЛАСТТА НА МОЗЪЧНАТА ПРОТЕКЦИЯ С ПОДКРЕПАТА НА ФОНДАЦИЯ „АЛЕКСАНДЪР ФОН ХУМБОЛДТ“

Проф. Х. Васман
Директор на Неврохирургична клиника, Университет Мюнстер

The neurosurgical team of the University of Muenster would like to express its high appreciation for the organization of the present symposium. It is a result of a long lasting (more than 15 years) successful scientific cooperation between the Bulgarian and German academic neurosurgery and in particular between our clinical institutes in Sofia and Muenster. The main topic of our mutual investigations is cerebroprotection in its experimental and clinical aspects, and the results we have achieved in this field of research would not be possible without the support and promotion of the Alexander von Humboldt Foundation, Bonn, Germany.

In 1860, shortly after the death of Alexander von Humboldt by a joint initiative of the Royal Society in London, the Academy of Sciencies in St. Petersburg and the Prussian King Friedrich Wilhelm IV, the first foundation with the same name was established. In the following 90 years its credo and main purposes evolved, but the way of the Foundation was quite uneven, and its activities interrupted by the stormy historical events in the last century.

The modern Alexander von Humboldt Foundation, as we know it today was reinstituted in 1953 with the idea to promote the international politico-cultural relations of the German state.

By promoting bilateral cooperation with leading researchers from all over the world the AvHumboldt foundation contributes also for strenghtening and development of fundamental and practical science performances and innovation ability in Germany itself.

Today, we cordially congratulate the Foundation on its 50th birthday and express our deep gratitude for the promotion of our scientific and practical collaboration. In this moment, we would like also to aknowledge the personal contribution of Prof. M. Marinov. Starting as a Humboldt Fellow 1988/89 in Bonn, and later continuing his fellowship in Muenster, he used the support of the Humboldt Foundation for a fertile scientific work and cooperation with his German colleagues - entirely in concordance with the principal idea of the Foundation.

I would like to only highlite some of our already realized scientific projects and chapters of the main topic „Neuroprotection“. The experimental examinations of cerebroprotective substances like calcium antagonists were in the foreground of our investigations, initiated in 1989 (1-4). Several clinical and experimental studies dealt with focal cerebral ischemia, the salvage of the so-called „penumbra“ region and the cerebroprotective measures during carotid endarterectomy (5,6).

The emphasis in our investigational program since 1998 was put on the intraoperative use of computer neuronavigational systems with analysis of the significance of frameless stereotaxy for the protection of the brain in intracranial tumor surgery (7).

In continuation of this joint program in minimally invasive neurosurgery and with the support of the AvHumboldt foundation we started January 2002 a new, 3-year project for approbation and evaluation of a new method for virtual computer planning of neuroendoscopic procedures. The aim of this ongoing study is to prove, that the fusion of both preoperative virtual endoscopy and intraoperative image guidence (neuronavigation) may be of value in increasing the safety and efficacy of endoscopic intraventricular surgery (8,9).

Taking into consideration the specific area of our scientific collaboration it is not surprising, that the topic of today's conference is the current state of application of innovative minimally invasive neurosurgical and neuroimaging techniques. It is very important also to stress, that young neurosurgeons from both institutions have already committed themselves to the implementation of this scientific exchange program.

Bulgaria stands before it's joining to the European Union and in very near future will get closer to us. Undoubtedly, this will strenghten our future scientific cooperation and make it more efficient.

In conclusion, we want to thank the Bulgarian Neurosurgical Society, especially Prof. Marinov and Prof. Bussarsky for their overwhelming Bulgarian hospitality!

I look forward to welcome our Bulgarian-German working group and all you here today to our next meeting, which is scheduled in September, 2004 in the „Westphalian Metropolis" Muenster!

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MINIMALLY INVASIVE NEUROSURGERY - THE BULGARIAN EXPERIENCE

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Abstract: The authors review the present status of various minimally invasive neurosurgical procedures according to literature data and their own experience. Minimally invasive neurosurgery includes microneurosurgical interventions as well as certain novel technologies - neuroendoscopy, stereotaxy, endovascular surgery, stereotactic radiosurgery, percutaneous spinal nucleotomy, percutaneous spinal fusion, neuronavigation, etc.

The introduction of these techniques in our country followed shortly after their debute in the developed world. Despite economic problems due to lower standard, underfunding of the health system, certain scientific and technological isolation a group of modern Bulgarian neurosurgeons pioneered the application of the new techniques for the treatment of neurosurgical problems. As a result most of the advanced technologies in neurosurgery are at the disposal of certain neurosurgical centres and are increasingly used with success for the benefit of growing number of patients.

МИНИМАЛНО ИНВАЗИВНА НЕВРОХИРУРГИЯ - БЪЛГАРСКИ ОПИТ

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Резюме: Авторите правят преглед на съвременното състояние на разнообразните минимално-инвазивни неврохирургични процедури по данни на литературата и съобразно собствения си опит. Минимално инвазивната неврохирургия обхваща микроневрохирургичните интервенции както и някои нови технологии - невроендоскопия, стереотаксия, ендоваскуларна неврохирургия, стереотактична радиохирургия, перкутанна спинална ендоскопска нуклеотомия, перкутанна спинална фузия, невронавигация и т.н./.

Въвеждането на тези нови техники в нашата страна е в кратки срокове след първите съобщения в развитите страни. Независимо от финансово-икономическите проблеми поради по-ниския стандарт, недостатъчното финансиране на системата на здравеопазване, известна научна и технологична изолация редица съвременни български неврохирурзи с пионерски усилия внедриха много новости при лечението на неврохирургичните болести. В резултат повечето от съвременните технологии в неврохирургията са на разположение във водещите неврохирургични звена и се използуват с успех при все по-нарастващ брой болни.

Minimally invasive neurosurgery /MINS/ is a new and exciting field of modern treatment of various disorders of the central nervous system. The principles of this technique include less trauma to the superficial tissues during the approach to lesions of varying depth in the brain or spinal cord, less manipulation of important perilesional neurovascular structures and decrease of accompanying discomfort and morbidity of the procedure.

Historically the introduction of microneurosurgery marked the first attempt for minimally invasive procedures - the excellent magnification and illumination provided by the operating microscope coupled by numerous delicate fine microinstruments / bipolars, scissors, dissectors, aspirators, etc./ and improved knowledge of the microsurgical neuroanatomy and neurophysiology have had the greatest impact on the outcome. The dramatic decrease in mortality and morbidity with microneurosurgery resulted in significant improvement of results providing cure or better outcome for most patients. Following the work of the pioneers of microneurosurgery /M. G. Yasargil, L. Malis, etc./ microneurosurgical procedures were introduced in our country some years later /1967-1977/ with the efforts of L. Karaguiozov and A. Karkesselyan / at the Department of Neurosurgery, Medical Academy /now Medical University/ - Sofia. Since that time most of cerebral and spinal interventions were performed with microneurosurgical techniques and principles and the improvements of results of treatment were amazing - mortality dropped down 5-10 times and morbidity was decreased significantly. Microneurosurgery offered safe and effective treatment for many neurosurgical disorders / cerebral aneurysms, cerebral and spinal arteriovenous malformations, brain and spinal cord tumors, spinal discs, epilepsy, pediatric neurosurgery/ and became standard of operative management for the next decades /A. Karkesselyan, V. Bussarsky, K. Romansky, S. Undjian, S. Gabrovsky, M. Marinov, Chr. Tzekov, Al. Petkov et al./.

Stereotactic neurosurgery has been introduced during the same time /G. Savov, 1967/ for the treatment of Parkinsonism and since 1996 CT-based stereotactic interventions have become routine for diagnosis and treatment of most deep seated or critically located lesions /biopsy, excision, cyst aspiration, drainage, etc./ either through burr-hole or with CT-guided stereotactic limited craniotomy /V. Karakostov and V. Bussarsky/. CT guidance of stereotactic procedures with the Leksell frame is also an example of minimally invasive procedure and even with the introduction of neuronavigation / frameless stereotaxy/ remains as „gold standard“ for diagnosis and treatment of certain lesions.

During the next two decades key-hole approaches have been developed and popularized /endonasal transsphenoidal approach, retrosigmoid mini-craniectomy, cervical and lumbar microdiscectomy, superolateral orbitocraniotomy with „an eyebrow incision“, etc/. Their role for the improvement of results with minimal morbidity can not be underestimated and so they serve excellently for the purpose of minimal invasiveness. Percutaneous application of isotopes as minimally invasive neurosurgical treatment for cystic tumors / gliomas, craniopharyngiomas/ have been introduced since 1986 with evident benefit in certain cases /V. Bussarsky and P. Nikolov/.

Major technological advances in neuroimaging /CT, MRI, PET, ultrasound/ greatly contributed to the precise diagnosis and improved knowledge of the lesions and presented background for the concept of minimal invasiveness - precise and small skin incision, preferably straight or curvilinear; minimal and exactly centered bone flaps, micromanipulation of brain tissue during cortical dissection, avoidance of excessive cerebral retraction, etc. Inevitably there was increase of the cost and duration of neuroimaging but the detailed pictures of the lesional and perilesional anatomy enabled neurosurgeons to plan and prepare the least traumatic and most effective approach to the lesion.

The new equipment for the minimally invasive neurosurgical procedures turned out to be rather expensive and some time was needed to persuade hospital and public health administrators of the cost-effectiveness of MINS.

Percutaneous techniques - transoval glycerrhol retrogasserian rhizolysis /K. Romansky and Chr. Ranguelov/ percutaneous lumbar nucleotomy with fluorographic control /V. Bussarsky, etc./ were also introduced shortly after the first reports of their effect were published.

The next steps were the introduction of neuroendoscopy in 2000 /V. Bussarsky/ and neuronavigation /V. Bussarsky, K. Romansky, M. Marinov et al./ in 2003. Neuroendoscopy had its first attemps at the beginning of the 20-th century but its fast and efficient clinical application had been during its last decade. The endoscope was applied either as „endoscope assisted microneurosurgery“ or as the only tool for intraventricular or endocystic lesions. Neuroendoscopy allowed for treatment of lesions with minimal trauma to the scalp and the brain while certain advantages of the new technology made it superior to conventional microneurosurgery - better illumination with closer magnified three-dimensional view of the lesion and surrounding anatomy, possibility to „look around the corner“ and „through membranes“ without additional retraction and injury to adjacent neuro-vascular structures. The nearly 3-years experience with about 200 cases and various neuroendoscopic procedures / third ventriculostomy, aqueductoplasty, foraminoplasty /Monro/, pellucidotomy, septostomy, cystoventriculostomy, cystocisternostomy, biopsy, excision, membranectomy, evacuation and drainage of hematomas and abscesses, coagulation and excision of hyperplastic pl. choroideus, endoscopic assisted microneurosurgery for inspection and control, etc./ has been most encouraging for the possibility to treat with minimal morbidity and high effectiveness lesions that previously were considered too risky or untreatable. The combination of neuronavigation with neuroendoscopy appears to provide additional advantages in terms of precision, safety, intervention control of radicality and minimal invasiveness.

The introduction of neuronavigation has provided impetus for better planning of the individual procedure in every patient, small incisions and bone flaps, the option to choose the best /direct, atraumatic through less critical zones, shortest/ cerebral dissection. The improved peroperative orientation and control of the extent of the intervention are of exceptional benefit for the most complex procedures for deep seated lesions near important neurovascular structures. As this technology is rather new it may be predicted that with larger experience its contributions to more radical, less traumatic, less invasive, safer and less expensive neurosurgical interventions will be more evident and convincing.

Most of the new exciting technologies ensure more safety, more efficiency, less invasiveness, less morbidity, shorter and less expensive hospital stay all of which will pay for the significant initial investments in the new equipment. Certain technologies / intraoperative MRI, PET, stereotactic radiosurgery, etc./ due to their huge price will remain the privilege of selected centers and developed countries.

Our final words are aimed to introduce our German colleagues to some milestones of the past and present of Bulgarian neurosurgery:

1937 - the first neurosurgical operations were performed by N. Vassilev /a pupil of Clovis Vincent in Paris/ and Ph. Philipov /trained with W. Tonnis in Germany/ ;
1942 - the first Division of Neurosurgery was opened at the Neuropsychiatric Clinic of the University Hospital „ Alexandrovska“ - Sofia which later turned into the first Chair of Neurosurgery in 1952 headed by Prof. Ph. Philipov; The following years other University Departments of Neurosurgery were founded at Plovdiv/ 1952/, Varna /1961/, Pleven /1975/, Stara Zagora /1993/; Neurosurgical Clinics were established at the Military Medical Academy / 1954/ and the Institute of Emergency Medicine /1973/ in Sofia.
1959 - The Section of Neurosurgery of the Joint Society of Neurology, Psychiatry andNeurosurgery;
1975 - The Bulgarian Society of Neurosurgery with the following Presidents :
    Prof. Dr. P. Petrov /1975 - 1980/; Prof. Dr. L. Karaguiozov /1981-1986/;
    Prof. Dr. M. Vanev /1987- 1991/; Prof. Dr. A. Karkesserlyan /1992 - 1999/;
    Prof. Dr. V. Bussarsky / 2000 -
1961-1991 - The Journal of Neurology, Psychiatry and Neurosurgery;
1992 - The Journal „Bulgarian Neurosurgery“ - three times annually;

The Bulgarian Society of Neurosurgery holds annual Conference of Neurosurgery with international participation and most reports are published in the journal.

For many decades Bulgarian neurosurgery was rather isolated due to political and /or financial reasons with minimal contacts with developed countries. We do hope that things are changing for the better and we will have many neurosurgical meetings in United Europe.

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UPDATING OF NEUROIMAGING DATABASE FOR IMAGE-GUIDED SURGERY: A STRATEGY TO ACCOUNT FOR BRAIN DISPLACEMENT AND DEFORMATION

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ABSTRACT

Object: Intraoperative displacement and deformation of the brain leads to deterioration in the co-registration between the surgical field and the preoperative neuroimaging database used by image-guidance systems. We investigated the feasibility of using computational modeling of the brain and intraoperatively acquired sparse data to update the image-guidance database.

Methods: A computational model using patient-specific MRI data and 3-D finite element modeling was generated. Intraoperative data was acquired from co-registered ultrasound and from stereoscopic cameras integrated into the binocular operating microscope. The 3-D finite element mesh was morphed in accordance with both the computational model and the intraoperatively acquired imaging data, and then incorporated into the image-guidance display.

Conclusions: Computational modeling incorporating inexpensive and easily acquired sparse data may be used to update the preoperative MRI for improved image-guidance during surgery.

Key words: *Computational modeling, frameless stereotaxy, image-guided surgery, intraoperative CT, intraoperative MRI, ultrasound*

АКТУАЛИЗИРАНЕ НА НЕВРОИЗОБРАЗИТЕЛНАТА БАЗА ДАННИ ПРИ ОБРАЗНО-ВОДЕНА НЕВРОХИРУРГИЯ: СТРАТЕГИЯ ЗА КОМПЕНСИРАНЕ НА ИНТРАОПЕРАТИВНОТО ИЗМЕСТВАНЕ И ДЕФОРМАЦИЯ

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РЕЗЮМЕ

Цел: Интраоперативното мозъчно изместване и деформация водят до влошаване на ко-регистрацията между хирургическото поле и предоперативната база неврообразни данни, с които работи невронавигационната система. Ние проучихме възможността да се използва компютърен модел на мозъка заедно с епизодично получени интраоперативни образни данни и с цел актуализиране на данните за образно водене.

Метод: Беше създаден компютърен модел, основаващ се на специфичните за пациента ЯМР-данни и на триизмерно ограничено моделиране на обектите. Мрежата на триизмерно ограничения елемент беше моделирана съответно на компютърния модел и на интраоперативно получените образи, след което мрежата се инкорпорираше в дисплея на невронавигатора.

Изводи: Компютърното моделиране, включващо евтино и лесно осъществимо периодично получаване на интраоперативна образна информация може да се използва за актуализиране на предоперативните ЯМР данни и оттук - за подобряване на образното водене по време на операция.

Ключови думи: *Компютърно моделиране, безрамкова стереотаксия, образно водена хирургия, интраоперативна КТ, интраоперативен ЯМР, ултразвук.*

INTRODUCTION

With widespread adaptation of frameless stereotactic, or image-guided, methodology in neurosurgery, increasing attention is being directed at brain displacement and deformation - so called „brain shift." As the surgical field changes over the course of an operation, there is increasing spatial disparity between that field and the preoperative imaging database on which image-guidance is based, the implications of which can be profound.

A number of investigations have attempted to characterize brain movement during surgery, with findings of cortical movement often exceeding 1.0 cm (2, 6, 23). Various strategies have been adopted to minimize such movement, including placement of the craniotomy superiorly to minimize CSF loss and to limit displacement to principally one direction, avoidance of osmotic and diuretic agents during surgery, and initiation of surgical dissection at the most critical boundaries. Nevertheless, a desire to retain valid spatial registration over the course of an operation remains.

One approach to address this issue is to use intraoperative imaging during surgery, and intraoperatively acquired CT and MRI studies may then serve as updated image databases for image-guidance systems. Such systems are expensive, sometimes cumbersome, and inefficient, and a methodology that uses brain modeling algorithms in combination with more easily and inexpensively acquired imaging during surgery may achieve similar results. We sought to demonstrate the feasibility of such an approach using 3-D finite element modeling integrated with intraoperative stereoscopic imaging and ultrasonography.

MATERIALS AND METHODS

A 3-D finite element model methodology has been developed, by which an individual model based upon a high-resolution MRI is created and then morphed on the basis of simulated surgical phenomena such as the craniotomy opening, CSF drainage, gravity, retraction, and most recently, resection. The method has been validated in a porcine model, and up to 83% of brain deformation has been recovered on the basis of predictive modeling alone. The model and validating investigations have been previously published (13-18, 20).

The accuracy of the newly morphed image database can be assured by requiring it to adhere to data acquired intraoperatively. Such data need not have the density of a high resolution, diagnostic quality CT or MRI scan since the model can interpolate between its data points, but the overall accuracy of the system will reflect the accuracy with which those sparse data points are located. The two sparse data sources used in this study were intraoperative, co-registered ultrasound and intraoperative, co-registered stereoscopic image pairs acquired through the operating microscope.

Co-registered ultrasound image acquisition

A SONOLINE Sienna Digital Ultrasound System (Siemens Medical Systems, Inc., Iceland, NHJ) has been adapted for co-registered image acquisition using a Polaris optical tracking system (Northern Digital, Inc., Waterloo, Ontario) (8-11). The transformation between the ultrasound image and the Polaris tracker attached to the ultrasound transducer is determined by a calibration process. The transformation between the transducer tracker and the camera array is provided by the Polaris system, and the transformation between the camera array and both the patient and the preoperative MRI data-set is determined using scalp-based fiducials visible both on the MRI and to the camera array at the start of the procedure. A matrix equation using these transformations enables correlation between any point in the ultrasound image and the MRI database.

Co-registered operating microscope stereoscopic images

Intraoperative digitization of the cortical surface is accomplished using two CCD cameras that have been attached to the binocular optics of the operating microscope.[26,27] These cameras acquire stereo pairs of images at a rate of 15/sec, and although these can be viewed with 3-D display techniques such as polarizing goggles to produce a 3-D image, they are used in this setting to generate 3-D coordinates of the exposed cortical surface. This is accomplished by automated identification of corresponding points in both images, and then using triangulation to determine their 3-D coordinates. The relationship between these coordinates and those of the surgical field and the preoperative imaging database is known from tracking of the operating microscope's position using the same Polaris optical tracking system.

Integration of sparse data into the finite element model

Integration of data from both of these sources into the computational model is a non-trivial task. Computational modeling may be forced to satisfy a subset of conditions, such as the location of the exposed cortical surface, the initial corticotomy, the immediately surrounding subcortical gyral pattern, or the ventricular surface. What is immediately apparent in any such implementation is that rigid transformations of the original imaging data-set are unsatisfactory.

RESULTS

Acquisition of co-registered ultrasound in the operating room has been reliably accomplished. An image pair showing a 2-D ultrasound image and the corresponding reformatted MRI is shown in **Figure 1.** Investigation of the accuracy of this technique has shown correspondence between points on ultrasound and MRI to be better than 2 mm. (10)

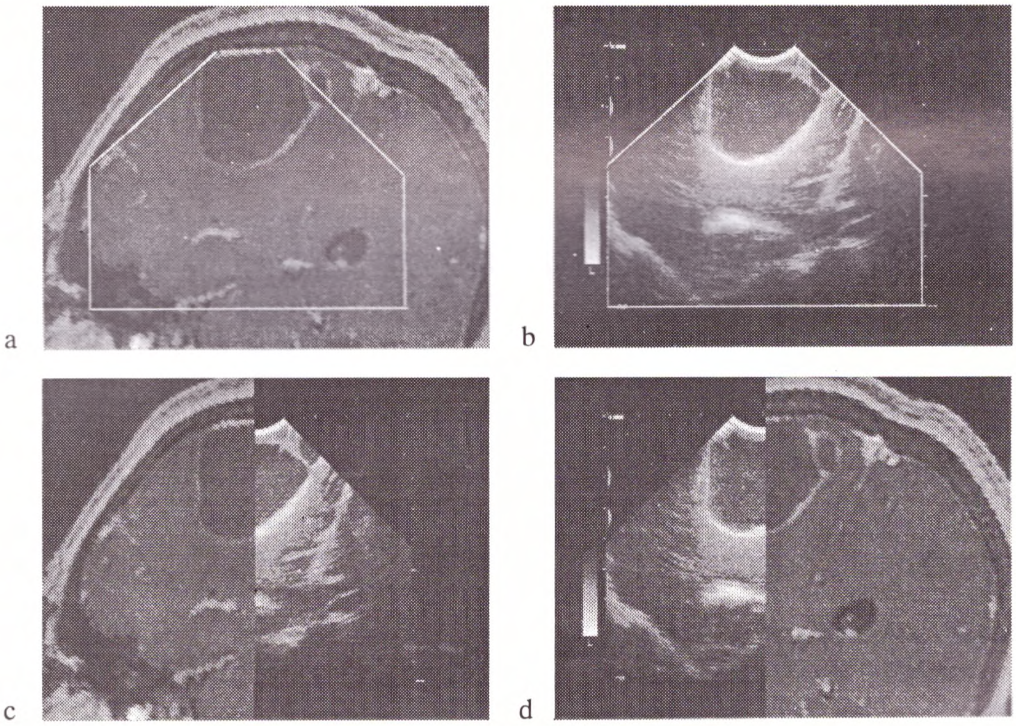

Figure 1. Corresponding intraoperative ultrasound (b, c, d) and reformatted MRI (a, c, d) images in a case of resection of a cystic metastatic tumor.

Figure 2 shows a stereo pair of images as acquired through the operating microscope. The digitized surfaces generated from these as well as later in this case are illustrated in **Figure 3.** Accuracy of this digitization process has been determined to be better than 2 mm, when compared to digitization using the Polaris optical pointer (26, 27).

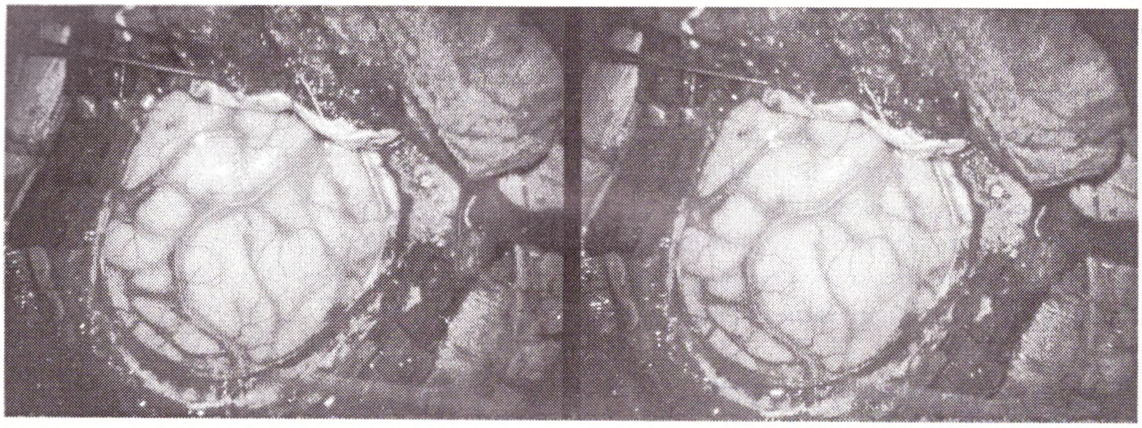

Figure 2. A stereo pair of images of the cortical surface during implantation of subdural strip and grid electrodes for the evaluation of a patient with intractable epilepsy.

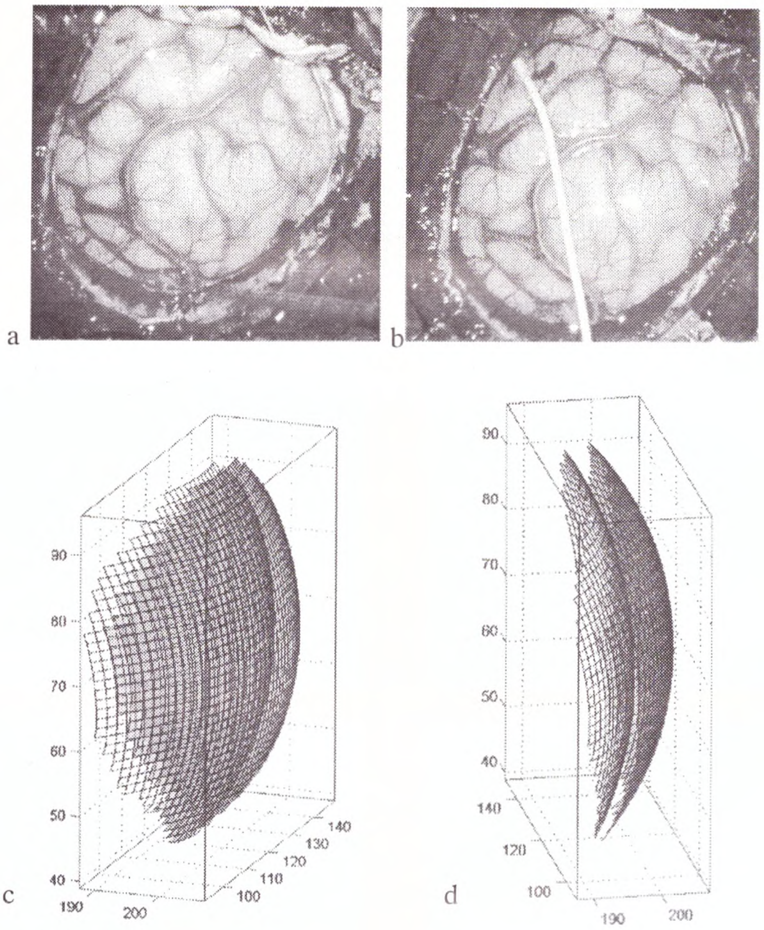

Figure 3. The digitized cortical surfaces acquired from stereo pair imaging (c, d), acquired at the time of dural opening (a) and at the close of the procedure (b).

In **Figure 4**, the location of the focal point of the operating microscope is depicted in both the original, preoperative MRI data-set (top) and in the computationally updated, deformed image set (bottom). The loss of valid co-registration that may occur over the course of a procedure, as well as the intuitive desirability of the latter, assuming reliable accuracy, are apparent.

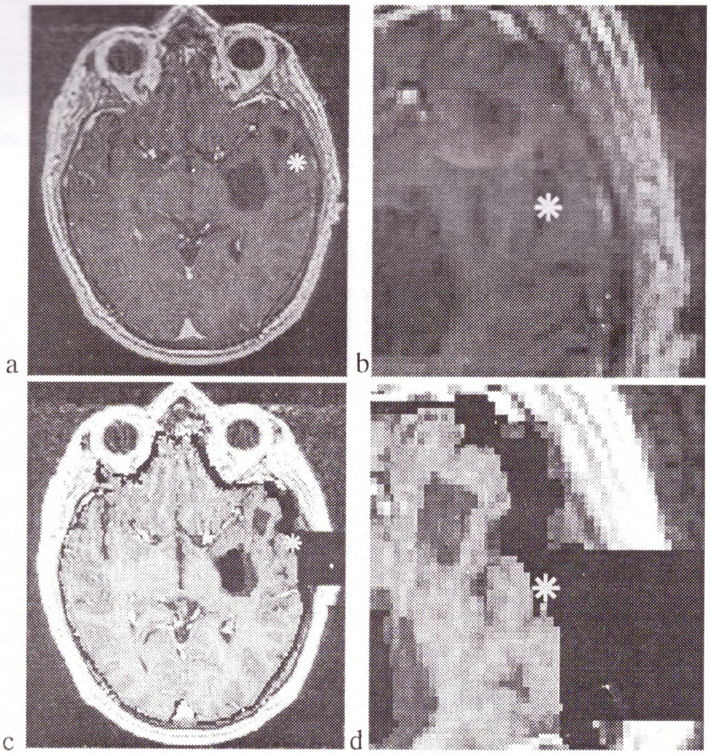

Figure 4. Graphic displays showing the position of the focal point of the operating microscope late in the course of the procedure, using the preoperative MRI data-base (above) and the updated image data-base (below).

DISCUSSION

In an attempt to maintain accurate image-guidance during neurosurgical procedures, many centers have implemented intraoperative CT or MRI systems (1, 3-5, 7, 12, 19, 21, 24, 25, 28-30). The utility and cost-effectiveness of this technology is not yet determined, but it is clear that the functionality sought by the operating surgeon and that desired by the diagnostic neuroradiologist are not identical. It is very possible and indeed likely that deployment of a diagnostic quality imaging modality into the operating room will not be the optimal approach to the surgical need driving this development.

For purposes of accounting for brain displacement and deformation, diagnostic quality imaging is not essential, and less experience, more easily acquired sparse data□such as intraoperative ultrasound and the optical image of the operating microscope-will enable through computational modeling one to update the image-guidance data-base (22). The current experience confirms the feasibility of this approach.

Whether or not such an approach will function satisfactorily to account for other intraoperative change remains to be determined. Modeling of tissue resection, including tumor removal, has been accomplished, but it is not clear that such complex processes or such critical issues as whether or not residual tumor is still present will be efficiently or reliably addressed by this strategy.

Ultimately there may well be a role for sparse-data-driven computational modeling regardless of the actual imaging modality integrated into the operating room environment. Specifications of an intraoperative CT or MRI that takes advantage of computational modeling can be optimally designed to fill the surgical need and meet the constraints of the surgical environment. Such an approach may enable equipment such as Odin's PoleStar intraoperative MRI, currently criticized for its poorer image quality, to generate better-suited graphical assistance.

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CRANIAL NEURONAVIGATION WITH VECTOR VISION2®: A BELATED, BUT PROMISING EXPERIENCE

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ABSTRACT

The authors report on their initial experience with the cranial neuronavigation system. In the 9 month period since its introduction in clinical practice 78 patients (49 intracranial tumors, 18 pituitary adenomas, 3 AVMs, and 8 endoscopic procedures) have been operated on using image guidance. The initial results concerning accuracy, reliability and usefulness are discussed in comparison with recently published data from other institutions.

Key words: *image guided surgery, minimally invasive neurosurgery, intracranial tumors.*

КРАНИАЛНА НЕВРОНАВИГАЦИЯ С VECTOR VISION2®: ЗАКЪСНЯЛ, НО ОБНАДЕЖДАВАЩ ОПИТ

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РЕЗЮМЕ

Авторите представят резултатите си от първоначалния си опит със системата за краниална невронавигация VectorVision2® на фирма BrainLAB. От въвеждането ú в клиничната практика на клиниката по неврохирургия на УМБАЛ „Александровска" на 19.03.03 до края на същата година с помощта на навигация са оперирани 78 пациента (49 с интракраниални тумори, 18 хипофизни аденома, 3 артериовенозни малформации и 8 ендоскопски процедури). Обсъжда се началния опит по отношение полза, точност и надежност на системата в сравнение с наскоро публикувани резултати на други автори.

Ключови думи: *образно водена хирургия, минимално инвазивна неврохирургия, интракраниални лезии.*

INTRODUCTION

Frameless stereotactic systems have been introduced in the 1980s by Roberts et al (1). Over the next two decades image guided methodology has gained widespread acceptance, and today in most academic centers the navigation system is already considered a standart component of the neurosurgical armamentarium (2,3). They are episodic publications in the Bulgarian neurosurgical literature on intraoperative neuronavigation (4), it's real introduction in our country however, was only recently. The first neurosurgical procedure with the aid of an image guidance system was done March 19, 2003 at the Department of Neurosurgery, University Hospital „Alexandrovska", Sofia. The authors report on their initial experience with the navigation system.

METHOD

At the Neurosurgical Clinic, University Hospital „Alexandrovska", Sofia the basic configuration for cranial neuronavigation of the navigation system VectorVision2® (BrainLAB, Heimstetten, Germany) was used. The preoperative image sets were acquired using two standard protocols - for CT (22 pts.) or MR- based navigation. The sets for MR-based navigation consisted of T1 weighted axial images with a slice thickness of 1,6 mm, 0 mm slice interval and a number of slices between 160 and 280, obtained on a 1.5T MR scanner GE Signa at the Radiology Department, Clinical Hospital „Losenetz". For CT-based navigation image sets with a slice thickness 2 or 3 mm (btw 20 and 40 slices) from the Siemens SIRETOM CT-scanner at the Neurosurgical Clinic of University Hospital „Alexandrovska" were obtained and stored on optical disk. The image sets were then transferred to the workstation for planning the navigation, fusion of different modalities (MRI with MRA in 4 cases or CT in one case), setting registration points, targets and trajectories, as well as for segmentation of the lesion and vascular structures. The prepared data was then transferred to the navigation station for implementation of the actual intraoperative neuronavigation. The reconstructed data sets were co-registered in the operating room with the patient's head using either the Z-touch® infrared markerless registration or preoperatively identified anatomical landmarks (in 5 patients), aiming at an calculated accuracy of 2 mm or less. The standart scalp fiducials for imaging and preoperataive registration were employed only in our first case. The BrainLAB passive marker instrument adapter clamp was easily attached to the standart neurosurgical instruments (for instance the bayonett forceps), allowing for their tracking and navigation use as a pointer throughout the procedure. Intraoperatively the working instruments (endoscope, forceps, pointer) were calibrated by touching their tip to the center of the star-shaped reference tool or by using the available calibration matrix.

Table 1. Patient distribution according to pathology and procedure

Patient population in the series		
Supratentorial hemispherial tumors		
	Glioma	23
	Metastasis	7
	Cavernoma	3
	Meningeoma	2
Paraventricular tumors		5
AV malformations		3
Infratentorial tumors		
	Astrocytoma	2
	Epidermoids	2
	Metastasis	1
Transsphenoidal surgery		
	Pituitary adenomas	18
Cranial base tumors		
	Meningeoma	2
	Craniopharyngeoma	1
	Chordoma	1
Neuroendoscopy		
	ETV for aqueductal stenosis	5
	Cystic lesions	3
Total		78

PATIENT POPULATION

Since the introduction of neuronavigation on March 19, 2003 til the end of the same year 78 image-guided neurosurgical procedures were performed. The patient population included 35 patients with supratentorial tumors (23 patients with glioma, 7 metastases, 3 cavernomas and 2 meningeomas), 5 cases with paraventricular glial tumors, 5 patients with posterior fossa tumors (2 astrocytoma, 2 epidermoids and 1 metastasis), 18 patiens with transsphenoidal surgery for pituitary adenomas, 8 patients who underwent endoscopic surgery (5 for hydrocephalus secondary to aqueductal stenosis and 3 for cystic lesions), 3 patients who harboured AVM, and 4 with tumors of the cranial base **(tab. 1)**.

RESULTS

Intraoperative registration failed in only one patient due to technical reasons. In all remaining cases registration was achieved with a mean mathematically calculated accuracy of 1,8 mm (range between 0,7 and 4,9 mm) (Table 2). The predicted accuracy for Z-touch® registration was 1,7 mm (0,7-3,3 mm) versus 3,4 mm (2,1-4,9 mm) for landmark registration. The mean registration time was 6,4 min (0,8-32,0 min) with times of 6,5 min (0,8-32,0 min) for Z-touch® and 5,0 min (2,9-14,3) for landmark registration. The number of registration attempts made until satisfactory accuracy was achieved was on average 2,9 (1-22) and 3,0 (1-22) for Z-touch®, respectively 1,6 (1-2) for landmark registration.

Intraoperatively, the navigation system demonstrated a good correlation between the predicted and actual position of the navigation instruments. The potential brain-shift was taken into account by the positioning of the patient so that the direction and magnitude of the shift could be at least partially reduced. In two cases however, navigation had to be abandoned because of an unacceptable discrepancy between the intraoperative location of the pointer and its position on the navigation screen, which occured not as a result of brain shifting.

No difference was noted in the accuracy and usefulness depending on whether T1- weighted MR or CT - images were used for navigation. Both modalities lacked accuracy in distinguishing brain edema from tumor when used alone without referring to other imaging modalities but displayed good anatomical detail helpful for orientation. T2-weighted images were not used for navigation because of the longer time needed for acquisition and worse anatomical detail.

Table 2. Registration parameters

Accuracy (mm)	Registration time (min)			No of attempts		
	mean	range	mean	range	mean	range
For the series	1,8	0,7-4,9	6,4	0,8-32,0	2,9	1-22
Z-touch	1,7	0,7-3,3	6,5	0,8-32,0	3,0	1-22
landmark	3,4	2,1-4,9	5,0	2,9-14,3	1,6	1-2

DISCUSSION

In the last years, many publications address different aspects of the application of neuronavigation in clinical practice. Our initial results do not differ significantly from the results published by other authors. The registration accuracy was found to be comparable with the results of Steinmeier et al, (5) and Reinges et al, (6,7). In our series, we used natural anatomical landmarks for registration with acceptable accuracy not differing much from the result of Wolfsberger et al, (8). The decrease in accuracy with the increase (beyond 5) of the number of points used for registration noted by Abbasi et al, (9) was also found in our experience. The mean prolongation of operation time caused by the use of neuronavigation (and not only due to the registration process) was similar to that reported by other authors (16). The difference noted by Schlaier et al, (10) between the Z-touch® and landmark registration (laser registration being slower) is also in accordance with our experience. However, we did not find Z-touch registration to be less accurate. Finally, the positioning of the patient was found to be important in one case, where rotation of the operating table led to a situation when the pointer located on a midline structure was displayed several centimetres to the side of the patient's head - something we didn't find described in the literature and in discordance with other author's experience (11).

In our experience, the greatest benefit from frameless stereotaxy was in treating surgically subcortical or deep-seated lesions in eloquent brain areas. In such cases, neuronavigation allowed first, a precise positioning and minimization of the craniotomy, and second - a better (although still statistically unproven) outcome regarding postoperative morbidity and length of hospital stay (12-14). Due to the small series, the latter statement needs to be proven statistically in the future. In 3 cases with hemispheric cavernous angiomas with no reliable brain surface clues as to the precise location of the underlying pathology, a better surgeon's orientation was achieved with the aid of image guidance. As a result, unnecessary dissection and brain trauma were avoided (15, 16). The extent of resection in smaller low grade gliomas was also increased (11). As Benveniste and Germano, 2003 (17) stated, frameless stereotactic techniques can be reliably used for accurate resection of high-grade gliomas only when the tumor is less than 30 ml in volume and not adjacent to the ventricular system. In larger and paraventricular tumors where a significant intraoperative brain shift is inevitable, intraoperative ultrasonography or MRI updates should be considered.

The use of navigation in 3 cases with AVM surgery allowed early identification of feeding arteries. The recognition of the exact size and location of the nidus allowed to use tailored craniotomies instead of the wide craniotomies traditionally used in this type of surgery (18,19).

In the subgroup with endoscopic procedures neuronavigation was not found essential in cases with uncomplicated third ventriculostomy, which comprised the majority of cases. In cases where anatomical orientation was difficult however, image guidance was undoubtedly helpful. One example is the cytsoventriculostomy, where identification of the best position of the stoma would be impossible without making several attempts with possible trauma to brain tissue. On the other side, in cases with intraoperative bleeding where the blood impeded clear endoscopic view, navigation was helpful to the surgeon to stay oriented within the ventricular system. These results are in accordance with the views of other authors regarding the application of navigation to endoscopy (20-22).

In transsphenoidal technique, the use of image guidance obviated the need for fluoroscopy and allowed for safer approach and better appreciation of the extent of tumor removal. The use of image fusion of different modalities (MR and CT) provided better identification of osseous and soft tissue structures which would be impossible with the use of a single imaging modality (23).

CONCLUSIONS

Our initial experience shows that neuronavigation is a valuable and reliable tool in everyday clinical practice. Further enhancements of its applicability may lay in the use of computational modeling of the brain and intraoperatively acquired sparse data to update the image-guidance database (24) or in intraoperative imaging to compensate for the brain shift (25). The use of functional imaging modalities (26) may allow to better delineate the eloquent brain areas and pathways and increase the safety and radicality of glioma surgery.

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ENDOSCOPY AND NEURONAVIGATION FOR THE MANAGEMENT OF HYDROCEPHALUS, VENTRICULAR TUMORS AND INTRACRANIAL CYSTS: PERSONAL EXPERIENCE IN 81 CASES

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ABSTRACT

Objective: In occlusive hydrocephalus, intracranial cysts and ventricular tumors, endoscopic procedures are an accepted and, in parts, preferred alternative to shunt placement and microsurgery. There is an ongoing discussion, if neuronavigation could be of value during neuroendoscopy. In the present series, the usefulness of neuronavigation during endoscopy was investigated.

Method: In 85 consecutive endoscopic procedures (endoscopic third ventriculostomy (ETV) n=52, biopsy/resection of intra- or periventricular tumor n=18, cyst fenestration in tumorous and non-tumorous cystic lesions n=15) neuronavigation was provided. After surgery, the usefulness of neuronavigation for a safe and efficient endoscopic operation was evaluated.

Results: The usefulness of neuronavigation depends on the type of endoscopic procedure. In 37 of 52 ETVs (71%), in 4 of 18 operations for intra/periventricular tumors (22%) and in none of the endoscopic cystostomies, neuronavigation was considered to be dispensable. In the remaining operations, neuronavigation was helpful for the surgeon.

Conclusion: In the majority of ETVs, neuronavigation is not beneficial. If time restrictions and limited human ressources are of importance, it is justified to perform ETV without navigational help. In the remaining endoscopic procedures however, the authors strongly suggest to apply neuronavigation as it might contribute to higher safety and efficacy.

Key words: *neuroendoscopy, neuronavigation, third ventriculostomy*

ЕНДОСКОПИЯ И НЕВРОНАВИГАЦИЯ ПРИ ТРЕТИРАНЕТО НА ВЪТРЕШНА ХИДРОЦЕФАЛИЯ, ВЕНТРИКУЛНИ ТУМОРИ И ИНТРАКРАНИАЛНИ КИСТИ: ЛИЧЕН ОПИТ С 81 СЛУЧАЯ

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РЕЗЮМЕ

Цел: При оклузивна хидроцефалия, интракраниални кисти и вентрикулни тумори ендоскопските процедури са утвърдена и отчасти предпочитана алтернатива на поставянето на шънт и конвенционалната микрохирургия. Все още е спорно доколко използването на невронавигация по време на ендоскопия има някаква стойност. В настоящата серия се проучва ползата от невронавигация при ендоскопски процедури.

Метод: Осемдесет и пет последователни ендоскопски интервенции (ендоскопска трета вентрикулостомия (ЕТВ) n=52, биопсия/резекция на интра/перивентрикулни тумори n=18, фенестрация на туморни и нетуморни кисти n=15) бяха извършени с навигационна асистенция.

Следоперативно беше анализирана ролята на невронавигацията за сигурността и ефективността на ендоскопската интервенция.

Резултати: Ползата от невронавигацията зависи от типа ендоскопска интервенция. Като излишна беше преценена невронавигацията при 37 от 52 ЕТВ (71%), при 4 от 18 операции (22%) на интра/перивентрикулни тумори и при нито една от ендоскопските цистостомии. В останалите случаи навигацията беше от полза за хирурга.

Изводи: В болшинството от ЕТВ невронавигацията не беше от полза. Поради това считаме, че ако има ограничения от страна на време и персонал, извършването на ЕТВ без навигация е оправдано. В останалите ендоскопски процедури обаче авторите препоръчват прилагането на невронавигация, която би допринесла за по-висока хирургическа сигурност и ефикасност.

Ключови думи: *невроендоскопия, невронавигация, трета вентрикулостомия*

INTRODUCTION

Today, endosocopy is an accepted tool in the management of occlusive hydrocephalus and intracranial cysts (4,5,16). For intra- and periventricular tumors, endoscopic techniques are gaining increasing acceptance. Especially pineal region tumors and colloid cysts are attacked endoscopically with sucess (1,11,12). Often, these endoscopic operation are performed as free-hand procedures, with the risk to damage vital neurovascular structures and to loose orientation in cases without clear anatomical landmarks. Stimulated by reports on severe surgical complications in free-hand operations (7,15,17), endoscopy was combined with framebased and, more recently, with frameless stereotaxy to enhance safety and efficacy (3,9,13). There is an ongoing debate, if neuronavigation should be routinely used in neuroendoscopy, or if the decision for or against neuronavigation should be made individually on the base of preoperative imaging. After having performed 85 consecutive neuronavigationally guided endoscopic procedures, the authors want to evaluate the usefulness of neuronavigation in endoscopic intracranial surgery.

PATIENTS AND METHODS

Patients

Between January 1997 and April 2003, 81 patients underwent 85 endoscopic procedures in combination with neuronavigation. There were 42 men and 39 women, the age ranged between 0.3 and 77 years. In most patients, diagnosis was made by magnetic resonance (MR) imaging. Occlusive hydrocephalus was diagnosed in 44, communicating hydrocephalus in 4, intra- and periventricular tumor in 18, symptomatic tumor cyst in 3, and CSF-filled cysts (arachnoidal cyst, polycystic hydrocephalus) in 9 patients. In 2 patients, the cause of hydrocephalus remained unknown. In 1 patient, a posttraumatic abscess in the interhemispheric fissure was diagnosed **(table 1)**.

Table 1. Preoperative data in 81 patients

Age (years) at surgery	range	0.3 - 77
	mean	34
Male / female		42 / 39
Diagnosis	Occlusive hydrocephalus	44
	Communicating hydrocephalus	4
	Hydrocephalus unknown origin	2
	Intraventricular tumor	7
	Periventricular tumor	11
	Tumor cyst 3	
	Arachnoidal cyst	4
	Intraventricular cyst / polycystic hydrocephalus	5
	abscess	1
Procedure	ETV	52
	ETV + biopsy	6
	ETV + biospy + septostomy	1
	biopsy + septostomy	3
	biopsy + cystostomy	2
	biopsy	4
	tumor resection	2
	ventrikulocystostomy	14
	abscess aspiration	1
	total	85

Neuronavigation

Before surgery, T1-weighted gradient echo MR images (TE 4.5 ms, TR 30 ms, flip angle 30°, field of view 240 mm, scan matrix

256 x 256, slice thickness 3 mm) with external scalp fixed fiducials for image-guidance during endoscopy were acquired. This imaging was performed on a 0.5 T or a 1.5 T system (Gyroscan ACS NT, Philips Medical Systems, Best, The Netherlands). The MR set was used as source for neuronavigation. For neuronavigation either the EasyGuide Neuro™ (Philips Medical Systems, Best, The Netherlands), or the Stealth Station™ (Medtronic SNT, USA) were used. Both are infrared based neuronavigational devices, which consist of a mobile workstation, an optical localizing system with two infrared-sensitive cameras and pointers with three light-emitting diodes. The EasyGuide Neuro™ allows to elongate the pointer virtually, whereas the Stealth Station™ enables the surgeon to plan the operative path to the target. Attachment of infrared light-emitting diodes to the rigid endoscope itself is possible with both neuronavigational devices, but was not routinely used. Immediately before surgery, the imaging data were transferred to the workstation of the neuronavigation system for reconstruction of an individual 3-dimensional model of the patient‘s head and brain.

Surgery

All procedures were performed under general anaesthesia with the head rigidly fixed. The coordinates of the reconstructed 3-dimensional model of the patient‘s head and brain were correlated with the head position by touching the skin fiducials on the patients head. Before draping, the burr hole site and the optimum straight trajectory to the target area were selected by virtual pointer elongation (EasyGuide Neuro™) or by path preplanning (Stealth Station™). After skin incision, burr hole trephination and dura opening, a self-developed articulated arm with a guiding tube for both the neuronavigational pointer and the endoscope was brought in place, adjusted and fixed according to the preselected trajectory (8). The rigid endoscope (Aesculap AG, Tuttlingen, Germany) was introduced into the guiding tube and slowly advanced along the preselected trajectory under direct visualization. Only in selected cases with target areas not accessable on a straight trajectory or with substantially distorted anatomy, infrared light-emitting diodes were attached to the rigid endoscope for intraoperative navigation with the endoscope tip. At target, ETV, cyst fenestration, biopsy or partial tumor resection were performed.

Evaluation

Immediately after surgery, the surgeon (VR) evaluated if the availability of neuronavigation was helpful (higher level of confidence during the surgical procedure, identification of non-visible structures at risk, completion of surgery despite lacking anatomical landmarks and/or poor endoscopic view) or dispensable. In selected cases, the video tapes of the operation were reviewed for final evaluation.

RESULTS

ETV

The first author performed 52 ETVs in 50 hydrocephalic patients. ETV was successful in 36 patients (72 %) (mean follow-up period 1.1 years). The mortality and permanent morbidity rate were 0 %. In 38 ETVs with normal endoscopic anatomy (73.1 %), neuronavigation was not required. In 14 ETVs, the surgeon appreciated the availability of neuronavigation either for puncture of a small lateral ventricle (n=1), determination of the optimal trajectory through a small foramen of Monro (n=2), and perforation of an opaque, thick tuber cinereum without visualisation of the basilar artery (n=10) **(Fig. 1)**. In one patient with a non-ruptured giant basilar tip aneurysm and occlusive hydrocephalus, the use of neuronavigation was essential for safe perforation of the third ventricular floor **(Fig. 2)**.

Tumor biopsy, tumor resection

In 17 patients with intra- and periventricular tumors, a biopsy was performed. This procedure was combined with either ETV or septostomy in 4 patients with tumor-associated blockage of the cerebrospinal fluid (CSF) pathways. Sufficient tumor tissue for histopathological diagnosis was obtained in all patients. In 1 patient, a colloid cyst was resected. Neuronavigation was not required in 4 of the 18 patients (22 %). In the remaining 14 patients (68 %), neuronavigation helped to localise the tumor **(Fig. 3)**, to open intratumoral cysts to the ventricular system, and to select the site of septostomy.

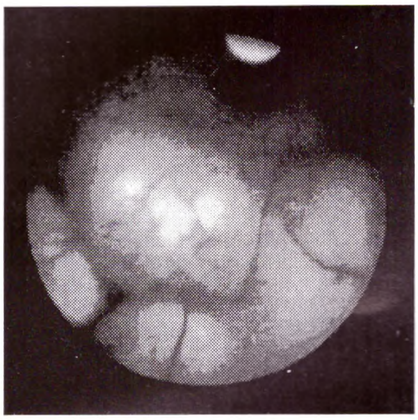

Figure 1. Endoscopic view of the third ventricular floor in a patients with occlusive hydrocephalus. The mamillary bodies are clearily visible. The bulging, thick and opaque third ventricular floor does not allow to localize the basilar artery prior to puncture. Neuronavigation was helpful to select a puncture site in safe distance to the basilar artery.

(See color appendix)

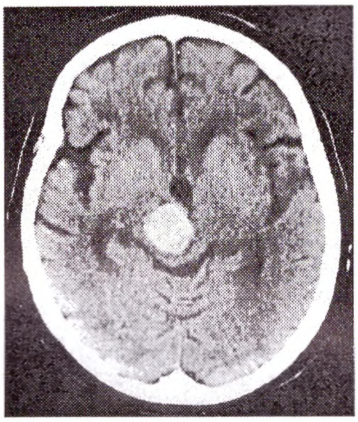

Figure 2. Computerized tomography scan of a 67-year old female patient with obstructive hydrocephlalus due to a giant non-ruptured basilar tip aneurysm. Neuronavigation was essential for opening the third ventricular floor in close vicinity to the basilar tip aneurysm.

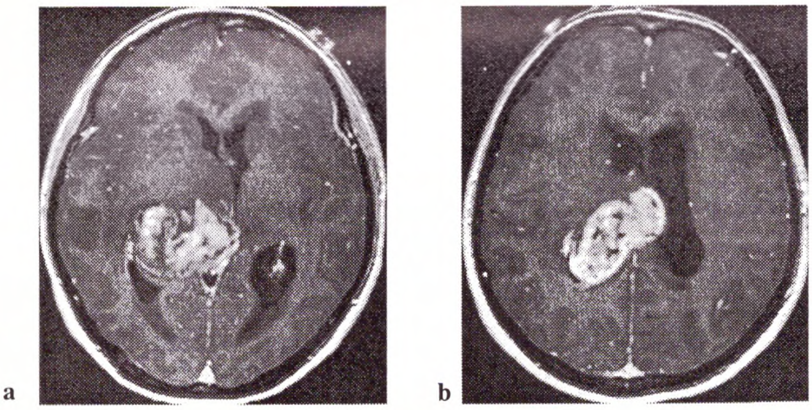

Figure. 3a, b. Magnetic resonance images of a 33-year old female with a malignant tumor in the right thalamus and a hydrocephalus. Tumor biopsy and restoration of the CSF flow were the aims of the endoscpic procedure. Because of a partly obstructed right foramen of Monro, left-sided ETV was performed and the tumor was approached transseptally. Neuronavigation was essential for transseptal biosy.

Cyst fenestration

Fenestration of tumorous and non-tumorous cysts to the basal cistern or the ventricular system was successfully performed in 14 patients. Cyst refilling in 1 patient and secondary cyst enlargement in 2 children with polycystic hydrocephalus later required a second operation. A post-traumatic abscess in the interhemispheric fissure was endoscopically opened to the lateral ventricle (**Fig. 4**). Neuronavigation was beneficial in each operation.

DISCUSSION

Initiated by the pioneering work of Watanabe et al. (19) and Roberts et al., (10) several frameless stereotactic localizing systems (neuronavigation) have been developed in the recent years, and are routinely used today. Rhoten et al. (9) and Rohde et al. (13) were the first, who linked neuronavigation with the endoscope during intracranial operations. Both hypothesized that safety and efficacy of neuroendoscopic procedures could be enhanced by adding frameless stereotaxy. They believed that: 1) selection of burr hole site and trajectory before penetrating cortex and white matter reduces endoscope movements during the procedure; 2) lack of anatomical landmarks as well as poor sight could be compensated by neuronavigation; 3) structures not visible endoscopically could be localized. The suggestion was made to use neuronavigation routinely during endoscopic operations.

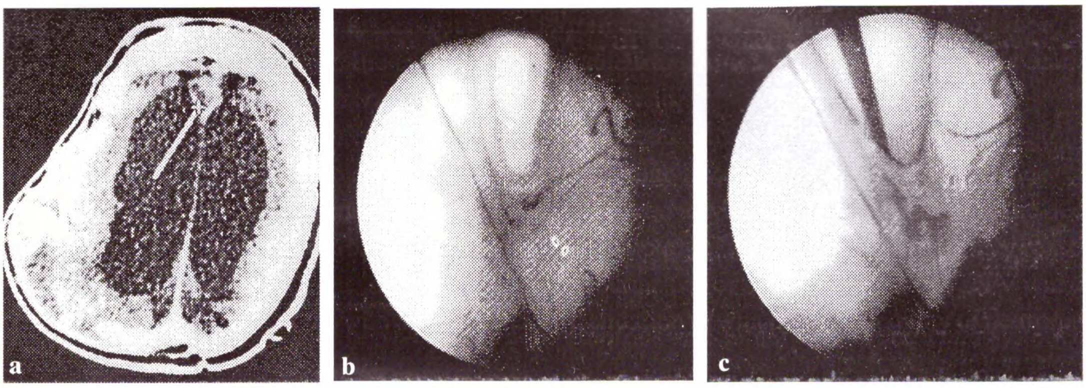

Fig. 4a,b,c. Computerized tomography scan axial with the neuronavigationally displayed tip of the endoscope (a) in a 25-year old patient with a post-traumatic abscess in the interhemispheric fissure. Endoscopically, the anteromedial ventricular wall was perforated (b) and the abscess was aspirated (c). For puncture of the small abscess, neuronavigation was required. *(See color appendix)*

This point of view was not generally shared. The major argument against was, that neuronavigation is time-consuming, requires additional imaging and is often not necessary in standard endoscopic procedures because of adequate visual control and orientation (18). It was proposed to limit application of neuronavigation to selected cases.

This ongoing debate stimulated the initiation of this prospective study. Since 1997, every intracranial neuroendoscopic operation was combined with neuronavigation at the authors institution. After surgery, the role of frameless stereotaxy was evaluated. This evaluation was based on the impression of the surgeon, because of the scarcity of clearly defined criteria of useful- and uselessness of a surgical tool. This methodological problem is shared by many recent studies on new technologies in microneurosurgery (6).

In the authors series, neuronavigation was not needed in 71 % of ETVs. In these cases, the hydrocephalic ventricular system allowed safe puncture of the lateral ventricle and early identification of structures leading to the floor of the third ventricle, which was translucent and allowed visualisation of the basilar artery prior to puncture. In 13 cases however, neuronavigation was useful during ETV. In the majority of these patients, the third ventricular floor was not translucent and did not allow to identify the basilar artery. Neuronavigationally, a stoma site in safe distance to the basilar artery could be selected by the surgeon. Some authors propose to abandon ETV in cases of an opaque third ventricular floor to avoid damage of the basilar artery (2). Our results indicate that the neurosurgeon can proceed safely with ETV even in patients with opaque third ventricular floor if neuronavigation is available. In the remaining 3 cases, neuronavigation helped to puncture small lateral ventricles and to advance the endoscope through a small foramen of Monro. Without neuronavigation, repeated attempts of ventricular puncture, and the use of a less suitable trajectories with the risk of fornix damage and endosocope movement in the brain for trajectory correction impend.

Preoperative MR imaging allows identification of a small ventricular system and interventricular foramen, but fails to detect thickening and opacity of the third ventricular floor, which are by far the most common variations of the normal endoscopic anatomy (14). Thus, preoperative MR imaging cannot guide the decision of the neurosurgeon whether or not neuronavigation should accompany ETV for safety and efficacy reasons. The neurosurgeon has to keep in mind, that the decision against routine use of neuronavigation in ETV will confront him in more than a fifth of the patients with an intraoperative situation in which the availability of neuronavigation could be desirable.

Neuronavigation was beneficial in 68 % of tumor biopsies and tumor resections. Neuronavigation allowed orientation in patients with distorted anatomy due to tumor growth, and safe opening of obstructed cerebrospinal fluid pathways either by tumor removal, by ETV or septostomy. Some of the tumors have not been endoscopically visible on the ventricular surface because of subependymal tumor spread. In these cases, neuronavigation was essential to select this biopsy site, which allows to harvest typical tumor tissue. Based on our experiences, the authors recommend to use neuronavigation routinely in intra- and periventricular tumor cases.

In all endoscopic fenestrations of tumorous and non-tumorous cysts either to the ventricular system or to the basal cisterns, neuronavigation was essential for a safe and successful completion of the operation. Especially the loss of anatomical landmarks in large cysts, and the need to use different trajectories to perforate one or more cysts explains why frameless stereotaxy was considered to be an indispensable tool. There were no suprasellar and no temporal arachnoidal cysts in the series, which possibly could be treated successfully without neuronavigational help (18).

In summary, in almost fifty percent of intracranial endoscopic procedures, neuronavigation was helpful for the surgeon. The application of neuronavigation allowed to define the best trajectory to the target, to proceed with the operation despite the lack of anatomical landmarks, to overcome problems of poor sight, and to identify hidden structures such as subependymal tumor tissue or the basilar artery beneath an opaque third ventricular floor. The authors assume that the safety of intracranial neuroendoscopic procedures is enhanced thereby. The proof of this assumption would require the conduction of a prospective randomized trial, which is not very likely to come. In the authors opinion, the optimum management of patients undergoing an intracranial endoscopic procedure includes the use of neuronavigation.

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NEURONAVIGATIONAL AND ENDOSCOPIC ASSISTANCE IN TRANSSPHENOIDAL PITUITARY ADENOMA SURGERY

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ABSTRACT

Nowadays, transsphenoidal approaches are characterized by the expanding use of minimally invasive techniques and instrumentation, but this requires improved intraoperative visualization and orientation. The aim of this study is to evaluate whether endoscopic assistance and neuronavigation can further improve safety and efficacy in difficult cases with transsphenoidal pituitary adenoma surgery. In our series, 18 patients have undergone transsphenoidal approach with the aid of frameless image guidance, and in 39 cases endoscopic assistance was utilized. Endoscopy and neuronavigation are in our experience promising and useful technical adjuncts to transsphenoidal pituitary surgery in reoperations and in difficult complex cases.

Key words: *pituitary adenoma, transsphenoidal surgery, neuroendoscopy, neuronavigation.*

НАВИГАЦИОННО И ЕНДОСКОПСКИ АСИСТИРАНА ТРАНССФЕНОИДАЛНА ХИРУРГИЯ НА ХИПОФИЗНИ АДЕНОМИ

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РЕЗЮМЕ

Съвременната транссфеноидална хирургия се характеризира с навлизането на минимално инвазивни методи и инструментация. Това налага подобряване на интраоперативното изобразяване и ориентация. Целта на настоящото проучване е да анализира доколко невронавигацията и ендоскопското асистиране могат да подобрят сигурността и ефикасността при трудни случаи с хипофизни аденоми, оперирани по транссфеноидален път. Проучването обхваща 18 случая, оперирани с невронавигация и 39 пациенти, при които сме използвали ендоскопска асистенция. Според първоначалния ни опит ендоскопията и невронавигацията са ценни допълнителни методи при транссфеноидална хирургия на трудни и рецидивни хипофизни тумори.

Ключови думи: *хипофизни аденоми, транссфеноидална хирургия, невроендоскопия, невронавигация.*

INTRODUCTION

Transsphenoidal pituitary surgery (TSPS) has come a long way since its introduction at the beginning of the last century. Although the transsphenoidal procedure was abandoned for decades because of unacceptable complication rates, in the last 30 years technical advances in microsurgery, instrumentation and intraoperative fluoroscopic control have led to its remarkable resurrection. The transsphenoidal approach, as we know it today, was introduced by Jules Hardy in the late 60s (1). Currently it is the preferred access route for the treatment of pituitary adenomas (PA) and other sellar lesions. Specialized centers with extensive experience have recently reported mortality rates between 0% and 1%, rendering the procedure reasonably safe and effective (2). Newly described extended modifications of the classic approach have been used to gain additional exposure of the skull base for lesions of the parasellar and clival regions (3,4).

Recent technological advances such as endoscope-assisted microsurgery and purely endoscopic transsphenoidal method (4-7), frameless stereotaxy (image guided neuronavigation) (8), transsellar color Doppler ultrasonography (9), and real-time intraoperative MRI (10) have been introduced to reduce morbidity rates while improving the effectiveness of the approach further.

We started applying the rigid endoscope as a complimentary tool during transphenoidal approach 4 years ago (11), and neuronavigational localization and guidance is utilized in this setting since March 2003. Our experience and opinions using these innovative surgical technologies in transsphenoidal surgery are presented.

ENDOSCOPE-ASSISTED TSPS

MATERIALS AND METHODS

Between June 2000 and October 2003 endoscopic assistance was used in 39 patients with PA (aged 20-59 years, 18 men and 21 women, 9 microadenomas and 30 macroadenomas), who underwent transsphenoidal surgery in our department; in half of the cases we applied the technique in re-operations for recurrent or residual invasive PA. Other 2 patients required detailed endoscopic inspection of the sphenoid sinus and the sella in order to determine precisely the site of the spontaneous cerebrospinal fluid fistula and to seal the defect.

In the beginning, we used 2 types of rigid endoscopes, having either a 0° viewing angle and 5 mm outer diameter, or a 30° angled endoscope with a 3 mm outer diameter (Smith-Nephew®, USA). In the last 1,5 year we made a transition to Aesculap® endoscope system, Tuttlingen, Germany - 30° angled Neuroscope (150 mm shaft length, 4 mm shaft diameter) and high resolution David 3 chip-camera. The endoscopic image was displayed continuously throughout the surgical procedure on the videoimaging system and images were stored for postoperative evaluation. The use of three-point pin fixation of the head was mandatoty. In the setting of endoscopy-assited TSPS we do not use the self-retaining endoscope holding system; instead, we guide the rigid endoscope with the non-dominant surgeons hand. In the very early stage of this study only we applied the holding system for endoscope fixation in position after its insertion through one nostril while performing bimanual microscopic manipulations through the other (4). This paradigm proved inconvenient for endoscopy-assited TSPS first, because of the need to continuously change the trajectory, angulation and rotation of the endoscope and second, because of the need to often withdraw the endoscope and clean the front optics from blood staining.

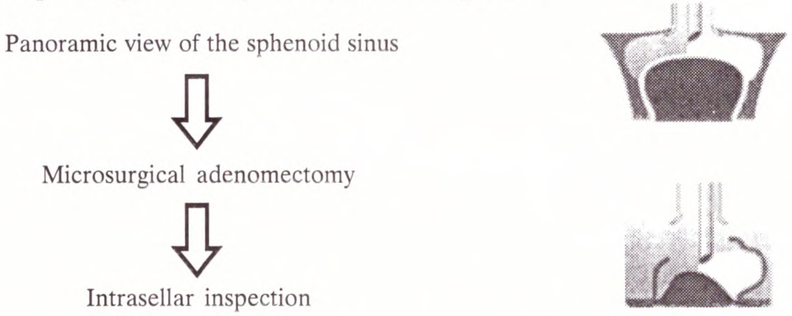
With endoscopy-assited TSPS the same patient positioning and instrumentation are used as in the standart microsurgical endonasal procedure.

RESULTS

There was no morbidity/mortality due to the intraoperative use of the rigid endoscope. The operation time in these cases was prolonged as a result of the endoscopic procedures within the range of 5-18 minutes, which is considered insignificant taking into account the potential advantages of the endoscopic assistance as related to enhanced surgical safety and effectiveness.

- ***Re-operations for recurrent and residual adenomas***

In these conditions the surgeon faces a distorted nasosphenoidal anatomy with extensive scarring and perforations of the septal mucosa, especially if at the time of the first operation a more extensive and traumatic septal dissection has been employed. During the endonasal stage of the approach endoscopic assitance is usually not necessary, since the nasal speculum separates the postoperative synechiae and one may find easily the already opened anterior sphenoidal sinus wall. During the sphenoidal sinus stage we are usually confronted with a significant sinus rearrangement and scarring. We found the introduction of the endoscope at this stage useful because it provided excellent panoramic view of the internal structure and various bony landmarks - the optic protuberances and planum sphenoidale, the carotid protuberances, the clivus and the distorted by the initial operation sellar floor with dural scarring **(Fig. 1)**. In our opinion, the possibilty to apply various viewing angles with endoscope helps preventing loss of midline orientation and a potential injury to the carotid artery, optic nerves and other parasellar structures. During the sellar phase of the operation the endoscope is used intermittently in the process of PA resection and at the completion of the excision for inspection of the sellar content. The 30° Aesculap® Surgiscope proved very useful in cases with lateral and suprasellar tumor remnants, which are impossible to visualize with the operating microscope solely („blind angle").



Fugure 1. Stages of the TSPS with a potentially usefull application of endoscopic assistance

- ***Initial operations for pituitary adenoma***

We found the endoscopic inspection of the PA bed and the sellar content especially helpful in 7 patients with macroadenomas, in which cases the technique allowed to observe hidden (superiorly and/or laterally) tumor remnants and following additional tumor removal to confirm the completeness of tumor resection; in 4 cases in this group a direct observation of the intact medial wall of the cavernous sinuses was made possible with endoscopic assistance. In another group of 9 patients the main advantage the technique offered was the possibilty to visualize the descensus of the suprasellar arachnoid membrane, as well as to localize precisely the site of a possible arachnoid laceration with even minor CSF leak, thus helping to more adequately accomplish the final repair of the sellar floor. In 3 patients with extensive arachnoid lacerations following radical PA resection the insertion of the endoscope provided an untraditional view from below of the optic nerves and chiasm, as well as of the anterior circle of Willis and the infundibular part of the 3rd ventricle.

In our opinion, endoscopic inspection of the sellar content has been useful only in larger tumors that provide after debulking enough space for insertion of the endoscope tip. In microadenomas however, this seems to be of lower usefulness due to the limited space available for the endoscope to be positioned within the sella and frequent staining of the tip of the lens with blood and moisture.

- ***Endoscopic sphenoidal sinus inspection in cases with CSF fistula***

In 2 patients with extremly pneumatized, thin-walled sphenoidal sinus and spontaneous CSF leak we found the use of the endoscope valuable to observe the lateral and inferolateral portions of sinus. This allowed us to localize the site of the bony and dural defect and consequently to successfully seal the CSF leak.

Frameless image guidance in transsphenoidal surgery

Materials and methods

During a 10-month period 8 men and 10 women whose ages ranged from 21 to 67 years (mean 43,7 years), underwent an image-guided transsphenoidal surgery. All patients presented with PA - 12 macro- and 6 microadenomas; in 7 of the cases the TSPS was performed because of a PA regrowth following a previous operation. The characteristics of the cases are described in Table 1. Clinical records were reviewed retrospectivelly with attention to the clinical features, reliabilty and usefulness of the navigational guidance.

Localization was accomplished based on MRI and/or CT imaging. CT scanning provides excellent visualization of the bony structures (sphenoidal sinus and sella confines), whereas MRI demonstrates precisely the adenoma and its relationship to important structures such as the cavernous sinus, carotid artery and optic apparatus.

In preoperative planning process, the PA volume and both carotid arteries were segmented in a MRI/CT-3D dataset (T_1-weighted, 3D FLASH after Gadolinium).

An optical infrared-based neuronavigation system (Vector Vision, BrainLAB®, Heimstetten, Germany) was used in all cases for frameless guidance. Intraoperative fluoroscopy was not applied. The patients head was fixed in a standard Mayfield clamp, and a modified head position with 45-degree head tilt (patient's chin toward the surgeon) was used. A star-shaped reference tool equipped with 3 passive reflective spheres was screwed to the Mayfield adapter clamp, which was fastened to not move in relation to the Mayfield headrest during surgery. After primary registration in non-sterile conditions the reference tool was removed, the patient was prepped and draped, and then a sterile star-shaped tool was reapplied to the fastener. A special pointer tool with two highly reflective markers as well as the Z-touch infrared device were used for markerless patient registration. The BrainLAB passive marker instrument adapter clamp was easily attached to the standart transsphenoidal instruments (for instance the bayonett forceps), allowing for their tracking and navigation use as a pointer throughout the procedure.

The intraoperative accuracy was checked every 30 min by touching with the optically guided instrument easily recognizable bony landmarks (sphenoidal rostrum).

RESULTS

The mean calculated accuracy of image guidance was 1,35+0,3 mm. In our whole series of 78 patients, operated on with image guidance for the 9-month period, mean registration time was 6,4 min (0,8-32,0 min) with times of 6,5 min (0,8-32,0 min) for Z-touch® and 5,0 min (2,9-14,3) for landmark registration. In none of the 18 cases with TSPS the use of the navigation system did interfere with standart surgical manipulations, neither any damage to perisellar key structures has been observed.

During the initial (endonasal) stage of TSPS navigation is used in lieu of a fluoroscopic C-arm to keep the proper trajectory to the sella turcica in lateral and rostrocaudal direction. We feel, that the modified patient's head position and microscope set-up for the assitant surgeon in conjunction with neuronavigation resulted in greater surgeon's comfort.

In the sphenoidal stage, image guidance was used to determine depth and trajectory of the approach, especially in patients where midline anatomical landmarks were obscured by tumor or previous surgery (7 cases). In cases with complex and misleading septal anatomy in the sphenoid sinus, as well in assymetrical or atypical sellar floor bulge, image guidance provided a fast and correct anatomical orientation, thus reducing the working area and allowing proper placement of the sellar osteotomy. The latter applies especially for the patients with conchal type of sella and microsella, where intraoperative visualization on the screen of the navigation station of preoperatively segmented perisellar key vascular and neural structures is important to avoid a deleterious carotid damage during instrumentation. Another occasion, where detailed anatomical knowledge of intracavernous structures is extremely important are transsphenoidal re-operations for recurrent and residual PA, in which cases the perisellar space is invaded and/or distorted.

During intrasellar instrumentation image guidance was helpful locating exactly microadenoma (**Fig 2a.**). In macroadenomas however, where in the process of tumor resection descensus of the sellar diaphragm or the intracranially buldging tumor capsule occurs, its localization reliability has to be questioned (**Fig. 2b**). To avoid spurious information in this situation, 0Barnett, 1999 (13) recommends updated visualization by means of injecting air intrathecally and following it in suprasellar position on lateral fluoroscopy to more relevantly show the relationship of instruments to the tumor outlines. In this respect, the interactive use of iMRI seems much more efficient for intraoperative resection control in large PA (14).

DISCUSSION AND CONCLUSIONS

Nowadays, transsphenoidal approaches are characterized by the expanding use of minimally invasive techniques and instrumentation, but this requires improved intraoperative visualization and orientation (8,13,16,21). In this report, we describe our early experience with modifications to the standard microsurgical TSPS with the

Table 1. Characteristics of 18 patients with image guided transsphenoidal surgery

Pt. Age, No Sex	Clinical Presentation	MRI findings	Indication for NN	Image database	Registr accuracy	NN utility
1 24, M	Prolactinoma, no remission	Macro right CSi	Re-operation, CSi	MRI &CT	1,51 mm	Midline orientation, avoid intraCS vascular structures
2 55, M	M. Cushing, insufficient remission	Micro micro sella	Re-operation, bleeding during initial surgery	MRI	1,13 mm	Avoid misdirection& vascular injury
3 21, M	Prolactinoma	Macro, right CSi	Re-operation, CSi	MRI	1,56 mm	Avoid misdirection
4 35, M	Acromegaly	Micro, excentric	Possible right CSi	MRI	1,69 mm	Avoid carotid injury
5 40, F	Acromegaly	Macro, suprasellar	Optic chiasm compression	MRI	1,24 mm	Midline orientation
6 62, F	NS, visual disturbances	Giant, para/suprasell.	Chiasm&CS encroachment	MRI	1,43 mm	Avoid carotid injury
7 48, F	Acromegaly, recurrence	Macro, parasellar	Re-operation, CSi	MRI	1,22 mm	Avoid misdirection
8 55, M	NS, visual disturbances	Macro, dumb-bell suprasell. extension	Firm tumor, omplex adenoma shape	MRI	1,17 mm	Better surgeon's orientation
9 27, M	Acromegaly	Macro, left CS growth	Possible left CSi	MRI	1,56 mm	Avoid carotid injury
10 67, F	NS, visual disturbances	Macro, para/suprasell.	Chiasm&CSi	MRI	1,13 mm	Midline orientation, avoid carotid injury
11 53, F	NS, visual disturbances	Macro, complex sph. sinius	Re-operation, (previuos transcranial)	CT	2,10 mm	Midline orientation, avoid vascular injury
12 35, F	Prolactinoma	Micro, CSi	Micro sella	MRI	1,14 mm	Midline orientation
13 40, F	Acromegaly, CSF leak	Micro, partial empty sella	Re-operation	MRI	1,19 mm	Midline orientation
14 40, F	Prolactinoma	Micro, CSi	Micro sella	MRI	1,44 mm	Midline orientation
15 57, F	NS, visual disturbances	Macro, residual firm adenoma	Re-operation	CT	1,34 mm	Avoid misdirection& vascular injury
16 48, M	Prolactinoma, visual disturb.	Macro, CSi	Chiasm compr., CSi	MRI & MRA	0,71 mm	Avoid CS carotid injury
17 29, F	Prolactinoma	Micro	Conchal type sella	CT	1,62 mm	Better surgeon's orientation
18 40, M	Acromegaly	Macro,CSi, suprasellar	Left CSi	MRI	1,23 mm	Avoid CS carotid injury

CSi = cavernous sinus invasion, NS = non-secreting

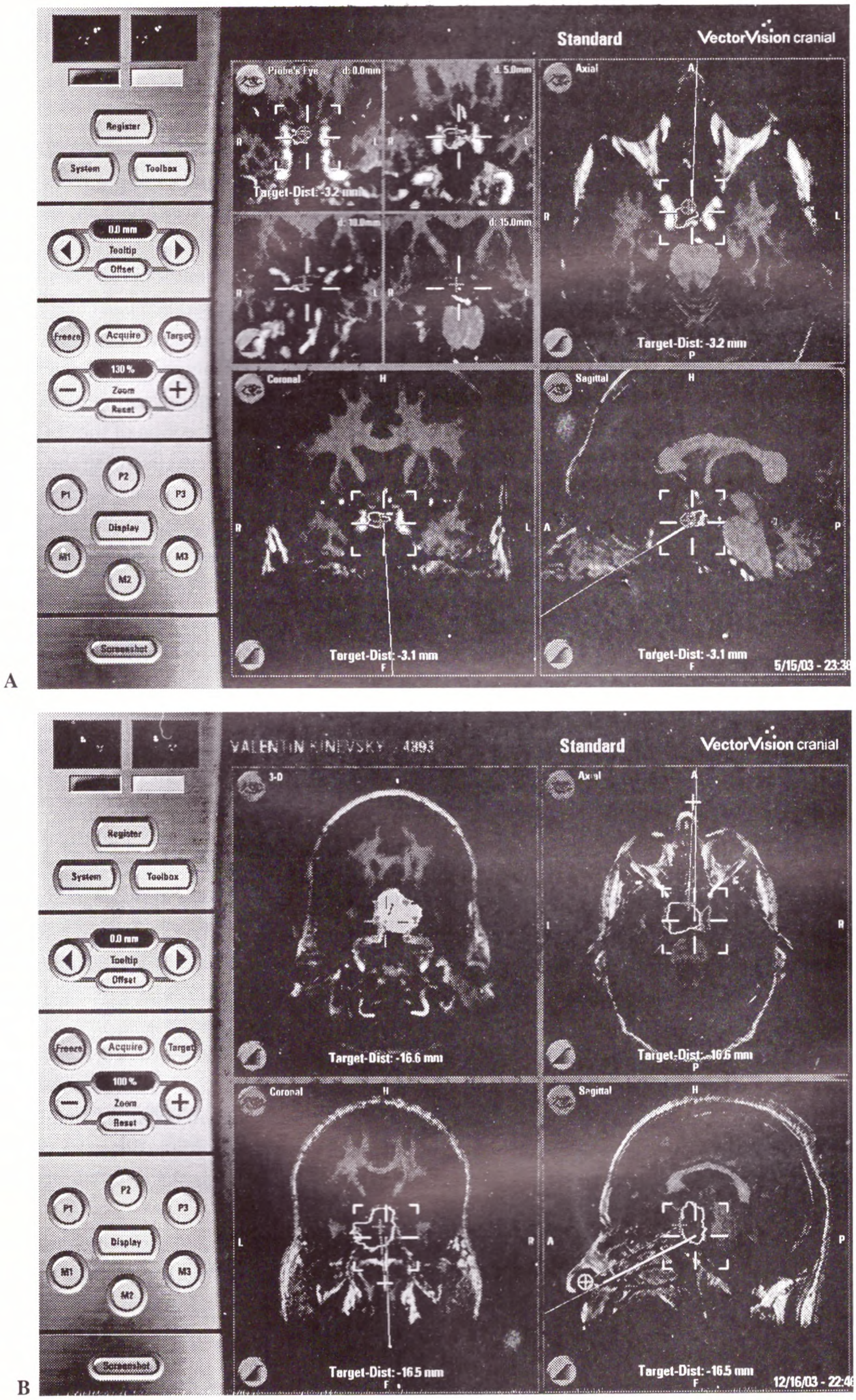


Figure 2. A typical snapshot display of the VectorVision system during surgery, while pointer has been placed on the structure of interest. Segmented PA and perisellar vascular structures; a - case No 4 with acromegaly and excentric microadenoma and b - case No 18 with acromegaly and macroadenoma with para/suprasellar extension.

(See color appendix)

use of endoscopic assistance and image guidance in selected cases with recurrent PA and in some complex cases of first-time pituitary surgery. We feel that each of both techniques further improves safety and efficacy of TSPS. The added bonus from the combined intraoperative use of frameless image guidance&endoscopy in TSPS has been recently also addressed (15,16).

Endoscopic (and endoscopy-assited) TSPS is a natural extension of the concept of endoscopic ENT surgery of paranasal sinuses, developed in the 19-20th century. In the 60ties of the last century the pioneers of modern TSPS J. Hardy and G. Guiot used the endoscope in selected cases for intrasellar observation, but technical imperfections prevented them from more frequent use of this method (17). K. Bushe and E. Halves reported in 1978 (18) for the first time in the German literature an endoscopy-guided transsphenoidal PA resection. In the next decades, not neurosurgeons but ENT surgeons proposed during TSPS the endoscopic inspection of the sellar content as a way to improve the extent of tumor resection (19,20). The widely utilized today direct endonasal approach is undoubtedly less invasive, but it has also some drawbacks - a very narrow surgical corridor, which is slightly off the midline. The use of an endoscope, with its major advantage of panoramic illumination and visualization of the anatomical structures through different viewing angles allows inspection of the „blind corner" of the surgical microscope. Our results show, that endoscopic assitance in TSPS seems useful in the sphenoidal stage of the approach in re-operations, where extensive scarring and loss of reliable bony landmarks can be encountered. In the sellar phase of TSPS endoscopy is warranted only in macroadenoma, in which cases it allows visualization of residual PA with lateral and/or suprasellar growth, as well as of a possible intraoperative arachnoid laceration. PA engaging the cavernous sinus tend to have poorer surgical and endocrinological outcome, and in these cases we hope that endoscopy will enable more efficient removal of tumor tissue.

Although in many routine cases of first-time pituitary surgery image guidance is not an absolute necessity, it certainly can be helpful in some occasions. First, it seems to us valuable to be able to study the specific anatomy in each individual case, to perform a detailed pre-operative planning and to customize the approach. Second, we found neuronavigation in TSPS to be extremely useful in that it provides continuous intraoperative three-dimensional information for localization, surgical trajectory and position of surgical instruments to the tumor or delicate anatomic structures. As a result, neuronavigation has replaced the use of a fluoroscopic control in TSPS, which is stated also in the literature (21-23). The system not only was accurate in identifying the boundaries of the sella, but frameless stereotaxy demonstrated its advantages over traditional fluoroscopic procedures in that it provided a virtual trajectory of the surgical instruments after registration and visualization of soft tissue and anatomical structures, thus decreasing the risk of inadvertent damage to vital parasellar structures (21). As many authors point out, inspite of the relative reliability of bony landmarks, in difficult cases major complications due to misdirected surgical approach are possible, and some of them can be disastrous (cranial nerve palcies, visual disturbances, temporal lobe and carotid artery injury) (2,13,16) . Similar to Kreutzer et al, 2002, (24) we found intraoperative visualization of perisellar vascular key structures very helpful in TSPS with narrow/asymetrical sella floor, in primary complex cavernous sinus anatomy and in re-operations without existing bony landmarks. In all cases we used the system, including the more difficult, image guidance warranted correctly directed midline approach and uncertainty about position and trajectory of our instruments was avoided. When working within the sellar content however, movements of the macroadenoma capsule compromize significantly the accuracy and reliabilty of the navigation system.

In conclusion, endoscopy and neuronavigation are in our experience promising and useful technical adjuncts to TSPS. Additional operative time requirements are minimal and added capabilities in respect to improved safety and effectiveness of transsphenoidal interventions seem worthwile. These new surgical techniques require careful and statistically significant evaluation of their cost-effectiveness and assessment as to whether they improve the overall patient outcome.

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PREOPERATIVE PLANNING FOR SURFACE BRAIN LESIONS USING SURFACE ANATOMY SCANNING (SAS) IMAGES

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ABSTRACT

After its initial introduction by Katada et al, 1989 a number of trials with SAS technique were conducted, attempting to establish the perimeter of its usefulness for preoperative planning in surface brain lesions. With its advantages and limitations, the technique was used for preoperative imaging in patients with superficial AVM's and supratentorial intra- and extraaxial tumours, especially metastases, as well as in assessment of gyral abnormalities, arachnoid cysts and focal brain atrophy.

With the present study, we are trying to compare the effectiveness of SAS-based image navigation with other methods of neuronavigation (namely CT-guided stereotaxy) in cases with extraaxial or superficial hemispheric lesions. Nine patients with extraaxial or superficial intraaxial lesions, as well as with superficial AVM's were included. MRI was performed with standard T2W, pre- and post contrast T1W images; TSE-based SAS images were obtained in all useful planes. The size of the lesion and its distance to a certain anatomic point (central sulcus or glabella, external acoustic passage or torcular) were measured, sometimes using a grid. The size of craniotomy, the duration of operation, the blood loss and the degree of permanent postoperative disability were taken for outcome criteria and were compared to those in lesions with similar type, size and location, localized with stereotaxy.

At this early phase of the study it appears that incorporation of SAS images in preoperative planning process results in reduced surgery duration and less invasive approach (smaller and properly positioned craniotomy, improved intraoperative orientation).

Key words: *Surface anatomy scanning, surface brain lesions, preoperative planning.*

ПРЕДОПЕРАТИВНО ПЛАНИРАНЕ ПРИ ПОВЪРХНОСТНИ МОЗЪЧНИ ЛЕЗИИ С ПОМОЩТА НА ПОВЪРХНОСТНО МОЗЪЧНО СКЕНИРАНЕ

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РЕЗЮМЕ

След въвеждането на скенирането на повърхностната мозъчна анатомия от Katada et al, 1989 техниката е изпробвана в редица проучвания, целящи да очертаят нейната полза за предоперативното планиране при повърхностни мозъчни лезии. Със своите предимства и недостатъци методиката е използвана при повърхностни артериовенозни малформации и супратенториални интра- и екстрааксиални мозъчни тумори, особено метастази, както и за предоперативна оценка на корови аномалии, арахноидни кисти и фокална мозъчна атрофия.

С настоящото проучване ние целим сравнителна оценка на повърхностното анатомично скениране с други невронавигационни методи (като КТ-базирана стереотаксия) при случаи с екстрааксиални или повърхностни хемисфериални процеси. В анализа са включени 9 пациенти с екстра/

интрааксиални тумори и повърхностни съдови малформации. ЯМР-изследване извършвахме със стандартни Т2 акцентуирани, както и с пре- и постконтрастни Т1 акцентуирани образи; TSE-базирани повърхностни анатомични образи бяха регистрирани във всички необходими проекции. Размера на лезията и нейното отстояние от определени анатомични репери (sulcus centralis, glabella, meatus acusticus externus, torcular Herophilii) бяха калкулирани, понякога с помощта на решетка. Размера на краниотомията, продължителността на операцията, размера на кръвозагубата и степента на трайния постоперативен неврологичен дефицит бяха използвани като критерии за оценка на изхода и бяха сравнявани с тези при лезии с подобен тип, размер и местоположение, локализирани с КТ-базирана рамкова стереотаксия.

На този ранен етап от проучването се очертава извода, че включването на повърхностно анатомично планиране в процеса на предоперативно планиране води до намалена продължителност на интервенцията и по-малко инвазивен достъп (по-малка и по-точно позиционирана краниотомия, подобрена интраопоеративна ориентация)

Ключови думи: *Повърхностно анатомично скениране, повърхностни мозъчни лезии, предоперативно планиране.*

Introduction and overview of the technique:

Surface anatomy scanning (SAS) was introduced by Katada et al. in 1989 (1, 2). It is a magnetic resonance imaging technique, which provides a 3-8 cm thick single slice heavily T2 weighed image, typically with grey scale inversion (3). Initially the sequences used were time-consuming spin-echo sequences and imaging times ranged 3-5 minutes (7). In the following years, technical developments allowed us to obtain such an image in less than a minute, using Turbo Spin Echo sequences with Half Fourier reconstruction (4) **(Figure 1).**

Other imaging techniques that may give heavily T2W images, i.e. Fast Field Echo and Inversion Recovery, were experimented with more or less unsatisfactory results **(Figure 2)**.

Nowadays, 2D TSE sequences with TR/TE 3000-5000/100-250, NSA 2-10, and Half Fourier Reconstruction and often with Spectral Saturation with Inversion Recovery (SPIR) are in use in some institutions and are commercially available on some MR scanners. The typical slice thickness is 3-5 mm, the matrix size is 512 or 1024 with rectangular FOV and the imaging times vary from several milliseconds to several seconds. T2W EPI sequences also are in use.

Compared with other MRI techniques that display the surface of the brain, for instance 3D imaging with volume rendering, SAS imaging has certain advantages. First, it requires no complicated software. Second, with some simple measurements, every point of the brain surface can be firmly related to a point at the cranium rather than to another point of that surface **(Figure 3)**. This makes it useful in surgical planning. Third, because of its high spatial resolution SAS imaging shows fine details of the brain surface and depicts even smaller lesions with very short imaging times.

Fourth, TSE based SAS images have inherited flow sensitivity, which may be important in planning surgery for AVM's (6) **(Figure 4).**

They are also some limitations of this technique: it is of no use in deep brain lesions, the demonstration of a lesion depends very strongly on the brain/lesion contrast on T2W images and the thin cortical layer that covers

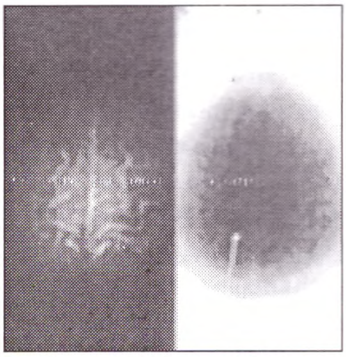

Fig.1

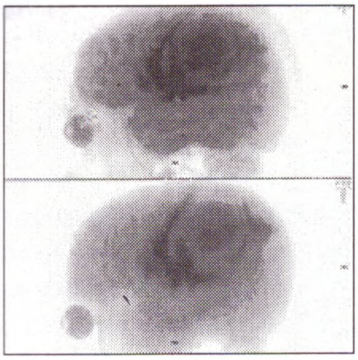

Fig.2

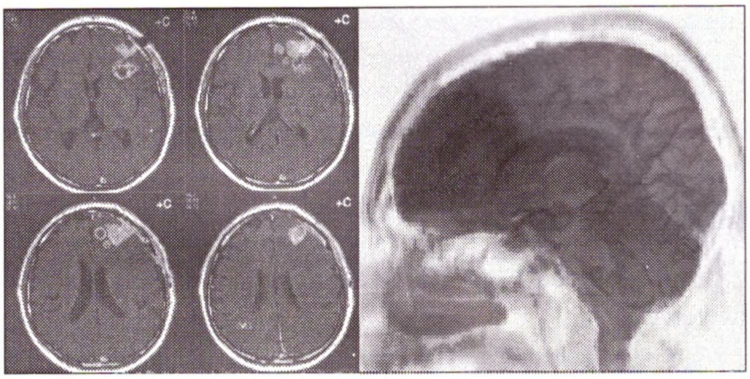

Fig. 3

the lesion will not be displayed. The brain surface cannot be covered in one image, so that the visualisation of a lesion depends on the selection of the proper imaging plane. Finally, because of the convex shape of certain lesion parts, some distances over that surface will be miscalculated. In a number of institutions, SAS images are used for surgical planning in superficial AVMs and circumscribed supratentorial intraaxial tumours, mainly metastases **(Figure 5)**. This technique was found useful for biopsy planning also in cases with supratentorial extraaxial tumours **(Figure 6)** and in patients with diffuse intraaxial tumours[5] **(Figure 7).**

The extent and chartacter of an epileptogenic gyral abnormality can be appreciated too. It is used also in some patients that are not surgical candidates - for assessment of focal brain atrophy.

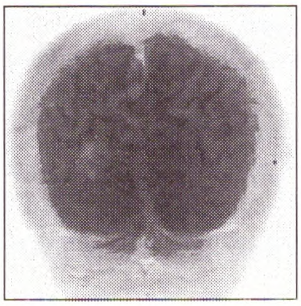

Fig. 4

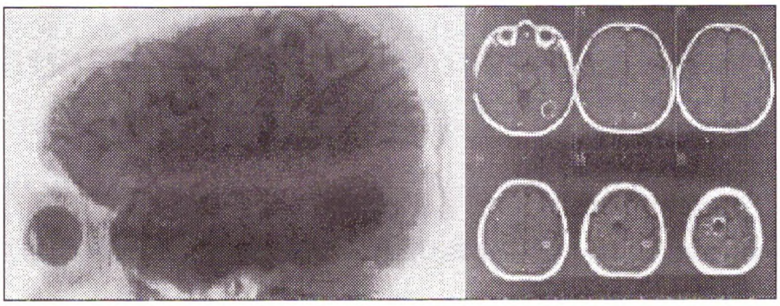

Fig. 5

Fig. 6

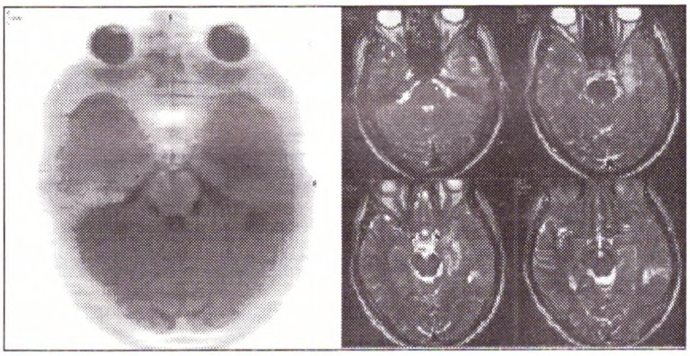

Fig. 7

MATERIAL AND METHOD

Our group is conducting a prospective study in order to evaluate the potential usefulness of SAS images as a primary source of information for preoperative planning in a broad spectrum of surface brain lesions. A surgical group of patients with superficial intraaxial tumours (both circumscribed and diffuse), extraaxial tumours and superficial AVM's is recruited in the Neurosurgical Clinic of University Hospital „Alexandrovska". Included in the study are patients with solitary or multiple lesions located not only over the convexity, but also on the basal or medial surface of the brain hemispheres. In every case, MRI is the source of information for surgical planning. The imaging protocol includes standard T2W, not enhanced and contrast enhanced T1W images, as well as TSE-based SAS images, obtained in all useful planes. On the latter, the size of the lesion and its distance to a certain point, „a start point" of the cranium or of the brain surface is measured **(Figure 8).**

The start points that we use are: the central sulcus, glabella, external acoustic passage or torcular. We perform these measurements with two lines, orientated at right angle; sometimes calliper or grid comes into use **(Figure 9).**

The site and the size of the craniotomy are chosen based on the results of the measurements in cases of convexity lesions. In basal and parasagital lesions, as well as in all AVM's we made this choice taking into consideration other factors too. The duration of the operation, the size of the craniotomy and the blood loss in every case are recorded and compared to available results in similar in type and size lesions, located with other methods, namely CT-guided stereotaxy. For AVM's no such records are available in our institution. We will compare also the size of an possible residual lesion on follow-up MRI examinations and the outcome of the operation, using EDSS at discharge and following visits.

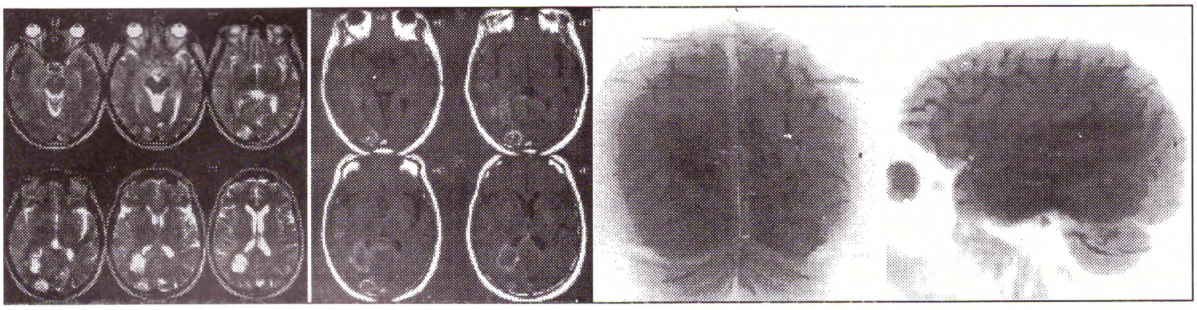

Fig. 8

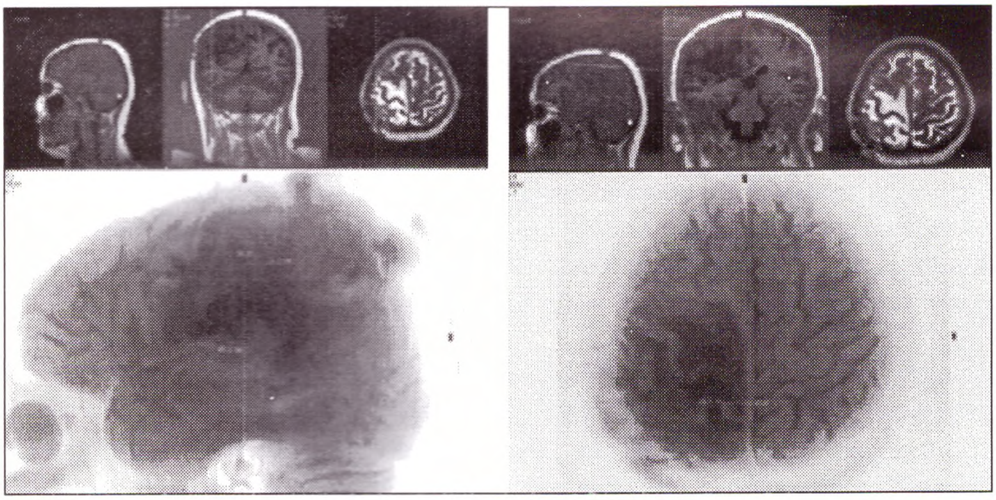

Fig. 9

COMMENT ON THE PRELIMINARY RESULTS

At a very early stage of this work in progress, only 9 patients are included in the study. Two of them have AVM's, three have convexity meningeomas, one - intrasylvian meningeoma and three - cortical or superficial subcortical metastases. The average size of meningeomas is 3,87 cm and of the metastases - 2,63. Though the material at this point is insufficient for statistics, it appears that incorporation of SAS images in the process of preoperative planning results in reduction of the size of craniotomy, duration of the operation and blood loss in patients with convexity lesions, which do not involve sagital sinus. In cases with involvement of the sinus, as well as in AVM's and temporobasal or interhemispherial lesions the duration of the operation and blood loss are reduced.

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VIRTUAL REALITY AND NEUROSURGERY: A BRIEF OVERVIEW

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ВИРТУАЛНА РЕАЛНОСТ И НЕВРОХИРУРГИЯ: КРАТЪК ОБЗОР

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SUBJECT

Over the past ten years the concept of virtual reality (VR) has made great advances. Clinical applications are already numerous and expectations are high. We give a concise overview of the current state of the art of virtual reality and its value for neurosurgery.

DEFINITION

Virtual reality is a „...*breakthrough technology* that allows you to step through the computer screen into a 3-D artificial world. All you have to do is put on the special video goggles & then almost everything is possible - you can fly, visit exotic lands, play with molecules, swim through the stock market, or paint with 3-D sound and colour“ (Pimental & Teixeira 1993).

This outlook was given in 1993. It nicely represents the enthusiastic expectation in that period.

CURRENT SITUATION

There are three major applications for VR in medicine/neurosurgery (**fig. 1**). *Administrative tools* help in everyday work and are used for economical as well as for scientific evaluation of patient data.

The second field is that of *simulators*. There are systems to learn theory, to train skills or to perform virtual procedures. The typical simulations in learning theory are systems which enable the users to teach or learn anatomy. A famous example is the visible human project and its countless spin-offs. This system has the advantage to be independent from laboratories and cadavers, they allow the student to repeat and extend his studies according to his individual needs.

There are some quiet sophisticated simulators which allow the training of skills. They help to save resources, especially human and animal subjects. They make training results comparable and allow a systematic evaluation. Whether they improve outcome after real procedures or do they lower the costs of training are questions that have to be answered in the future. Though the graphic solutions come close to perfect, the quality of haptic interfaces is still far from optimal.

Computer integrated surgery eases information integration; it may enhance surgeon's dexterity and his/her visual feedback. It mainly consists of a human-computer cooperation to accomplish delicate and difficult tasks (**fig 2**).

Surgical CAD (computer aided design) and CAM (computer aided manufacturing) systems (e.g. robots) transform preoperative informations and help in developing optimized treatment plans and then to execute the planned intervention.

Surgical-assistant systems (e.g. neuronavigation) extend human capabilities. They concentrate on skill enhancement and intraoperative decision support.

Computer integrated surgery offers many advantages:

- New treatment options
- Quality improves
- Less invasive surgery
- More accurate and precise surgery
- Revision rates decrease
- Time and cost reduced
- Follow-up easier
- May speed research trials

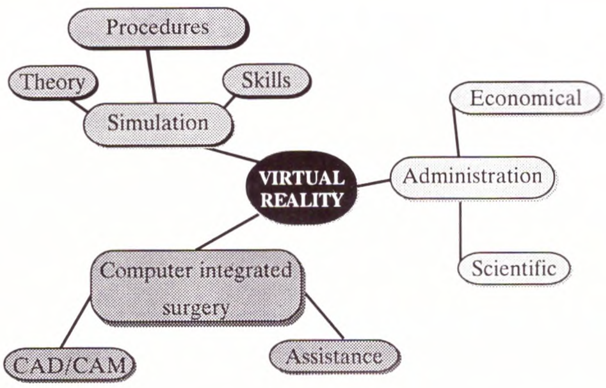

Figure 1. Applications for VR in Neurosurgery *(See color appendix)*

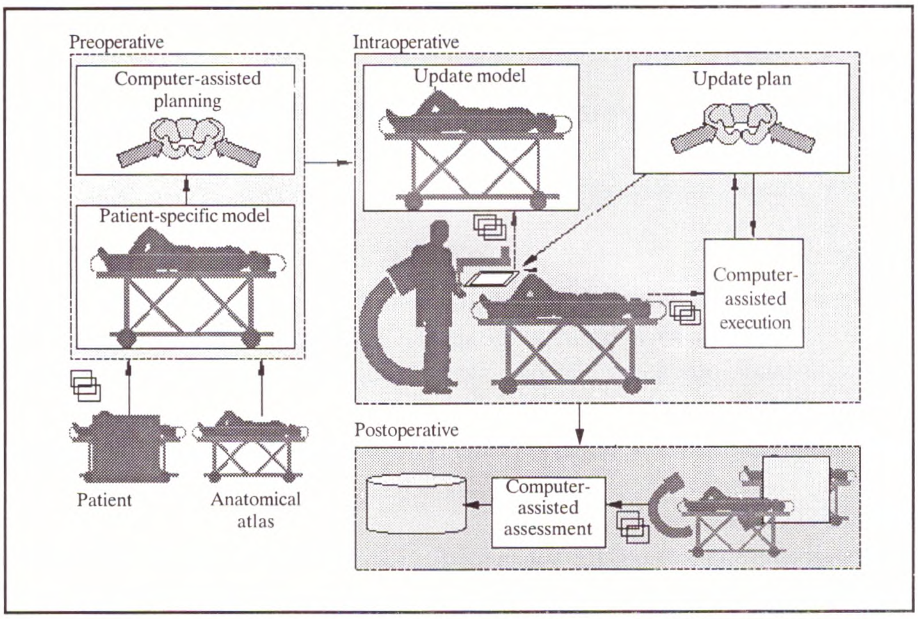

Figure 2. Modules of computer integrated surgery

(See color appendix)

Computer integrated surgery will have the same impact on health care as computer-integrated manufacturing had on industrial production. It might lead towards a quality-improved and more cost-effective health-care. „Real-time“ applications will be the next step to take.

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VIRTUAL ENDOSCOPY FOR PLANNING ENDOSCOPIC INTRAVENTRICULAR SURGERY - OUR EARLY EXPERIENCE

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ВИРТУАЛНА ЕНДОСКОПИЯ ПРИ ПЛАНИРАНЕ НА ЕНДОСКОПСКИ ИНТРАВЕНТРИКУЛНИ ИНТЕРВЕНЦИИ - НАШИЯТ РАНЕН ОПИТ

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ABSTRACT

The authors report on their preliminary experience with virtual endoscopy for planning endoscopic intraventricular surgery.

Material and Methods: Virtual endoscopy was performed before endoscopic third ventriculostomy in three patients with non-communicating hydrocephalus (one with a suprasellar arachnoid cyst and two with aqueduct stenosis) and after endoscopic third ventriculostomy in another with a posterior third ventricular tumor. The virtual endoscopic images have been evaluated in comparison with the real images obtained during the endoscopic procedures (endoscopic third ventriculostomy and inspection of aqueduct or tumor).

Results: Virtual endoscopic images were found highly concordant with the real endoscopic views showing most of the important neural and vascular structures. They reliably showed anatomical variants it present and allowed for customizing the operative strategy. Virtual endoscopy failed to render visible small structures like perforators, pituitary stalk etc. but, unlike other studies, it suggested the presence of a thick floor of the third ventricle.

Conclusions: In the authors early experience virtual endoscopy appears to be of essential value as a planning tool for neuroendoscopic interventions.

Key words: *virtual endoscopy, endoscopic intraventricular surgery*

РЕЗЮМЕ

Авторите докладват първоначалния си опит с използване на виртуална ендоскопия при планиране на ендоскопски интравентрикулни достъпи.

Материал и метод: При 3 пациенти с некомуницираща вътрешна хидроцефалия (1 със супраселарна арахноидна киста и 2 с аквердуктна стеноза) виртуално ендоскопското изследване предхождаше ендоскопската трета вентрикулостомия, а при четвърти болен с тумор в задните отдели на III вентрикул то беше извършено след ендоскопската интервенция. Виртуално ендоскопските образи бяха съпоставени с реалните ендоскопски интраоперативни образи, добити по време на ендоскопска трета вентрикулостомия и инспекция на тумора на III вентрикул.

Резултати: Беше установено, че виртуалноендоскопските образи корелират в голяма степен с тези при реална ендоскопия, като демонстрират ясно невралните и съдови структури. Надеждното предоперативно изобразяване на евентуални анатомични варианти позволява индивидуализиране на оперативния достъп. На този етап от развитието си виртуалната ендоскопия не е в състояние да долови микроструктури като напр. съдови перфоранти, хипофизният инфундибулум и др, но за разлика от други изследвания притежава свойството да „вижда зад непрозрачни структури" и да подсказва наличието на задебелен под на III вентрикул.

Изводи: Според първоначалният си опит авторите заключават, че виртуалната ендоскопия има стойност при планиране на невроендоскопските интервенции.

Ключови думи: *виртуална ендоскопия, ендоскопска интравентрикулна хирургия*

INTRODUCTION

Today, neuroendoscopic procedures have gained wide acceptance for a variety of indications such as endoscopic third ventriculostomy (ETV), aqueductoplasty, diagnostic neuroendoscopy with or without biopsy etc. These procedures are considered to be relatively safe with reported mortality and permanent morbidity rates in ETV of 1,0% and 1.6%, respectively (1). Despite the low complication rates there are still problems related to the procedures, including possible injury to different neurovascular structures such as basilar artery, perforators, choroid plexus, fornix, hypothalamus etc.

There are three main directions in the attempts to avoid possible complications and to further minimize morbidity:

1. The use of real intraoperative imaging - CT, MRI, ultrasound, or specially designed for endoscopy Doppler ultrasound microprobes for localizing major vessels like basilar artery or a. comm. post. (2-5).
2. The use of stereotactic endoscope guidance: classical (frame-based) or frameless (neuronavigation) as means for precisely planning the entry and target points thus avoiding misplacement and minimizing the need for repositioning of the endoscope during the operation (6-8).
3. Precise preoperative planning and acquaintance with the patient's individual anatomy based on the recently developed 3D-imaging modality virtual endoscopy (9-16).

Virtual endoscopy (VE) is a post-processing technique based on special volume rendering algorithms to create perspective 3D-images that closely simulate the surgeon's view during intraoperative endoscopy thus facilitating preoperative planning of different operative approaches. It utilizes 3D-image sets from high-resolution spiral CT or MRI. The sequential steps in the technical implemention of VE are as follows: image acquisition, image transfer to the 3D-post-processing workstation, 3D-image reconstruction, image segmentation and perspective rendering of the reconstructed 3D-images. The position and viewing direction of the virtual endoscope are either predefined along the navigation path or set in real time.

AIM OF THE STUDY

To become familiar with the technique of VE and study its feasibility as a tool for pre-operative planning of neuroendoscopic procedures.

MATERIAL AND METHODS

In the period March and May 2003, four patients from the Department of Neurosurgery, University Hospital „Alexandrovska", Sofia were both investigated with VE and underwent neuroendoscopic interventions for non-communicating hydrocephalus. Using the MINOP® endoscopy system (Aesculap, Tuttlingen, Germany) we performed endoscopic third ventriculostomy with additional inspection of the rostral part of the aqueduct in order to confirm a putative pathological process (aqueduct stenosis or tumor). In 3 of the patients (one with a suprasellar arachnoid cyst and two with aqueduct stenosis), the VE-views and fly-through movies were obtained preoperatively, and in another patient with an immature teratoid tumor of the posterior 3rd ventricle, VE was performed following the endoscopic procedure. The MR-investigations and VE were performed in the Department of Diagnostic Radiology, Clinical Hospital „Losenetz“, Sofia. The technical implementation of the VE-investigation in our study included image acquisition on a 1.5T GE Genesis Signa MR scanner (usually T1-weighted 3D image sets with a 256/256 matrix and a slice thickness of about 1mm (1-3 mm), identical to those used for the purposes of neuronavigation. The post-processing of the MR-images was carried out on a GE Advantage workstation AW4.0_03 (Sun Microsystems) using the NAVIGATOR application software from the available 3D-rendering package with semi- automated selection of appropriate threshold to achieve the best resolution and detail. The navigation was either interactive (real-time) or by setting a path between a possible entry point and a target point and creating a fly-through VE movie.

The data from the preoperative VE was taken into account in the planning of the procedure. The VE images were then compared with the real images from the endoscopic procedure and evaluated in relation to their anatomical resolution and ability to depict details of the patient's pathology and any variations in the individual anatomy.

RESULTS

Both VE and ETV were performed successfully in all four patients. The average time for the generation of the VE images for the whole planning was between 15 and 20 min. In all 4 patients the anatomical structures of importance were rendered visible and easily recognizable by VE. A deviation from normal anatomical relationship usually encountered during endoscopic procedures like third ventriculostomy, was also noted.

Patient 1, an 18-year old male, harbored a large suprasellar arachnoid cyst bulging into the floor of 3rd ventricle. The VE view at the level of foramen of Monro showed clearly the landmark structures of the foramen used for orientation during real endoscopy, as well as the vessels of the circle of Willis. The latter were visible through the foramen of Monro due to the absent membrane consisting of the floor of the 3rd ventricle and the wall of the arachnoid cyst **(fig.1)**. The foramina of Monro were lying in the axial plane which could be appreciated on the coronal MR images but more clearly on the VE views. A view of the interpeduncular cistern after penetrating the floor of the 3rd ventricle showed well the vascular structures of posterior circle of Willis **(fig.2)**. The vessels could be recognized as lying in the cistern well apart from each other on the axial T2-weighted images but both conventional MRI and VE failed to show whether the 3rd ventricular floor or the cyst wall spreads over these vessels.

Patient 2 was a 26-year old male with non-communicating hydrocephalus due to idiopathic aqueduct stenosis. VE planning of endoscopic third ventriculostomy has been done. The VE images showed remnants of the floor of the ventricle suggesting that it was not very thinned. This observation proved to be true during the real

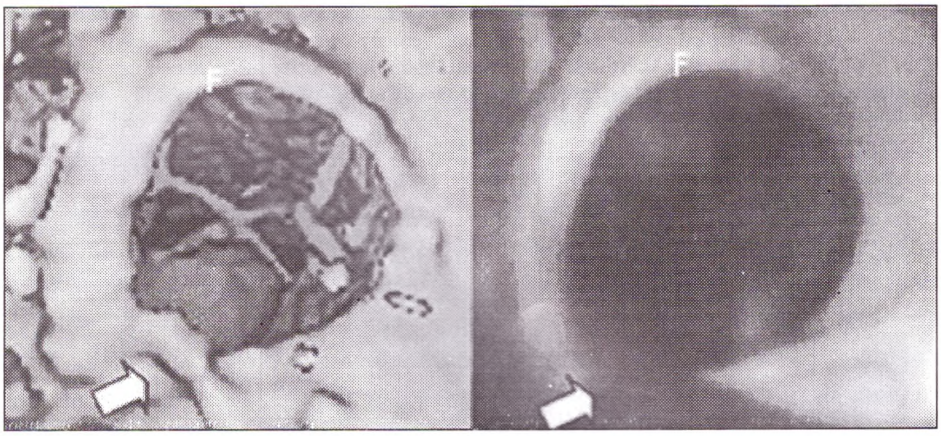

Fig. 1. Virtual endoscopic and real views of enlarged right foramen of Monro. The structures of posterior circle of Willis that are clearly seen in the VE image (left) are hidden on the real intraoperative image (right) by the membrane formed by the floor of the third ventricle and the wall of the arachnoid cyst. F- fornix, arrow - choroid plexus.

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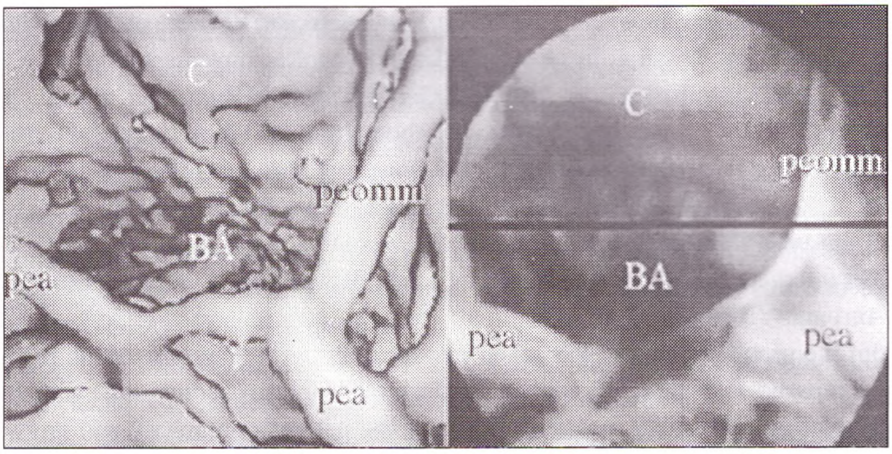

Fig. 2. Virtual endoscopic (left) and real views of the interpeduncular cistern. BA-basilar artery, p comm - posterior communicating artery, pca - posterior cerebral artery, C-clivus.

(See color appendix)

endoscopic procedure **(fig. 3)**. The position of the basilar artery was estimated by changing the threshold settings which rendered invisible the floor of the ventricle. In the same patient VE views of the rostral part of the aqueduct were obtained which showed again high concordance with the images from the real endoscopy. Both modalities showed the aqueduct stenosis but due to the lack of suitable trajectory for performing aqueductoplasty without injuring the neighboring structures the procedure was not carried out.

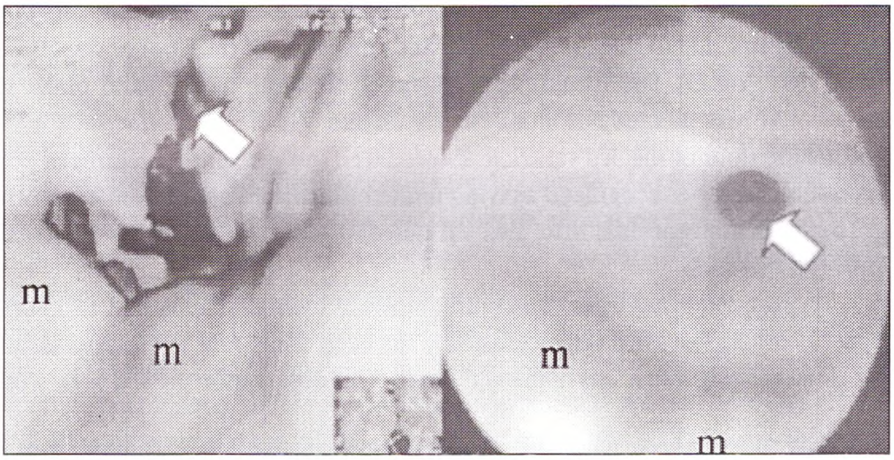

Fig. 3. VE and real views of the thick non-translucent floor of the third ventricle. Note the basilar tip showing through the defect in the third ventricular floor on the VE image (left). m-mammillary bodies, arrow- infundibular recess.

(See color appendix)

In *patient 3*, a 50-year old male with late onset membranous aqueduct stenosis and tri-ventricular hydrocephalus, the VE planning demonstrated an aberrant position of the basilar tip which was deviated to the right and lied close to the clivus. Additionally, the left p_1-segment of the posterior cerebral artery followed a long curve that bulged into the third ventricle whose floor appeared not very thinned. These findings correlated well with the real situation **(fig.4)** and caused the surgeon to choose a site for the perforation behind the left p_1-segment instead of the usual place between the basilar tip and the clivus. In the same patient, the VE inspection of the aqueduct was performed as planning for possible aqueductoplasty. It showed no visible obstruction **(fig.5)**. However, the real attempt for aqueductoplasty had to be abandoned due to a bleeding from the choroid plexus that obscured the surgeon's view.

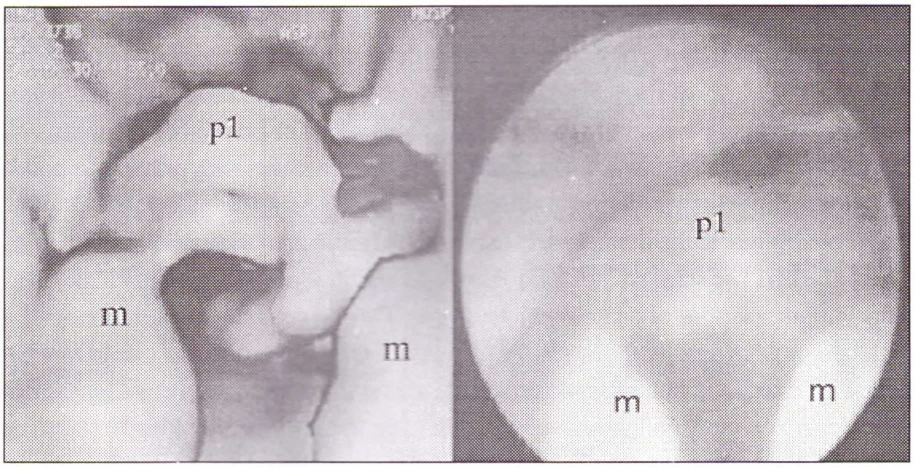

Fig. 4. VE (left) and real endoscopic images showing aberrant position of the basilar tip deviated to the right and left p_1 segment protruding into the ventricle. p_1- p_1 segment of posterior cerebral artery, m- mammillary bodies.

(See color appendix)

The fourth patient, a 3-month old girl with a tumor of posterior third ventricle, underwent third ventriculostomy on emergency basis and the MRI and VE were performed after the procedure. Nevertheless, the VE and real endoscopic views were again highly concordant and VE delineated well the vessels of the circle of Willis, the pituitary stalk, as well as the pathological process **(fig.6)**.

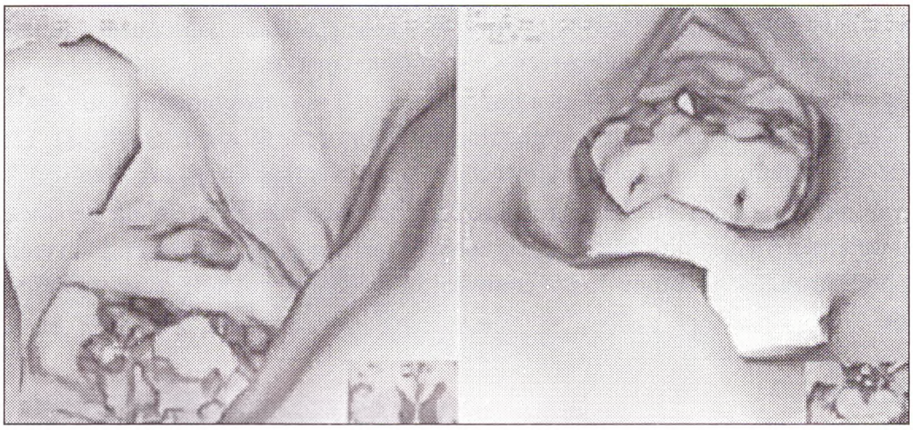

Fig. 5. VE inspection of the aqueduct: left- view at the level of foramen of Monro, choroid plexus showing on the left side; right - view through the aqueduct into the fourth ventricle.

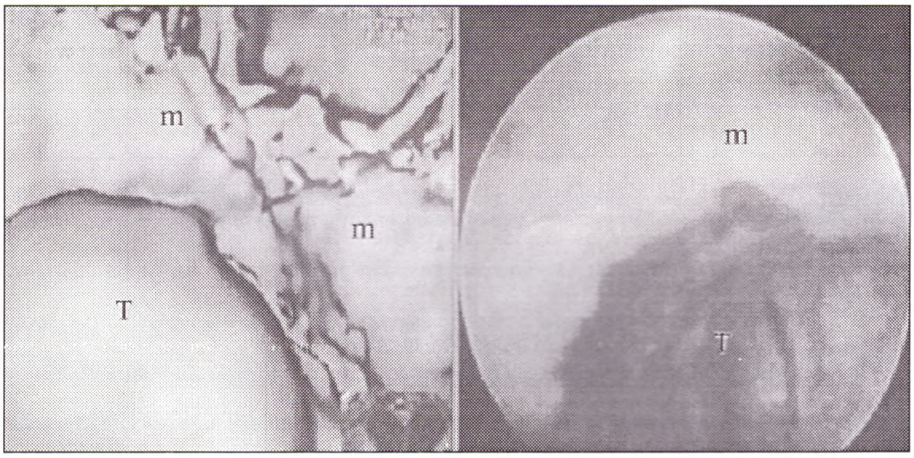

Fig. 6. VE (left) and real endoscopic views of a tumor of posterior third ventricle through the right foramen of Monro. T- tumor, m- mam-millary bodies.

(See color appendix)

DISCUSSION

Using VE in 4 patients we found that it provides views that are highly concordant with the images during real endoscopic procedures. The views of the foramen of Monro in VE and real modalities delineated well landmark structures like the fornix, choroid plexus and v. thalamostriata **(fig.1)**. The possibility to render visible pathological processes in VE modality was also impressive. Our findings are in agreement with previous reports of other authors (10, 11,13,14) except for the superior resolution for thin membrane-like structures like the floor of third ventricle and septum pellucidum, probably due to the thinner slices used for the volume reconstruction - 1 mm in our study vs. 3 mm used by Krombach et al. (13). The sensitivity of VE for anomalous anatomy was also very high - in all of the cases we were able to identify variant relations of anatomical structures. Thus, apart from the „experienced increased safety“ (15) the surgeon was also able to modify the operative technique according to the preoperative VE- planning.

The possibility of VE to „look behind structures“ that are on the path of the virtual endoscope was employed as well. This can be done by simply going through the object on the path and looking at the structures behind it, something that can have fatal consequences in real endoscopic circumstances. In VE it has the drawback that the perspective view of the structures from a distance is lost and the orientation can be difficult. Instead, structures can be removed or rendered invisible by either manually segmenting them which is more time consuming or simply by changing the threshold settings as done in our study. The latter approach unfortunately worsens the quality of the structures of interest.

The interactive navigation allowed for a detailed familiarization of the surgeon with the individual patient's anatomy, including present anomalies and giving the relations of a pathological process to anatomical landmarks. Unlike real-time navigation, the path-setting technique gives the relation of the predefined path to anatomical structures, occasionally displaying warnings like „This path will hit object“ or „Inside object“. In this way the surgeon can appreciate which structures are at risk along the chosen path and consequently modify the approach. This may be important when trying to combine VE with neuronavigation.

As stated by other authors (10, 13, 14) as a limitation of VE may be considered the lower resolution for small structures like perforators, membranes or the thinned floor of the 3^{rd} ventricle **(fig.1)**. This may limit the application of VE for planning of surgery in regions where many such structures are involved. The other noted drawback, e.g. vascular structures not being rendered in their original color, might be overcome by fusing conventional T1-weighted images with MR- angiography. In our experience however, such techniques are very time-consuming and we believe that they do not contribute significantly to the quality and informative value of VE investigations.

CONCLUSIONS

In our preliminary experience VE seems to be a promising tool for pre-surgical planning of endoscopic interventions in selected cases. Despite the still limited resolution capabilities it allows the surgeon to assess preoperatively the individual anatomy and pathology of each patient and allows for customizing of the optimal operative approach. We feel that a fusion of both VE and neuronavigation may potentially contribute to further increase the safety of endoscopic intraventricular surgery.

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NEUROENDOSCOPIC DIAGNOSIS AND TREATMENT IN ADULTS

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ABSTRACT

Objective: This study is aimed to contribute to the indications, surgical techniques and results of the pure endoscopic and endoscopic assisted neurosurgery in the treatment of 76 adult patients.

Study Design: The study analyses prospectively 76 adult patients operated on using pure or assisted neuroendoscopy.

Settings: All patients were operated on in the period March 2000 - April 2003.

Patients: The study includes 76 adult patients with different diagnoses. In 48 patients we have used pure endoscopic procedures and in 28 patients we have used endoscopic assisted neurosurgery.

Interventions: Pure and assisted neuroendoscopy. In 8 patients neuronavigation-assisted endoscopy was applied.

Main Outcome Measures: These included patient's clinical outcome and post-operative CT criteria for effectiveness of the procedure.

Results: In 5 patients postoperative complications were observed; postoperative motality was 2,6% (2/76).

In the subgroup of pure endscopic procedures 38 patients have experienced clinical and CT improvement 6 months after the intervention, in 10 patients there was no change in status.

Conclusions: The advantages of endoscopic neurosurgery are visualization of important neurovascular structures in hidden places and residual tumor, better control of adequate clipping in patients with aneurysms and minimally invasive operations - 3rd ventriculostomy in patients with internal hydrocephalus and aqueductoplasty in patients with aqueduct stenosis.

Key words: *Endoscopic third ventriculostomy, Endoscopic assisted neurosurgery, Internal hydrocephalus.*

НЕВРОЕНДОСКОПСКА ДИАГНОЗА И ЛЕЧЕНИЕ ПРИ ВЪРАСТНИ ПАЦИЕНТИ

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РЕЗЮМЕ

Цел: Целта на проучването са индикациите, хирургичните техники и резултатите на чистата и асистирана невроендоскопия при лечението на 76 възрастни пациента.

Дизайн на проучването: Това проучване анализира проспективно 76 възрастни пациенти, оперирани чрез чиста или асистирана невроендоскопия. Всички пациенти са оперирани в периода м. март 2000 - м. април 2003 г.

Пациенти: Проучването включва 76 възрастни пациента с различни диагнози. При 48 пациента използвахме чисти ендоскопски процедури, а при 28 пациента - ендоскопски асистирани неврохирургични интервенции. При 8 пациента използвахме асистирана с невронавигация ендоскопия.

***Резултати*:** От всички 76 пациента, подложени на асистирана или чиста ендоскопия, при 5 пациента наблюдавахме хирургични усложнения и при 2 пациента изходът бе летален.

При 38 пациента, при които използвахме чиста ендоскопия, наблюдавахме клинично и CT подобрение 6 месеца след интервенцията, 10 пациента бяха без промяна.

***Заключение*:** Предимствата на ендоскопската неврохирургия са визуализиране на важни невроваскуларни структури на труднодостъпни места, както и на резидуални туморни части; по-добър контрол при клипсирането при пациенти с аневризми; минимално инвазивни операции - III вентрикулостомия при пациенти с вътрешна хидроцефалия и аквeдуктопластика при пациенти със стеноза на акведукта.

INTRODUCTION

In the last years pure and assisted endoscopic neurosurgery have been approved as neurosurgical procedures with a lot of advantages. Nowadays, endoscopic third ventriculostomy is an established minimally invasive neurosurgical procedure. This report analyses our early experience with neuroendoscopic procedures .

CLINICAL MATERIAL AND METHODS

We have analyzed 116 patients, which have been operated in the Neurosurgical Departments of two University Hospitals in 3 years (2000 - 2003). The age of the patients varied from 6 months to 67 years. The distribution of the patients was 76 adults and 40 children.

Tthis study includes adult patients. In 48 patients we have used pure endoscopic procedures and in 28 patients endoscopic assisted neurosurgery. The male: female ratio was 1,3:1,0. In 28 of the patients with pure endoscopic procedures we have applied 3rd ventriculostomy and in 3 cases - aqueductoplasty. We have operated 8 patients with arachnoid cysts (including posterior fossa and Sylvian cysts), 4 patients with 3rd ventricle colloid cysts and 5 patients with periventricular cysts.

We have used endoscopic assisted microneurosurgery in transsphenoidal interventions and operations for cerebral aneurysms and paracellar epidermoids. In 11 patients with transsphenoidal interventions endoscopy for inspection of the sella floor or the inferior 3rd ventricle was applied. In 4 patients operated for pontocerebellar lesions (including tumors, trigeminal neuralgia and hemifacial spasm HFS), we have used endoscopic procedures for inspection of the lesion and for residual lesions. In 11 patients with cerebral aneurysms was assisted the main operation with neuroendoscopy for better control and adequate clipping. In 2 patients, operated for parasellar epidermoid we have used endoscopic assisted microneurosurgery for better removal of the lesions.

The following **Figures (1 - 5)** illustrate the use of neuroendoscopy, pure and assisted, in different cases:

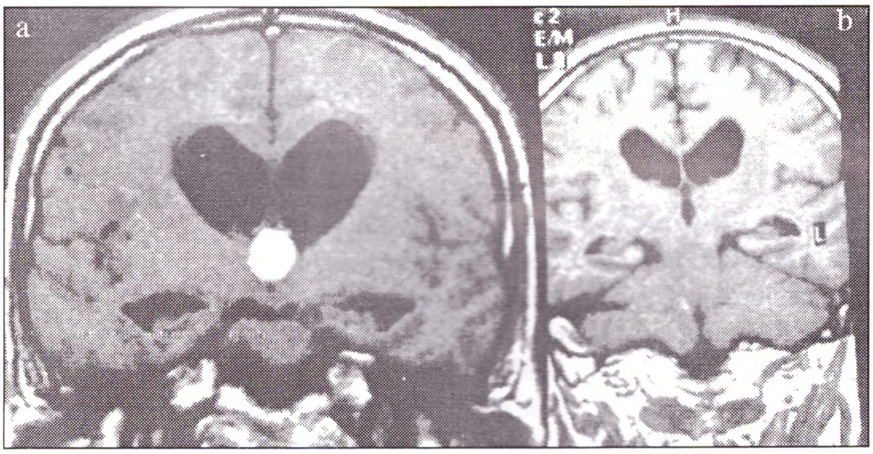


Fig. 1. MRI of a patient with colloid cyst of the III ventricle before /a/ and after /b/ endoscopic excision of the cyst, reduction of the internal hydrocephalus is noted.

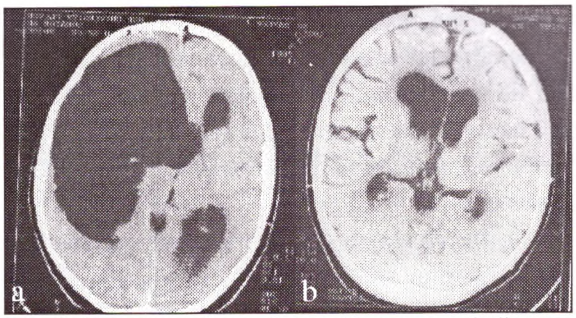


Fig. 2. CT scans of a patient with porencephalic cyst before /a/ and 3 months after /b/ the operation.

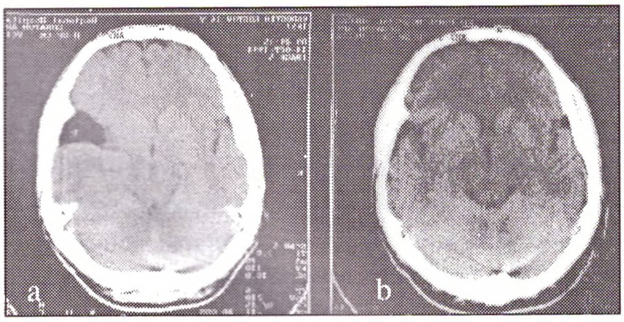


Fig. 3. CT scans of a patient with arachnoid cyst before /a/ and after /b/ endoscopic fenestration and excision.

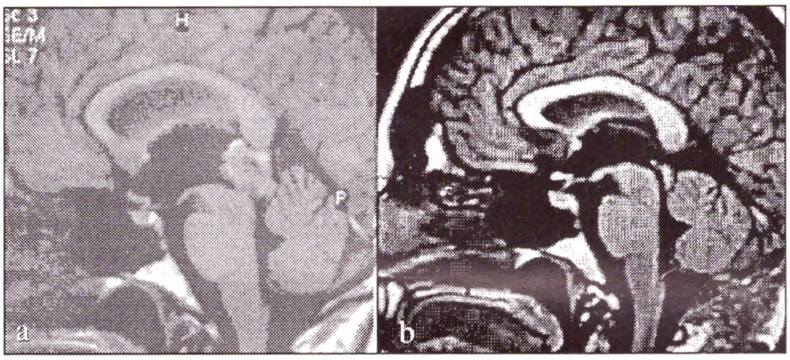
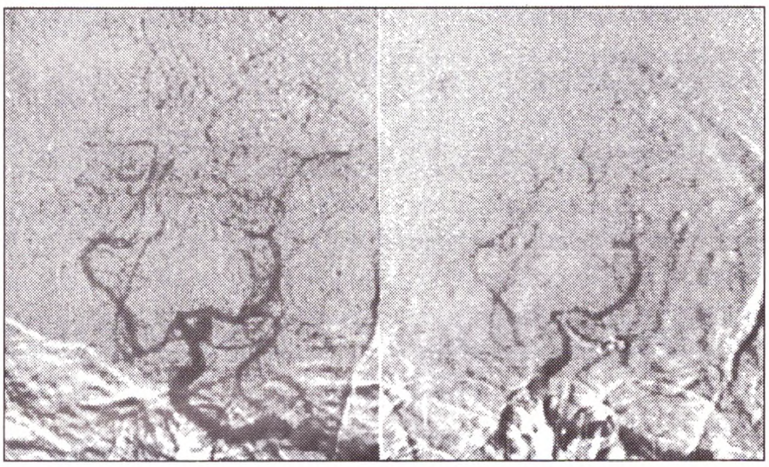


Fig. 4. MRI of a 21 years old patient with pineal tumor before /a/ and after /b/ the operation. The tumor has been totally removed. We have assisted the main operation with endoscopic neurosurgery for inspection of the posterior part of the III ventricle for residual lesion and for the position of important vessels.

Fig. 5. Angiographic images of a patient with a basilar/superior cerebellar after aneurysm before (a) and after the clipping (b). Here we have used endoscopic icroneurosurgery for control of adequate clipping



With the introduction of the neuronavigation in our clinic, we have used it in neuroendoscopic operations in 8 cases in our series. Thus, the accuracy of the neuroendoscopic operations was enhanced. This is illustrated in the following case on **fig. 6.**

The morbidity was 6,5 % (5 cases) and the mortality - 2,63 % (2 patients).

In 5 patients we have observed the following complications:

- 1 bilateral subdural hematomas following 3rd ventriculostomy;
- 1 prepontine hemorrhage following 3rd ventriculostomy;
- 2 meningitis in PF arachnoid cyst and 3rd ventriculostomy;
- 1 vertical gaze paresis in aqueductoplasty.

There were 2 cases with lethal outcome due to postoperative CSF leak and meningitis:

- A patient with PF tumor and internal hydrocephaly post 3rd ventriculostomy;
- A patient with internal hydrocephaly post 3rd ventriculostomy.

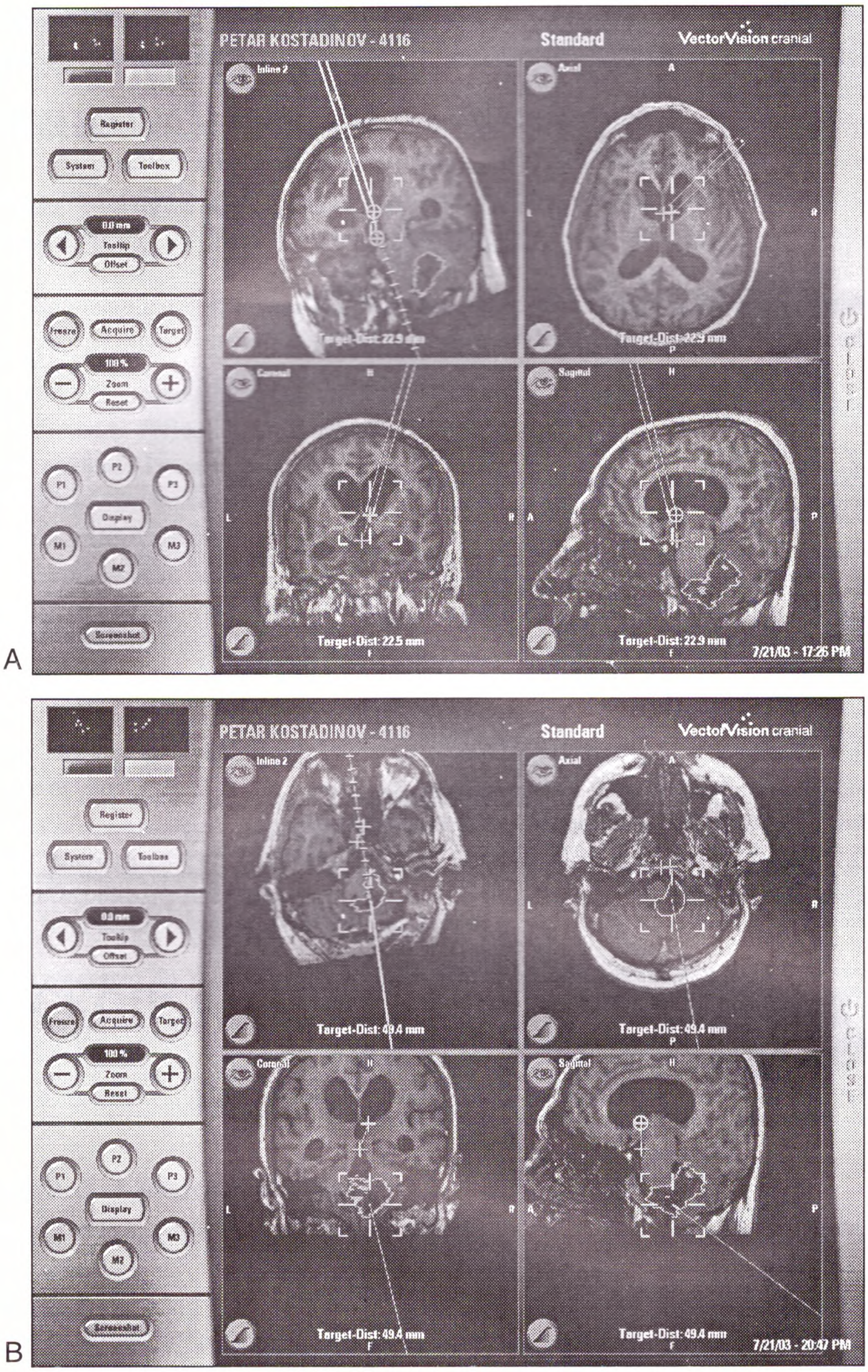


Fig. 6. 45 years old man with metastasis of the floor of the IV-th ventricle and internal hydrocephalus. Third ventriculostomy (a) followed by removal of the tumor of the forth ventricle (b). Both operations were assisted with neuroendoscopy and neuronavigation.

(See color appendix)

DISCUSSION

The benefits of using assisted neuroendoscopy are manyfold - visualization of important neurovascular structures in hidden places and residual tumor, better control of adequate clipping in patients with aneurysms and minimally invasive operations - 3^{rd} ventriculostomy in patients with internal hydrocephalus and aqueductoplasty in patients with aqueduct stenosis. Best results for endoscopic 3^{rd} ventriculostomy are reported with late-onset occlusive hydrocephalus due to acquired aqueduct stenosis - up to 93,5 % improvement in long-term follow-up.

sundoscopic 3rd ventriculostomy ETV is thought to resolve intracranial hypertension and to restore almost normal CSF dynamics. Flexible and rigid endoscopes have been used, the former demonstrating insufficient image quality and more cumbersome orientation, guidance and fixation.

A variety of techniques have been described to perforate the floor of the third ventricle, the most popular of them being a blunt balloon catheter perforation. We have adopted the latter method.

In 5 of our 76 patients with pure or assisted endoscopy there were surgical complications (6,5 %). According to published series hemorrhagic, neurological and infectious complications occur in 6 - 12 %, most being transitory (1-8).

In the subgroup of pure endscopic procedures 38 patients experienced clinical and CT improvement 6 months after the intervention, in 10 patients there was no change in status.

CONCLUSIONS

The advantages of endoscopic neurosurgery are:

- Visualization of important neurovascular structures in hidden places;
- Visualization of residual tumor;
- Identification of laceration of the arachnoid in transsphenoidal operations;
- Control of adequate clipping in patients with aneurysms;
- Minimally invasive procedures - 3rd ventriculostomy in patients with internal hydrocephalus and aqueductoplasty in patients with aqueduct stenosis.

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ENDOSCOPE - ASSISTED MICROSURGERY OF PATHOLOGICAL LESIONS AFFECTING THE POSTERIOR CRANIAL FOSSA: INITIAL EXPERIENCE

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ABSTRACT

Goal of the study: to present our initial experience with the endoscopy-assisted microsurgery of the posterior cranial fossa (PCF) and to define its advantages and drawbacks.

Material and methods: During a two-year period the technique was applied in 19 patients with PCF lesions. Ten of the patients had vestibular schwannomas, 2 - cerebellopontine angle meningiomas and 3 - epidermoid tumors. Four patients had trigeminal neuralgia.

Results: The endoscopic inspection of the anterior tumor surface allowed an early identification of the facial nerve in 3 patients with large schwannomas. In one case of vestibular schwannoma and one epidermoid, tumor remnants were detected, otherwise not visible by the microscope. In the patients with trigeminal neuralgia, the endoscopic inspection allowed accurate visualization of the vessel causing the compression.

Conclusions: The application of endoscopic techniques during surgery via the retrosigmoid approach helps to overcome some of the disadvantages, inherent to thuc approach. Even in cases of large schwannomas, the location of the facial nerve could be determined endoscopically early in the procedure. The possibility „to look around the corner“ increases the completeness of tumor removal, while decreasing the morbidity.

Key words: *endoscopy-assisted microsurgery, posterior cranial fossa, vestibular schwannoma, trigeminal neuralgia*

ЕНДОСКОПСКИ АСИСТИРАНА МИКРОХИРУРГИЯ ПРИ ПАТОЛОГИЧНИ ПРОЦЕСИ, ЗАСЯГАЩИ ЗАДНА ЧЕРЕПНА ЯМКА

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РЕЗЮМЕ

Цел на проучването: да се представи началния ни опит от приложението на ендоскопски-асистирана микрохирургична техника при лечението на заболявания в задната черепна ямка, както и да се анализират предимствата и недостатъците на методиката.

Материал и метод: За две годишен период техниката е приложена при 19 болни. Десет от тях са с вестибуларни шваноми, 2 - с понтоцеребеларни менингиоми, 3 - с епидермоидни тумори и 4 - с тригеминална невралгия.

Резултати: ендоскопското оглеждане на предната туморна повърхност ни позволи в ранен стадий от операцията да идентифицираме N. facialis при 3 пациенти. При един от шваномите и един от епидермоидните тумори, след видимо тотална микрохирургична екстирпация, се откриха остатъчни туморни части. При болните с тригеминална невралгия ендоскопският оглед ни позволи точно да идентифицираме мястото на съдово-нервния конфликт и причиняващия го съд.

Заключение: Съчетанието на ендоскопска и микроскопска техника при оперативното лечение на понтоцеребеларни лезии чрез ретросигмоиден субокципитален дъстъп, позволява да се преодолеят някои от недостатъците, присъщи на достъпа. Дори при шваноми с големи размери, благодарение на ендоскопа, n. facialis може да се идентифицира в ранен етап от операцията, което позволява анатомичното му съхранение. Възможността да се „погледне зад ъгъла“ намалява морбидитета и повишава радикалността при оперативното лечение на патологичните лезии в задната черепна ямка.

Ключови думи: *ендоскопски асистирана микрохирургия, задна черепна ямка, вестибуларен шваном, тригеминална невралгия.*

Endoscopy is used widely in contemporary neurosurgery. Its application is constantly broadening. In cases of obstructive hydrocephalus and in some ventricular and paraventricular lesions it is the preferred treatment method (22). The smaller craniotomy, less dural incison and need for retraction of the brain, cranial nerves and vessels, lead to a decreased morbidity and mortality (3,19). Thanks to the two main features of the endoscope - better illumination and magnification when approaching an object, as well as the possibility to „look around the corner“, it bacame an useful supplement to microneurosurgery. In the skull base surgery these features are especially helpful.

In the surgery of posterior cranial fossa (PCF) lesions endoscopy-assisted microsurgery has been applied since the last decade. In 1992, O‘Donoghue and O’Flynn (17) described and classified the endoscopic anatomy of the cerebellopontine angle. During the following years its application in the treatment of cranial nerve compression syndromes, tumors and vascular lesions affecting this part of the cranial base, was further refined (8,10,11,20,25,27).

The goal of this report is to present our initial experience with this technique and to define its practical and theoretical advantages and drawbacks.

MATERIAL AND METHODS

During the period June 2001 - May 2003 at the Department of Neurosurgery of the University Hospital „Alexandrovska“ 19 patients with PCF lesions have been operated using the endoscope-assisted microsurgical technique. Ten of the patients had vestibular schwannomas, 2 - cerebello-pontine angle (CPA) meningiomas and 3 - epidermoid tumors. Four patients with trigeminal neuralgia have been operated as well.

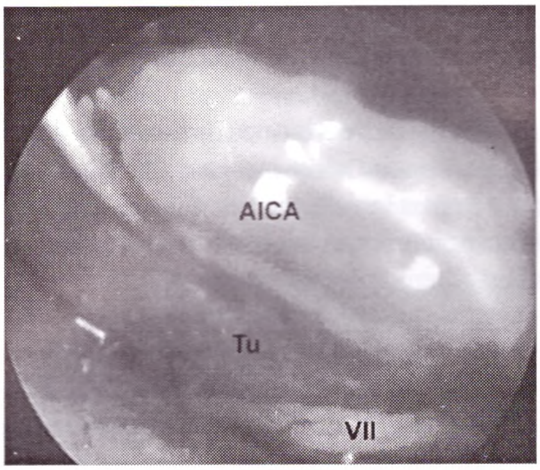
Tumors:

Vestibular schwannomas:

Eighty percent of the schwannomas were large sized - grade IV according to the classification of M. Samii (21). One of the tumors was 3rd and 1 - 2nd grade. Two of the patients had neurofibromatosis type 2 (NF-2). In all cases the approach applied was the retrosigmoid suboccipital. During the removal of the smaller lesion the CPA was inspected in the early stages with the endoscope and its structures were identified. The large tumors were initially debulked. Then, their caudal or cranial pole was removed. The endoscope was introduced through these surgically created corridors and the anterior tumor surface was inspected. The identification of the facial and abducent nerves helped for their subsequent preservation. During the latter stages of tumor removal the endoscope was used to determine the relations of the neural and vascular structures to the remaining tumor part. After the opening of the internal auditory canal and the extirpation of the intrameatal tumor part, the fundus of the canal was inspected endoscopically. Any tumor remnants, as well as opened and unoccluded air cells were noted. At the end the anatomical preservation of the cranial nerves and the completeness of tumor removal were documented with the endoscope. /**Fig.1**/

Other tumors:

The same approach (retrosigmoid suboccipital), was used during the removal of the CPA meningiomas and epidermoids. One of the epidermoids, affecting IVth ventricle, was removed through a median suboccipital craniectomy. The endoscope was used in all stages of surgery and helped in the determination of the relations of different structures to the tumor.



(See color aplication)

Fig.1. Endoscopic view of the anterior tumor surface. AICA- anterior inferior cerebellar artery, Tu- vestibular schwannoma, VII- facial nerve.

Trigeminal neuralgia - microvascular decompression:

In these cases the technique, described by P. Jannetta (6,16) was used. The endoscope was applied in order to identify precisely the site of the neuro-vacular conflict. After the microvascular decompression its completeness was assessed endoscopically.

RESULTS

Tumors:

The endoscopic inspection of the anterior tumor surface allowed us to identify early the facial nerve in 3 of the large schwannomas. In the cases of smaller schwannomas, the location of this nerve, as well as of the other neuro-vascular structures of the CPA and their relation to the tumor, were determined at the beginning of the procedure. In one case tumor remnant in the region of the fundus of the internal acoustic canal, that was not seen with the microscope, was visualized. Opened and unoccluded air cells were not identified. After an apparently total microsurgical removal of the IVth ventricle epidermoid, tumor remnant in the region of the roof of the ventricle was identified with the endoscope.

The application of the endoscope added 15-30 min (average 20 min) to the total operative time. Procedure-related morbidity was not observed.

Trigeminal neuralgia:

The endoscopic inspection allowed accurate visualization of the vessel/vessels causing the compression. The vascular groove on the trigeminal nerve was demonstrated clearly in one case. At the end, the completeness of the decompression was reassessed endoscopically.

DISCUSSION

The endoscopic technique is an effective method of bringing more light in the operative field and of preserving the clear image of different structures. These features of the endoscope compensate for two of the main disadvantages of the operating microscope: decreasing the light intensity while incresing the zoom (3,19). The possibility to „look around the corner", due to the „fish- eye" effect of the endoscopic lens, allows to visualize structures hidden from the surgeon by bone, neural or vascular structures.

Tumors:

In the treatment of vestibular schwannomas the preferred by most neurosurgeons approach is the retrosigmoid suboccipital (18,21,23,32). Its advantages are widely discussed in the literature. The main disadvantages of the approach are the need of cerebellar retraction, the late identification of the facial nerve and the impossible visualization of the most lateral part of the internal auditory canal without endangering the integrity of the bony labyrinth (7,32). As a result, there is an increased risk of leaving tumor remnants in the region of the fundus or of unoccluded opened air cells (2,5,15,24,26). The endoscope-assisted microsurgery offers the possibility to overcome most of these disadvantages.

In more than 80% of the cases the facial nerve is located on the anterior surface of the schwannoma (23). It is identified in the latter stages of tumor removal which increases significantly the risk of its injury. During the removal of small tumors some authors inspect initially the anterior tumor surface with the endoscope (12,13). The endoscope is introduced superior or inferior to the tumor and the medial portion of the facial nerve is idenitified. Using this approach during the removal of the smaller schwannomas in our series the facial nerve, as well as other important cerebellopontine structures, were identified at the beginning of the procedure. In cases of large tumors this approach is inapplicable. In such cases we perform initial tumor debulking, then we remove the cranial or caudal tumor pole. Through these surgically created corridors we introduce the endoscope and inspect the part hidden from the surgeon. This allowed us the early identification and subsequent preservation of the facial nerve in three large schwannomas.

The rostro-medial tumor propagation in direction towards the tentorial incisura was an obstacle to that approach because it did not allow the safe manipulation of the endoscope.

In the latter stages the endoscope was used to inspect and control the dissection of the tumor. The abducent nerve is usually distorted by large schwannomas. Its identification is very important for the intraoperative orientation of the surgeon and for its subsequent preservation. /**Fig.2**/

As some authors state, the most lateral part of the internal auditory canal can not be visualized safely when using the retrosigmoid appoach (7,15). This increases the risk of leaving tumor remnants in that „blind“ part of the canal. Due to the possibility to „look around the corner“with the endoscope the whole canal could be accurately inspected (4,8,25). The visualization of the transverse crest allows the precise identification of the cochlear and facial nerve. If a remnant is found it could be removed under microscopic or endoscopic control. Tumor remnants after „total“ microsurgical tumor removal are found in 0- 17,6% (28-30). In our series we found such remnant in one patient - 10%.

The opening of the internal auditory canal increases the risk of postoperative CSF leak (2,5). The endoscopic inspection allowes the precise identification of opened and unoccluded air cells (25,27,30). P.Wackym et al., (30) detected such unobliterated air cells in 51 patients of their series of 108 cases. In our series we did not find opened unoccluded air cells.

In the patients with cerebellopontine meningiomas and epidermoids the endoscope allowed us to define precisely the relation of the tumor to the surrounding structures. In the case of the 4th ventricle epidermoid an unidentified with the microscope tumor part in the region of the roof of the ventricle, was detected endoscopically.

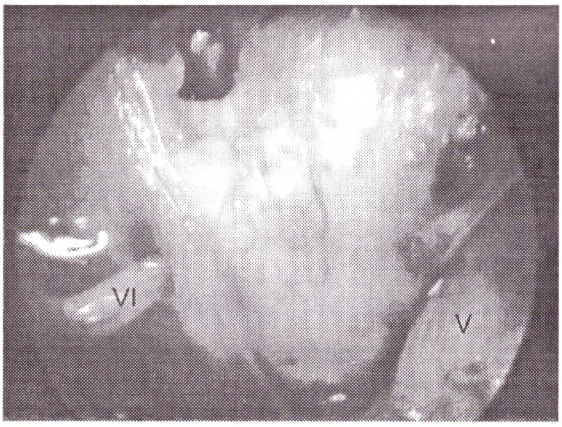


Fig. 2. Endoscopic view of the cerebellopontine angle after partial tumor removal. V- trigeminal nerve, VI- abducent nerve

(See color aplication)

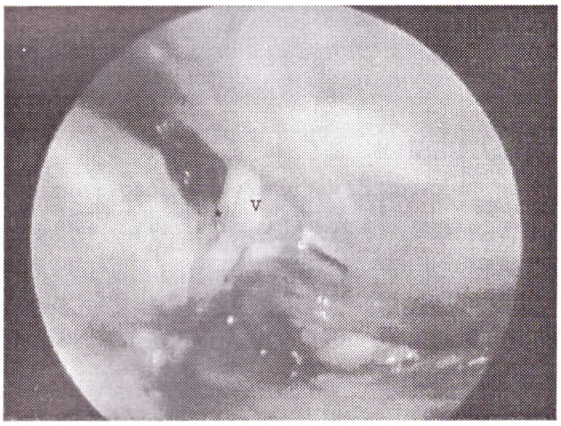


Fig. 3. Endoscopic visualization of the vascular groove (*) on the trigeminal nerve (V).

(See color aplication)

Tigeminal neuralia:

In 1967 P. Jannetta proposed a model for the pathogenesis of trigeminal neuralgia - the neurovascular conflict (6). He developed and introduced in the practice the operative technique for its treatment (16). The microvascular decompression is the treatment of choice in trigeminal neuralgia. The accurate microscopic visualization of the whole nerve and the potential sites of compression is of utmost importance for the good outcome (1,16). In spite of the great experience with this approach the failure rate is 2 -7 %, and the annual risk of recurrence is 3,5% (9,30). The absence of a significant neurovascular conflict is one of the possible explanations for the bad outcome. In the cases when only venous compression is found the risk of recurrence is higher (30). In a series of 116 patients reoperated for failure or recurrence of the complaints, RF Wilkins identified undetected previously arterial compression in 65,5% (31).

The endoscope offers the possibility of detailed inspection of the whole trigeminal nerve, from the root entry zone to its entry in the Meckels cave /**Fig.3**/. The ventral side of the root entry zone could be visualized either (3). The site of significant compression and the vessel causing it are also demonstrated precisely. At the end the completeness of decompression is assessed with the endoscope (30). As a consequense, the endoscope- assisted microvascular decompression reduces the incidence of failures or recurrences. The experience of J. Magnan (11) is a confirmation for the accuracy of the technique. During the treatment of hemifacial spasm he could identify microscopically the offending vessel in only 28% of the patients, whereas applying the endoscope he visualized the neurovascular conflict in 93%.

Disadvantages of the technique:

The utilization of the endoscope during cranial base surgery posses some special problems. The surgeon must navigate through a complex net, composed of cranial nerves and vessels (14). In contrast to intraventricular endoscopy the instruments are not introduced through the shaft of the endoscope, but parallel to it. The image acquired is different from the familiar microscopical image. Some structures, such as arachnoid membranes and trabeculas, have to be dealt with in a different manner with the endoscope. These all increase the risk of injury to surrounding structures and determines the more steep learning curve of endoscopy - assisted skull base surgery. (3, 8)

Other shortcomings of the technique are common to all types of intracranial endoscopy - lack of wide range of instruments, difficult control of the proximal to the endoscopic tip part of the operative field, two - dimensional image, necessity of bloodless operative field and potential of thermal injury. (22,30)

CONCLUSION

Based on our initial experience with the endoscope - assisted surgery of the posterior cranial fossa, we think that its utilization increases the safety and accuracy of the procedure. Its application during vestibular schwannoma surgery by the retrosigmoid approach helps to overcome some of the disadvantages, inherent to that approach. Even in cases of large schwannomas, the location of the facial nerve could be determined endoscopically early in the procedure. The possibility „to look around the corner“ increases the completeness of tumor removal, while decreasing the morbidity.

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EXPERIENCE WITH NEUROENDOSCOPY IN PAEDIATRIC NEUROSURGERY

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ABSTRACT

The results of the introduced in our clinic in the year 2000 neuroendoscopy in children were analyzed. During this 3 year period 89 procedures were performed, 36 of them were in patients younger than 18 years. Criteria for the efficacy were defined as a base for evaluation of the results.

Twenty-three 3rd ventriculostomies were performed: in 15 patients with occlusive hydrocephalus (during the follow-up, 66,7% of them needed postventriculostomy CSF shunting procedure) and in 8 cases with a communicating hydrocephalus with a success rate of 12,5%.

From 11 arachnoid and porencephalic cyst fenestrations, 18,2% were successful. Two aqueductoplasties were performed with a success rate of 100%.

Analyzing our results and comparing them with the data of other authors, we made the conclusion, that the success or the failure of the neuroendoscopy was closely related to the age of the patients. Our results were significantly better in cases with obstructive hydrocephalus, caused by aqueductal stenosis if the 3rd ventriculostomy was followed by an aqueductoplasty. With increasing age of the patient, the success rate of of the neuroendoscopic fenestration increased too.

Key words: *neuroendoscopy, pediatric neurosurgery, third ventriculostomy*

ОПИТ С НЕВРОЕНДОСКПИЯ В ДЕТСКАТА НЕВРОХИРУРГИЯ

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РЕЗЮМЕ

Бяха анализирани резултатите от въведената в нашата клиника през 2000 год. невроендоскопия при деца. През този 3-годишен период бяха направени 89 процедури, като 36 от тях бяха при пациенти по-малки от 18 години. Критериите за ефективност бяха определени като основа за оценка на тези резултати.

Бяха направени 23 тривентрикулостомии: 15 при пациенти с оклузивна хидроцефалия (по време на проследяването при 66,7% от тях се наложи шънтиране след вентрикулостомията) и 8 при пациенти с комуницираща хидроцефалия с честота на успех 12,5%.

От 11 фенестрации на арахноидни и поренцефални кисти 18,2% бяха успешни. Направени бяха 2 аквелуктопластики със 100% успех.

Анализирайки нашите резултати и сравнявайки ги с данните на други автори, ние правим заключението, че успехът или провалът на невроендоскопията е тясно свързан с възрастта на пациента. Нашите резултати бяха сигнификантно по-добри в случаите с обструктивна хидроцефалия, причинена от аквелуктна стеноза, където тривентрикулостомията беше последвана от аквелуктопластика. С увеличаване възрастта на пациента, процентът на успех на невроендоскопската фенестрация се увеличава също.

Ключови думи: *невроендоскопия, детска неврохирургия, тривентрикулостомия*

Neuroendoscopy was introduced in Bulgaria in the beginning of the year 2000 /2/. As one of the basic techniques in minimally invasive neurosurgery it was applied for relatively short period of time in many areas of the cranial surgery.

In pediatric neurosurgery it was most often used in patients with internal hydrocephalus for 3rd ventriculostomy (ETV), aqueductoplasty, fenestration of tumoral and non-tumoral cysts, septostomies, and for inspection and biopsy of peri/intraventricular tumours.

The purpose of this study was to analyze the results of our three years experience with neuroendoscopy in pediatric neurosurgery.

MATERIAL AND METHODS

During the period April, 2000 to April 2003 in the Department of Neurosurgery at Medical University Sofia, 89 neuroendoscopic procedures were performed - 36 in children and 53 in adults.

The pediatric patients ranged in age from 1,5 months to 18 years (mean age 65 months). Seventeen of 36 children were younger than 24 months. The distribution of the neuroendoscopic procedures in pediatric age according to their type in the childhood is reviewed in **table 1.**

For the purpose of the analysis the following criteria for an efficacy of the neuroendoscopic procedure were accepted:

- reduction of the ventricular sizes at neuroimaging investigations (CT, MRI);
- improvement of the clinical state of the patient (alleviation of the symptoms of intracranial hypertension).

Table 1.: Distribution of the neuroendoscopies by type in the childhood

3rd ventriculostomy	23
Cyst fenestration	11
Aqueductoplasty	2
Dilatation of foramen of Monro	2
Inspection and tumor biopsy	1

The neuroendoscopic procedure was defined as successful when during the follow-up the child was asymptomatic, respectively no further intervention was required. The follow-up period ranged from 1 month to 3 years (on average 15 months).

RESULTS

Twenty-three ETVs were performed - 15 of them were in cases with occlusive hydrocephalus and 8 - in patients with a communicating hydrocephalus.

From the children with obstructive hydrocephalus ETV was successful in 3 of them (20,0%). In 10 (66,7%) of the patients a CSF shunting procedure was subsequently necessary, and 2 were lost for follow-up.

Only in 1 case from the 8 children with communicating hydrocephalus (12,5%) a CSF shunting was not necessary during the follow-up. In other 4 cases (50,0%) CSF drainage was performed and for 3 patients no data were available.

From 11 cyst fenestrations (porencephalic and arachnoid cysts) only 2 (18,2%) were successful; another 5 procedures (45,5%) were ineffective upon follow-up; 4 children were lost for follow-up.

We performed 2 aqueductoplasties and both were successful (according to clinical and neuroimaging criteria).

Two procedures for restoration the patency of foramen of Monro were performed in asymmetric enlargement of the lateral ventricles following CSF shunting. Both procedures failed and the conditions required drainage of the isolated lateral ventricle with an additional „Y"-shaped connector.

DISCUSSION

The results of the neuroendoscopic procedures in children, performed for a period of three years in the Department of Neurosurgery, University Hospital „Alexandrovska" were analyzed and compared with the data from the literature.

T. Beems and J. Grotenhuis, 2002 (1) reported in a series of 250 patients, that depending on the etiology, success rates of ETV varied from 21,4% to 96,3%, best results being achieved in patients with secondary aqueductal stenosis. This is in concordance with our results.

In 230 neuroendoscopic procedures for hydrocephalus P. Perreta, 2002 (6) reported a success in 72% of them. He emphasized, that children younger than 12 months require shunts following endoscopy more frequently than adults (in 47,0% versus 40,0%). The percentage of children under 12 months of age in the subgroup of 128 shunt-free patients in his series was only 18,5%.

According to A. Cartmil et al, 2002 (3) ETV is more successful in patients older than 60 months. The secondary neuroendoscopic procedures were less effective, as well as those in cases with hydrocephalus, caused by meningitis or intraventricular hemorrhage.

J. Punt, 2002 (8) reported in 88 patients (aged between 1 day and 69 years) an ETV success rate of 52,0 %. H. Schroeder et al, (9) analyzed a series of 17 patients treated with aqueductoplasty; in half of them reduction of the ventricular sizes was achieved.

According to H. Carton et al, 2002 (4) the rate of efficient ventriculostomies (defined by the need of reoperation) at a mean follow-up of 35 months was 54,0%.

Other authors reported higher success rate of the ETV in children with tectal plate gliomas (10), as well as in the treatment of shunt malfunctions (4).

N. Hopf and A. Perneczky, 1998 (6) demonstrated very good results with neuroendoscopies and endoscope-assisted microneurosurgery in the treatment of intracranial cysts, especially those in the ventricles and in the posterior cranial fossa.

In the series of M. Tisell et al, 2000 (10), ETV in patients with non-communicating hydrocephalus was successful in about half of the cases. One third of his cases improved temporarily (1 to 12 months) following ETV, and afterwards they deteriorated to a state even worse than before the procedure. The patients without a permanent improvement after ETV were treated efficiently with shunting procedures of the hydrocephalus.

Analyzing our results and comparing them with the data of other authors, we can conclude, that the success or the failure of the neuroendoscopy was closely related to the age of the patients. From 14 patients with an ETV, which underwent additional shunting, 10 (71,4%) were children younger than 24 months. Three out of 5 cases with cyst fenestration failures were under 24 months, too.

One possible explanation for the worse results of ETVs and cyst fenestrations in children younger than 24 months might be the higher brain plasticity and the propensity to restore the integrity of the fenestrated tissue following endoscopy.

CONCLUSIONS

In children younger than 24 months, the need for a supplementary shunting procedure after ETV and/or cyst fenestration was higher than in older children. Our results were significantly better in obstructive hydrocephalus, caused by an aqueductal stenosis if the 3rd ventriculostomy was followed by an aqueductoplasty. With increasing age of the patient, the success rate of of the neuroendoscopic fenestration increased, too.

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INTRAOPERATIVE ULTRASONOGRAPHY IN NEUROSURGERY

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ABSTRACT

Background and significance: This study aimed at analyzing the capabilities and value of intraoperative ultrasound for image guidance in neurosurgical interventions. Intraoperative ultrasonic scanning provides real time imaging of normal and pathologically changed brain tissue. This technique is considered to provide a reliable vizualization of eloquent neural structures in relation to the lesion thus allowing safe control of the extent and radicality of the surgical resection. According to the literature, intraoperative ultrasound has been used in a broad spectrum of neurosurgical interventions - in subcortical and deep-seated brain neoplasms, haematomas, large or gigantic aneurysms, vascular malformations, spinal tumors and cysts, as well as for early postoperative control in decompressive craniotomies.

Material and Methods: Dynamic scanning in real time was based on the so-called B-mode. The instrument we used was *Logiq200 Pro* with two I-type and T-type transducers, with a visibility field of 35 mm and working frequency ranges of 6 MHz and 7 MHz, with a depth of imaging 25-80 mm.

Intraoperative ultrasonic imaging guidance was applied in 72 non-consecutive, randomly chosen patients. In 63 cases ultrasound was applied in intracranial space-occupying lesions, and in another 5 patients - for spinal pathology; in 4 cases the ultrasound imaging was used for early postoperative control and management following decompressive craniotomies.

Results: We observed and described the specific sonographic imaging features of various intracranial space occupying lesions. All images have being documented by means of a high resolution digital camera. In all patients, preoperative CT and MRI images were compared with the intraoperative ultrasound. We emphasize on the negligible invasiveness of intraoperative ultrasound combined with a reliable intraoperative localization information, especially in subcortical lesions in eloquent abrain areas, as well as on the opportunity to apply ultrasound in combined surgical approaches.

Conclusions: The benefits of intraoperative ultrasonography imaging are several: it is an entirely non-invasive method, the operating surgeon obtains imaging information in real time, i.e. watching the immediate changes and progress of the surgical intervention, and last but not least - the very low running costs and affordable prices of the equipment. In our experience, intraoperative ultrasound imaging may become a competitive alternative to other image-guided techniques.

Key words: *ultrasonography-guided neurosurgery, real-time intraoperative imaging, space-occupying CNS lesions.*

ИНТРАОПЕРАТИВНА УЛТРАСОНОГРАФИЯ В НЕВРОХИРУРГИЯТА

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РЕЗЮМЕ

Цел: Настоящото проучване цели да анализира и представи възможностите на интраоперативната ултразвукова диагностика като метод за образно ръководене на неврохирургичната интервенция. При ултразвуковото скениране се получават образи на нормални и патологични тъкани и обемни лезии в „реално време“. Това позволява динамичен контрол в радикалността на оперативната интервенция при същевременна минимална инвазивност по отношение на невралните структури. Приложението на ултразвуковата интраоперативна диагностика е твърде широко - при субкортикални и по-дълбоки туморни лезии, хематоми, големи и гигантски аневризми и съдови малформации, спинални тумори и кисти, както и за ранен следоперативен контрол при декомпресивно завършили краниотомии.

Клиничен контингент и методика: Динамичното скениране в реално време се основава на т.н. B-mode. Той се базира на свойството на ултразвука да се отразява по различен начин на границата на две среди с различна плътност и от тъканите с различни физикохимични характеристики. Отразяването частично се поглъща в зависимост от акустичния импеданс на биологичното поле. Използвания от нас апарат е LOGIQ200PRO с два трасндюсера I-тип и T-тип, които имат „поле на видимост“ 35 мм и работни честоти от 6 MHz и 7 MHz, при дълбочина на получените образи от 25 мм до 60 мм.

Ултразвуково ръководени оперативни интервенции бяха извършени при 72 непоследователно подбрани наши пациенти. В 63 от тях ултразвуковата диагностика беше използвана при интракраниални обемни процеси (най-често метастази), при 5 - за спинални обемни лезии и при 4 - за ранен следоперативен контрол при декомпресивно завършили краниотомии.

Резултати: Освен безспорно доказаната мининвазивност, особено при субкортикални лезии във функционално важни зони, бяха отчетени възможностите на ултразвуковото интраоперативно изследване при комбинирани неврохирургични достъпи. Беше наблюдавана специфична ехографска характеристика на образа на различни видове тумори. При всички пациенти извършихме съпоставка на предоперативните КТ- и ЯМР-образи с тези от ултрасонографията, като всички образи бяха документирани с дигитална фотокамера.

Заключение: Предимствата на интраоперативното ултразвуково изследване са няколко: неинвазивност, изображение в „реално време“, т.е. отразяват промените съпътстващи интервенцията, реална алтернатива на други образно водещи методики, достъпна цена на апаратурата.

Ключови думи: *ултразвуково ръководена неврохирургия, интраоперативно изобразяване в „реално време“, обемни процеси на ЦНС.*

INTRODUCTION

Ultrasonic scanning yields images of normal or pathologically changed tissue and mass lesions in real time. This allows the technique to be applied intraoperatively in order to achieve control over the process and extent of the surgical resection, as well as to reduce its invasiveness into eloquent neural areas. Intraoperative ultrasonic imaging has been reported to be successfully applied in a broad spectrum of situiations, such as subcortical or even deep seated cerebral tumours, haematomas, large or gigantic aneurysms and vascular malformations, spinal tumours and cysts, as well as for early postoperative control following decompressive craniotomies. The possibility to obtain dynamic intraoperative images of the lesion, thus accounting for the inevitable intraoperative brain shift gives intraoperative ultrasound some advantages when compared to other techniques for image guidence such as frameless stereotaxy.

This study aimed at analyzing the capabilities and value of intraoperative ultrasound for image guidance in neurosurgical interventions.

MATERIAL AND METHODS

Dynamic ultrasonic scanning in real time is based on the so-called B-mode. Ultrasonic diagnostic imaging instruments use a range of high frequency sound waves imperceptible to the human ear. These ultra-high frequency sound waves are proliferating through space by mechanical oscillations of the substances or media. The application of ultrsonic waves in practice is based on their property to have different reflectance at the borderline surfaces of two media with different densities or physicochemicl properties. Ultrasound is reflected only partially, and a rest of it is being absorbed in dependance of the acustic impedance of the biologic field. The transducer probes are in fact sensors, receiving the reflected pulses, transforming them into electric current, which is subsequently amplified and visualised by a monitor.

STATIC VERSUS DYNAMIC SCANNING

The static images are in fact a sum-total of the reflected sound waves, or an ultrasound echo, carrying information of a close fit to the original object. The received dots (as modulated amplitudes of the signal from the examined object) are being turned into an image by means of a dot matrix of scan convectors producing dots in various different nuances of gray (the so-called *gray scale*). The construction of dot matrix gave the ultrasound instruments the capability of obtaining various specific images, representing a broad range of pathologic changes. Without the dot matrix ultrasound imaging method would not have gained such a popularity and worldwide application in clinical practice, for the black-and-white monitor image is not that highly informative as to the details of a cross-sectional view of the examined object.

Dynamic imaging was achieved by a series of modern ultrasonography transducers, especially with adjustable focus ranges, which are a truly remarkable achievement in the field of instrumentation. Dynamic scanning was accomplished with one or more mechanically fast-moving details (sector scanning), or through a much larger number of electronically conected piezo-crystals set in line (linear scanning). The resulting „overlapping" (electronically synchronized information) produces a moving image on the monitor, thus allowing the surgeon to follow the movements of the organ or surgical instruments around it.

B-mode is basically imaging a two-dimensional cross-section of the examined area, each dot on the monitor screen corresponding to a dot of the cross-section. Such type of monitor imaging technique has so far yielded the best informative value. The principles of the A-mode are used in order to get the two-dimensional values of the image, but the *exam* is already made of light dots, simultaneously the light beam goes scanning crosswise (thus providing a summation of the two superimposed images in the two plains).

We used for intraoperative ultrasound scanning the unit *Logiq200Pro* with two I-type and T-type transducer probes, with a 35 mm „wedgeof space" visibility range, working frequency of 6 MHz and 7 MHz, capable of visualizing lesions at a depth from 25 mm up to 60 mm **(Fig. 1)**. Transducer probes operating at higher frequencies yield higher resolution, but they are applicable in subcortical and spinal lesions only, as raising the frequency of the ultrasonic beam reduces its depth of penetration. As a result, transducer probes with operative frequencies from 5.5 MHz up to 10 MHz are mostly being used for the purposes of intraoperative neurosurgery imaging. The unit we used is capable of storing the last nine images and comparing them with the actual images, simultaneously performing either a digital or an analogous signal video-recording of the entire surgical intervention.

A comparison and correlation were made between the images obtained by ultrasonic methods, the pre-operative images and the histological result.

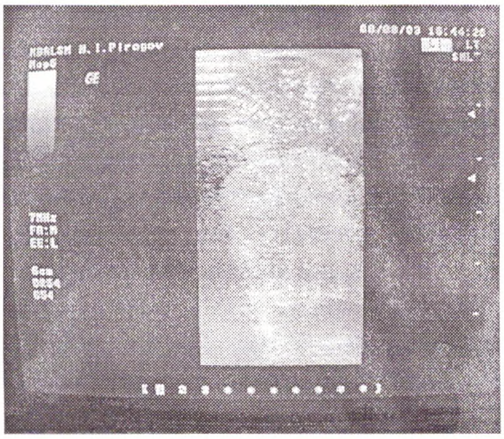

Fig. 1

CLINICAL MATERIAL

This series includes 72 randomly selected patients, harbouring:

1. Small subcortical mass lesions located within or in the vicinity of eloquent areas.
2. Subdural spinal mass lesions.
3. Space-occupying lesions, located supra- and infratentorially.
4. Lesions lacking clearly defined with the preoperative imaging diagnosis.
5. Traumatic deap-seated space-occupying lesions.
6. An additional group of 4 patients, treated with decompressive craniotomies was subjected to serial ultrasound scanning in the early postoperative period.

In this series male/female ratio was 2/1. On average, females were 53,3 years old, while in males the age was 52,1 years. The mean duration of the hospitalization was 15 days. Four of the patients died: 2 of them harboured multiple metastases, 1 had a large spontaneous intracerebral haematoma, and in another one death was caused by systemic complications. The distribution of the patients according to their pathololgy is reviewed in the following two tables below:

Table 1. Intracranial pathology

Low grade gliomas	5 cases
High grade astrocytomas and glioblastomas	12 cases
Metastases	19 cases
Meningeomas	11 cases
Haematomas	6 cases
Abscesses	3 cases
Cysts	2 cases
Primary non-Hodgkin's lymphomas	1 case
Aneurysms	2 cases
Tumours in	5 cases
Spinal-cord tumours	5 cases
Cavernous angiomas	1 case

Table 2. Intraspinal pathology

Meningeomas	1 case
Astrocytomas	1 case
Oligodendrogliomas	1 case
Arachnoidal cysts	1 case
Haematomas	1 case

From the patients with brain metastases 10 harboured solitary lesions, and 9 - multiple tumors (mostly 3 lesions); in 6 patients metastases were located supra- and infratentorially. All patients from the latter group were operated on in a single stage, with two flaps, or alternatively by a combined supra/infratentorial approach. We are of the opinion that the use of intraoperative ultrasound imaging guidance reduces the time needed for the surgical intervention, especially the time needed for localization of smaller metastatic lesions. On the other hand, the precise localization with intraoperative ultrasound imaging guides the access through the neural structures less traumatically. Actually, this applies to all the cases with space-occupying lesions, particularly those with malignant tumours with significant perifocal oedema, which are hard to localize with the standard surgical technique. The removal of the bone flap provides an access to the pathology with a minimum damage to the surrounding normal brain tissue. In our practice we use a ventricular needle, relatively well monitored on screen, thus providing the choice of a shortest and least traumatic path to the tumour. Interestingly, in metastatic lesions, irrespectively of the presence or absence of cystic transformation, the imaged field always remained hyper-echogenic, yielding a clearly hypo-echogenic imaging of the oedematous tissue.

In astroglial tumours, comparison of the ultrasonographic, morphological, and pre-operative imaging demonstrated a specific pattern according to their grade. Low grade gliomas displayed hyperechogenicity, which was always well delineated at the border between tumor and edema. On the contrary, edema in glioblastomas was iso- or hypoechogenic between tumor and perifocal edema, as well as between edema and normal brain tissue. In low grade gliomas a clearly delineated hypo-echogenic cystic areas have been observed, superimposed on the hyperechogenic background. With glioblastomas, hyper-echogenc features are in turn changing into sectors of mixed echogenic properties, without any sharp borderline delineation between them. The borderline delineation between the tumour and edematous perifocal neoplastic growth on the contrary, was always very well delineated, and quite clearly discernible, thus allowing intraoperative shaping up of a clear-cut plan of the resection.

The transdural ultrasound imaging in cases of spinal cord tumours always showed us how adequate the laminectomy has been positioned, and to what extent should it be widened in order to achieve a well visible field of the borderline between the normal medula and the tumour. The ultrasonographic features of the image do clearly predict whether the lesion is intra- or extraaxial. E.g., astrocytomas have homogenous echogenic properties, the hyper-echogenic meningiomas show the exact borderlines of their nests, rendering the medula atrophic from thereon, while with cysts, hypo-echogenity is clearly delineated by a thin hyperechogenic wall all around them.

Intraoperative ultrasonography imaging has turned out to be particularly useful in cerebrovascular pathology. Large and giants aneurysms of the middle cerebral artery are particularly well visualized by ultrasonic imaging. Other important characteristics that are quite well discernible transdurally are whether an aneurysm is of the saccular or fusiform type, finding out the exact dimensions of the aneurysm neck, the direction of blood flow, and the position relative to the bifurcation. The latter may allow a direct access to the aneurysm neck through the Sylvian fissure. We still have no experience with arteriovenous malformations, but they are numerous publications in the literature, demonstrating the benefits of intraoperative ultrasound imaging also for those type of lesions.

The use of intraoperative ultrasonic imaging also makes it easier to register in time any dynamic intraoperative developments. This is especially important when a displacement or shifting of the neural structures is expected to occur during resection of the lesion and helps to detect the presence of possible tumor residua. Unlike frameless stereotaxy, in ultrasonic image guidance we are not dependent on the brain shift phenomena, which significantly alter the accuracy of the latter method.

The intraoperative ultrasonography can easily identify a cerebral haematoma because of the different values of the acoustic impedance at the borderline between two different tissues. An ultrasonic probe is used in order to monitor the changing shape and localization of the residual collection, as well as for guidance and navigation in endoscopic intraventricular procedures.

Recently, we have also introduced ultrasonography imaging for the purposes of early post-operative check-up in patients whose operations were completed with a bone decompression. It is an easy, time-saving, and highly accurate way of coming to an early diagnosis of haematoma formation within the tumour resection cavity, as well as for documentation of how radical the extirpation of the tumour was.

RESULTS

1. Intraoperative ultrasound was carried out in a broad spectrum of pathological processes within the supratentorial, infratentorial, and intraspinal areas.
2. A good correlation between other preoperative imaging methods and the intraoperative ultrasonic imaging was documented in variuos histological types of lesions .
3. We started using ultrasonography routinely in various occasions, and was found to make the single-stage removal much easier.
4. Typical ultrasonographic images for some types of tumour lesions were described.
5. The use of ultrasonography imaging in aneurysmal surgery was successfully initiated and will be established in further practice as well.

Besides the minimally invasive character of ultrasound, especially in cases of subcortical lesions within functionally important areas, the usefulness of intraoperative ultrasonography imaging in combined surgical approaches was noted. It allowed the successful removal of two or even three metastases in one surgical session, even in cases with supra- and infratentorial lesions. Another important contribution of this investigation, we believe, is the good correlation between the morphological findings, the preoperative imaging (CT, MRI), and the results of the ultrasonographic scanning. The specific ultrasonographic imaging features of different types of tumours were examined. Intraoperative ultrasonic imaging guidance of the surgical intervention for cerebro-vascular pathology was applied for the first time in Bulgaria, and the ultrasonically guided surgical operation was recorded on a video-casette, simultaneously with the recording made through the surgical microscope.

Only 8 out of 72 patients (11 %) were discharged with some postoperative neurological deficit. Taking into consideration that the study has involved a variety of pathological conditions, predominantly malignancies (58,3%) and relatively older patients, we believe that ultrasound has contributed significantly for this outcome.

DISCUSSION

The initial clinical applications of neurosonology were related to localization of some intracranial lesions. The works of pioneers in this field like Turner, Lexell, and Gordon in the 50-ties of 20th century resulted in the introduction of echoencephallography, also known as sonoencephallography (9,11,14,15). Ultrasonography gained acceptance in neurosurgery through this technique with the intention to assess displacement and shifting of the structures across the brain midline in cases of space-occupying lesions. Although the initial technology used simply measurement of the movements and shifting of the structures across the midline only, the method was used in a number of various applications.

Ultrasound had often been used for localizing of subcortical lesions, too. Such small lesions are often surrounded by a considerable oedema, which makes it hard to discover the tumor using the routine surgical techniques. Finding out where exactly the lesion is located is a prerequisite for minimally invasive technique of surgical resection in eloquent brain areas (brain stem, sensomotor area etc) (6,7,10). Ultrasonography is useful before and after dura opening and helps to localize the lesion, and subsequently to plan the less invasive access trajectory. The high degree of ist accuracy, the simplified procedure, and the low cost of ultrasonography have made it an acceptable alternative to frame-based stereotaxy in guidance for tumor (2,8,9).

R. Goodkin et al, 1991 (5) demonstrated the application of „micro-bubble“ contrast in proving the *foramen Monro* pattency following resection of a 3rd ventricular colloid cyst. This technique has also found application in cardiac ultrasonography. It allows intraoperative examination of the liquor pathways and localiztion of potential obstructions. In addition, this is a valuable technique for identifyication of residual parts of cystic lesions during the surgical procedure. That method was later developed by N. Harrer et al, 2003 (3). By injecting a contrast medium preoperatively, the tumour formation may be well localized intraoperatively through a bone apperture, also determining the degree of its blood supply, as well as the patency of its majour supply vessel (3, 5).

The concommitant use of colour Doppler ultrasonography intraoperatively is an efficient tool for differentiation of the supplying and draining blood vessels of the cerebral AVM, and is widely used for verification of possible residual nidus before completion of the surgical procedure (1,2,9,15).

Oykarinnen et al described an elegant system of concurrent entering the feedback data of intraoperative ultrasonography into the medical databas in real time. They use a passive localization cross-piece for spatial registering of the images obtained during the intraoperative use of ultrasonography and computer-aided tomography. The computer system compares the preoperatively entered data of the CT images to the changes that have occurred at the ultrasonographically guided surgical operation (2,4,9,12).

By applying the above techniques, real time intraoperative localization of solid and vacular lesions has become a quick and repeatable method for enhancement of the surgical reliability. Although it has the same capabilities as the stereotactic localization, ultrasound provides a unique opportunity to observe in real time the changing intraoperative anatomy during surgery of tumor or haematoma and to analyze cerebrovascular lesions such as AV malformations (1,8,13,15).

CONCLUSIONS

Intraoperative ultrasonic imaging provides a real alternative to other image-guided methods in neurosurgery. Its advantages are several: noninvasive nature, imaging in real time during the the surgical procedure, easy preparatory work and maintenance of the instruments involved, afordable prices of the hardware

Another advantage is the possibility of simultaneous application together with an edoscope (in cases of ultrasonic control of the endoscoping imaging), the use of an auxilliary unit for colour Duplex scanning, the capability of being plugged-in into a computer-aided system for frameless neurosurgical guidance, either by fiber-optical or magnetic marking.

We recommend the use of intraoperative ultrasonography in selected neurosurgical interventions, especially in:

1. Multiple lesions, helping for a single-stage surgical resection.
2. Infiltrative intraxial processes - for determination the borderline limits of resection.
3. Small-size subcortical lesions.
4. Cranio-cerebral traumas.
5. Spinal subdural processes.
6. Cerebrovascular surgery.
7. Intracranial foreign bodies.

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MICROSURGICAL TREATMENT OF CRANIAL RHIZOPATHIES

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ABSTRACT

One hundred fifty eight patients suffering from hyperactive dysfunction syndromes of cranial nerves have been treated between 1981 and 2002. Microvascular decompression /MVD/ at the root entry or exit zones of the cranial nerves has been performed. The operative exploration of the parapontine root entry zone of the Vth nerve disclosed neurovascular conflict in 85,0% of the cases. There were displacement and/or distortion, sometimes pressure grooves, discoloration, altered vascularity of the V, VII, VIII, IX, XI nerves. The analysis of postoperative results has shown an excellent outcome in 88,4% of the cases, good in 6,7% and poor in 2,9%, with mortality rate of 2,0% (early in this series when no postoperative monitoring was available). The follow-up study longer than two years after surgery revealed 86,2% excellent and 7,7% good results, and poor outcome and recurrences in 6,0% of the cases. During last years partial sensory rhizotomy was performed in cases with trigeminal neuralgia /TN/, where no neurovascular conflicts were found. In cases with spasmodic torticollis /ST/ MVD was not enough, that's why rhizotomy of ventral C1- C3 roots was combined with sectioning of rootlets of spinal part of XI nerve. Patients with unquestionable arterial compression leading to displacement associated with distortion and pressure grooves had excellent outcomes. Patients with previous destructive procedures, venous compression, lack of convincible evidences for neurovascular conflicts had less favorable results or presented later on by recurrences. Early recurrences were associated with missed pathology, adhesions or change of isolation material at the entry zones. During reexplorations for late recurrences new arterial compression was found in less than half of the cases.

Keywords: *cranial rhizopathies, microvascular decompression*

МИКРОНЕВРОХИРУРГИЧНО ЛЕЧЕНИЕ НА КРАНИАЛНИТЕ РИЗОПАТИИ

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Резюме

Анализират се 158 болни с признаци на типични краниални ризопатии тригеминална невралгия /ТН/, лицев хемиспазъм /ЛХС/, вертиго, тинитус, тортиколис /ТС/, оперирани за периода 1981-2002. Осъществена е микросъдова декомпресия на входната/изходна коренчева зона на черепно мозъчните нерви. При интраоперативната инспекция на парапонтинната входна зона се установява наличие на съдовонервен конфликт в 85 % от случаите. Той се изразява в дислокация и/или компресия съчетана понякога с формиране на бразда от притискане, промяна в цвета, повишена васкуларизация или релативно анемизиране в коренчевата част на V, VII , VIII , IX, XI черепномозъчни нерви. Анализът на следоперативните резултати показва отличен изход в 88,4% от случаите, добър в 6,7% и лош резултат в 3 %, както и смъртност в следоперативния период в рамките на 2% от началото на серията (когато не е имало възможности за мониториране). Проследяването повече от 2 год. след операцията показва 86,2% отлични и 7,8% добри резултати, а лоши резултати и рецидиви в 6,03%. През последните години е правена и частична сензорна ризотомия при болни с ТН без категоричен невроваскуларен конфликт, а при болни със ТС ризотомия на предните коренчета на 3-те краниални шийни коренчета, съчетана с ризотомия на най-краниалните коренчета на 11 ч.м.н. Болните с несъмнена артериална компресия, водеща до изместване с разтягане и вдлъбнатини от притискане са имали отличен ефект. Болни с предхождащи деструктивни процедури, венозна компресия, липса на категоричен невроваскуларен конфликт са с по-висок процент на неблагоприятен изход или рецидив. Ранните рецидиви са били свързани с пропусната патология или промени на изолиращия материал в областта на входната зона. При реексплорация за късни рецидиви е намирана нова артериална компресия в по малко от половината случаи.

Ключови думи: *краниални ризопатии, микроваскуларна декомпресия*

INTRODUCTION

The term cranial rhizopathy is used to designate cranial nerve dysfunctional syndromes: trigeminal neuralgia, hemifacial spasm, tinnitus, glossopharyngeal neuralgia, distonic torticollis .

Cranial rhizopathies are relatively uncommon pathology. However, they are associated with severe pain in trigeminal and vagoglossopharyngeal neuralgia, or abnormal motor hyperactivity in hemifacial spasm and spasmodic torticollis. This leads to significantly reduced working capacity and disturbances of social adaptation. On the other hand successful surgery may offer amelioration or cure of these syndromes.

The surgical treatment of trigeminal neuralgia was one of the first successful interventions in the field of neurosurgery. In 1901, retrogasserian neurotomy performed by Spiller & Frazier (48) was introduced. The more physiological microvascular decompression (MVD) procedure has been developed step by step since the first observation in 1934 by Dandy (14), who had noted that the trigeminal nerve was often crosscompressed by a neighboring elongated artery, or sometimes by a satellite vein. The first vascular decompression of the V nerve was performed by Gardner (17). The method was further promoted by P.Jannetta since 1969 (20, 23). By that time vascular compression has been identified as a cause of TN (7, 14, 24, 37), and other cranial nerve hyperactive dysfunction syndromes, such as hemifacial spasm (HFS) (16, 24, 25, 35), glossopharyngeal neuralgia (GPN) (25, 28, 32), disabling positional vertigo (DPV) and tinnitus (25, 26), intractable hiccup (19), hypertension (17, 34, 36) and spasmodic torticollis (ST). The MVD of the cranial nerves at their entry zone is frequently used nowadays for treatment of drug resistant TN, HFS, GPN, DPV, and ST. It is recommended as relatively safe and effective surgical procedure preserving the functional integrity of the V, VII, VIII, IX nerves function (16, 23, 24, 25, 39, 40, 41, 47, 48). Surgical procedures for ST include MVD of the 11 nerve (17, 29) as well as rhizotomy of the upper rootlets of the 11th nerve and I-III ventral cervical roots (9, 10, 15).

PATIENTS AND METHODS

One hundred fifty eighth patients (53,2% male and 46,8% female) with signs of classical cranial rhizopathies have been treated by lateral suboccipital craniectomy and MVD for root compression of V, VII, VIII, IX and XI rootlets between 1981 - 2002. All patients have had regular preoperative CT examinations to rule out tumors or gross vascular pathology, and more recently MRI study was used to demonstrate more clearly possible neurovascular conflicts. The mean age of the TN-134 patients was 56,8 yrs. The 2nd and/ or 3rd division of the V nerve were affected in 67,6% of the cases. In 20,0% all 3 divisions were involved and in 12% of the cases the pain was located in the territory of the 1st and/or 1st and 2nd branches.

HFS - 9 patients with mean age 48,2 yrs.; Tinnitus-2 pts.- 47,2 yrs.; GPN-2 pts. -63 yrs. ; ST-11 pts. mean age 52,4 yrs. (all ranging from 20-80 yrs). Retrospective analysis of the patient's files including histories, neuroradiological investigations, surgical reports as well as data from follow up examinations was performed.

OPERATIVE TECHNIQUE

It is well known that much of the ease and difficulty of the MVD procedure may be determined by patient positioning (20, 23, 24). Surgery was done in lateral decubitus position (22, 39, 40), with few exceptions in which supine position (4) was used. Three point head-fixation pin holder was applied, the neck was flexed slightly with the chin approximately 2 finger breadths from the sternum. The head was rotated ~ 10^0 away from the affected side, and the vertex was kept parallel to the floor for TN pts., (to keep the VII - VIII cranial nerve complex at a more inferior) and vertex 15^0 down to the floor for lower cranial nerves. The patient was taped securely to the table to allow rotation of the table during the operation. A vertical skin incision 3-5cm long 0,5 cm posterior and parallel to the hair line in the retromastoid area according to the bone landmarks and operative technique of Jannetta (21, 23, 40) was utilized and the details of the microsurgical anatomy of the approach (45) were considered. The decompressed V VII, VIII, or IX nerve roots were isolated from the artery by piece of Gelaspon/ Surgicell, muscle, or more recently by interposition of subcutaneous fat fixed by fibrin glue. The fat tissue was clearly demonstrated on postoperative CT and MRI. The treatment of ST included bilateral sectioning of the ventral portions of the C1,C2, C3 roots and the most cranial rootlets of the spinal division of the 11th nerve ipsilateral to the spastic sternocleidomastoid muscle as well as sectioning of the sternocleidomastoid muscle in limited number of cases.

During the last three years endoscopy was used in addition to microsurgery in order to explore hidden areas and proved to be valuable tool to disclose missed pathology without additional retraction and manipulation of neurovascular structures.

RESULTS

During the suboccipital lateral posterior fossa exploration neurovascular conflicts were found in 136 patients (85%). In 76 patients the superior cerebellar artery (SCA) was responsible for the neurovascular conflict (NVC) displacing, distorting and/or grooving trigeminal root at root entry zone (REZ) **(Fig. 1)**.

It should be pointed out that in cases with longer duration of painful preoperative condition the pressure grooves on the V nerve were associated with grayish discoloration and alternating areas of reduced and/ or increased vascularity indicating local vascular disturbances. In some cases the loop of the SCA was wedged between the anteroposterior border of the trigeminal root and the pons. In 21 cases the anterior inferior cerebellar artery (AICA) was the offending vessel, in 6 patients both SCA and AICA were found to compress the 5th, 7th, 8th cranial nerves. PICA was found to be the reason for NVC in 3 cases. After decompression of the nerve root the artery was isolated from the nerve using piece of muscle or Gelaspon/ Surgicell/, or fat tissue **(Fig. 2)**.

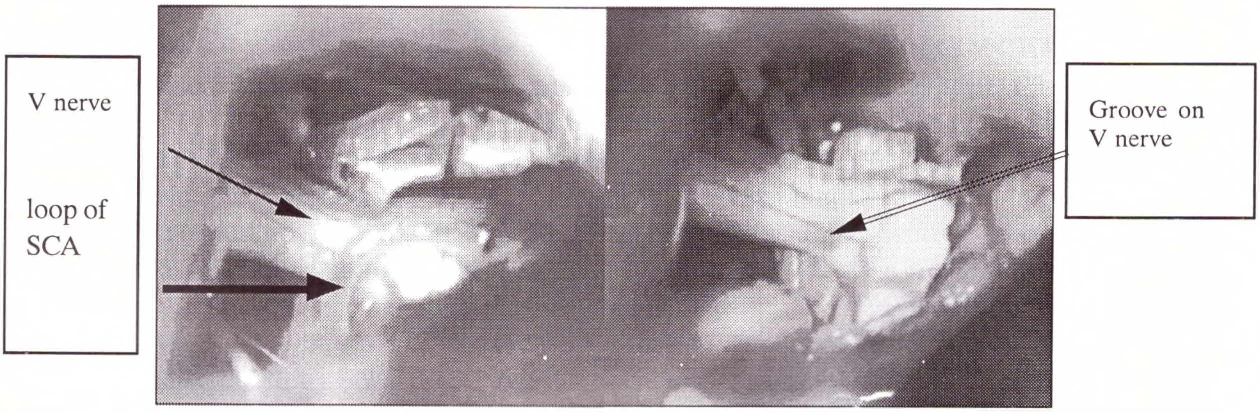

Fig. 1 NVC-SCA/V nerve

(See color aplication)

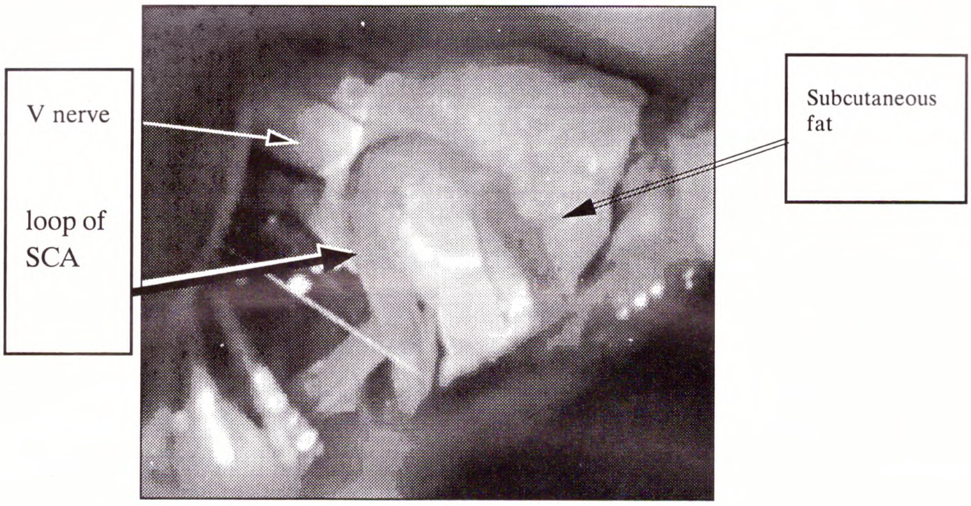

Fig. 2 MVD of V nerve with fat tissue.

(See color aplication)

In 5 cases of severe trigeminal pain, dolichoectatic basilar artery was found to cause compression and distortion of the 5th nerve root, and in another patient small AVM in the paratrigeminal pontine area and trigeminal root was found during surgery. In this case the pain characteristics were indistinguishable from those in the other patients. All cases with compression of the 5th root by dolichoectatic basilar artery underwent partial sensory rhizotomy with or without interposition of fat tissue. In 23 patients venous or simultaneous arterial and venous compression was observed and in 22 cases no convincible evidence for NVC was registered by the surgeon **(Table 1.).**

Table1. Neurovascular relations/NVC by 158 pts operated on for CR

SCA - 76	(51,7%)	PICA - 3	(2,0%
AICA - 21	(14,3%)	Veins - 23	(15,6%)
SCA +AICA - 6	(4,9%)	AVM - 1	(0,7%)
BA - 5	(3,4%)	No evidence - 22	(14,9%)
VA - 11	(7%)		

It should be emphasized that in the cases without any evidence of neurovascular conflict the clinical presentation did not differ from the typical cases of TN. In some of these cases conspicuous pallor and reduced vascularity of the 5th nerve was observed.

The early outcome was excellent in 88, 4% of the cases, good in 6,7%, poor in 3% and the mortality rate was 1,9%. The CT controls and postmortem examination have shown brain stem ischemia in patients with fatal outcome. The late follow-up results (more than one year after surgery) were excellent (patients free of pain/ complains w/o medication) in 86,2% , good (patients with mild pain/complains- not requiring medication or pain free on well tolerated medication) in 7,8% , and poor (patients without improvement after MVD, or recurrence of CR) in 6% of the cases **(Table 2.)**

Table 2. Surgical results of TN, HFS, GPN, DPV/T, and ST

Early:		**Late:**	
Excellent-	88,4%	Excellent -	86,2%
Good -	6,7%	Good -	7,8%
Poor -	3%	Poor/	
Mortality-	1,9%	recurrence -	6%

DISCUSSION

Trigeminal neuralgia is a relatively rare disease with annual rate of newly registered cases about 4,3/100 000 (5, 7 for females and 2, 5 for males) (27). Our study revealed different female to male ratio. It might be suggested that the severity of the attacks in male patients was greater than in female patients, or the latter had tolerated the pain better. The frequency of attacks varied from 1 to 11 per day, and their duration ranged from 1 to 1462 days (27, 28). Most of the patients in this study had crescendo attacks despite the increasing dosage of carbamazepine or intolerance to it. GPN is very rare with annual rate of new cases about 0, 8/100 000; F=M (1:1) L>R (3:2); For HFS the annual rate of registered new cases is 1/100 000 (R: L in about 3:2 and : ratio about 2:1 to 4:3. CR are disorders of adults - 5-7 decade, but 10% of patients are less then 40 years of age. (21, 27, 29, 30, 43)

Only patients meeting the criteria of classical CR (paroxysms of severe pain confined to one or more divisions of the Vth nerve, lack of objective evidence of motor or sensory deficits from the involved division, unpredictable remissions and exacerbations of pain, occurrence of trigger zones, type I of HFS- VII nerve, vertigo/ tinnitus/ hypacusis- VIII nerve, GPN - IX nerve) were considered candidates for MVD. All patients had long courses of carbamazepine treatment or other conservative management before surgery. A small number of patients could not tolerate medical treatment or had serious side effects.

The mortality figure in the present series was relative high compared to the literature survey (2, 4 , 8, 12, 23, 25, 39, 47, 40, 41) but all lethal cases were recorded early in this series when no precise monitoring was technically available and the patients had severe atherosclerosis noted by the surgeon.

The postoperative complications (temporary 4th , 7th and 8th cranial nerve deficit, cerebellar hematomas, or ischemia, CSF leaks, meningeal irritation, meningitis, brainstem ischemia) were similar to those reported by other authors (2, 6, 23, 24, 25, 29, 39, 40, 41, 49, 50). There is a clearcut tendency toward lower complication rate in recently operated cases, when the surgeon strictly followed the superolateral cerebellar route avoiding even the slightest retraction injury of other cranial nerves and using monitoring of the cranial nerve functions. **(Table 3.)**

Table 3 Postoperative Complications for CR in 158 pts.

Cerebellar hematoma-	1	Transient 4th n. palsy-	2
Brainstem ischemia -	3	Transient 7th n. palsy-	3
CSF leak -	3	Permanent hearing loss-	3
Meningitis -	3	Tinnitus -	1
Herpes zoster -	3	Gait Ataxia-	1

There seems to be general agreement that the rate of poor results is related to the duration of symptoms, previous surgeries and/or peripheral destructive procedures (2, 4, 5, 6, 8, 12, 16, 29, 30, 41, 49, 50) and this is confirmed by the present analysis. Partial sensory rhizotomy for TN has been recommended (8, 12, 30, 31, 40, 47, 49) in cases when: 1.) the V nerve was not found to be displaced by the arteries causing distortion and/or grooving of the nerve; 2.) no significant venous compression was evident; 3.) the patients local vascular anatomy was unsafe for MVD. Similar guidelines have been followed by us in the last years. The post operative examination disclosed milder than expected sensory loss within the territory of sectioned portion of the nerve. Usually the caudo lateral two thirds of the V nerve were sectioned according to the topographical distribution of the rootlets. In 5 cases the neurovascular conflict were caused by dolichoectatic basilar artery preoperatively diagnosed by CT and/or MRI. During surgery the V nerve was found to be severely compressed, tightened and elevated by the basilar artery. Recently, the surgical aspects of this infrequent cause of cranial nerves compression were thoroughly discussed (37, 40, 45, 48)

Small AVM's in the parapontine area have not been always detected by CT even with contrast enhancement. The only case encountered by us during surgery consisted of small feeders from SCA and AICA located in this area and the trigeminal root and the venous drainage was to the enlarged petrosal vein and their tributaries. Since the trigeminal nerve was penetrated by AVM some rootlets had to be sacrificed. Seven such cases had been reported (1, 3, 48) in large series of 1257 MVD surgeries.

The recurrence rates are compatible with those already discussed (8, 12, 27, 29, 31, 33, 39, 41, 48, 50, 52, 53). Early recurrences were unusual in this study and the re exploration disclosed missed pathology at the REZ. This happened in the beginning of this series. Late recurrences were encountered with a frequency similar to that already reported in the literature.

CONCLUSIONS

In this study the best results have been obtained in cases with shorter duration of symptoms of TN and other CR, and neurovascular conflicts representing severe, unquestionable compression/distortion distortion of the nerve at the root entry zone that resulted in pressure grooves, discoloration and altered vascularity. It seems that the use of fat tissue is better for controlling of isolation with MRI/CT postoperative controls. The additional endoscopical exploration of the hidden areas proved to be a valuable adjunct to the classical microsurgery by disclosing sometimes missed pathology and reducing the need for retraction of neurovascular structures. On the other hand, cases with long lasting symptoms of TN and/or those who had previous destructive procedures to control the pain as well as with neuro-vascular relationships representing simple contacts without associated displacement- distortion, and venous compression had less favorable outcomes and/or recurrences. Partial sensory rhizotomy of the affected divisions in addition to MVD seems to be advisable in such cases, despite the sensory disturbances that might follow. In cases with HFS, tinnitus/vertigo MVD is the treatment of choice. In cases of ST MVD of cranial roots of XI CN, but also C1, C2, C3 ramisectomy and sectioning of rootlets of the spinal part of XI nerve. to sternocleidomastoid muscle have to be done. Neuroendoscopy might be of significant value during operation for microsurgical treatment of cranial rhizopathies.

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APPENDIX (COLOR TABLES)

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ENDOSCOPY AND NEURONAVIGATION FOR THE MANAGEMENT OF HYDROCEPHALUS, VENTRICULAR TUMORS AND INTRACRANIAL CYSTS: PERSONAL EXPERIENCE IN 81 CASES

Veit Rohde, M.D., Volker A. Coenen, M.D.

Figure 1. Endoscopic view of the third ventricular floor in a patients with occlusive hydrocephalus. The mamillary bodies are clearily visible. The bulging, thick and opaque third ventricular floor does not allow to localize the basilar artery prior to puncture. Neuronavigation was helpful to select a puncture site in safe distance to the basilar artery.

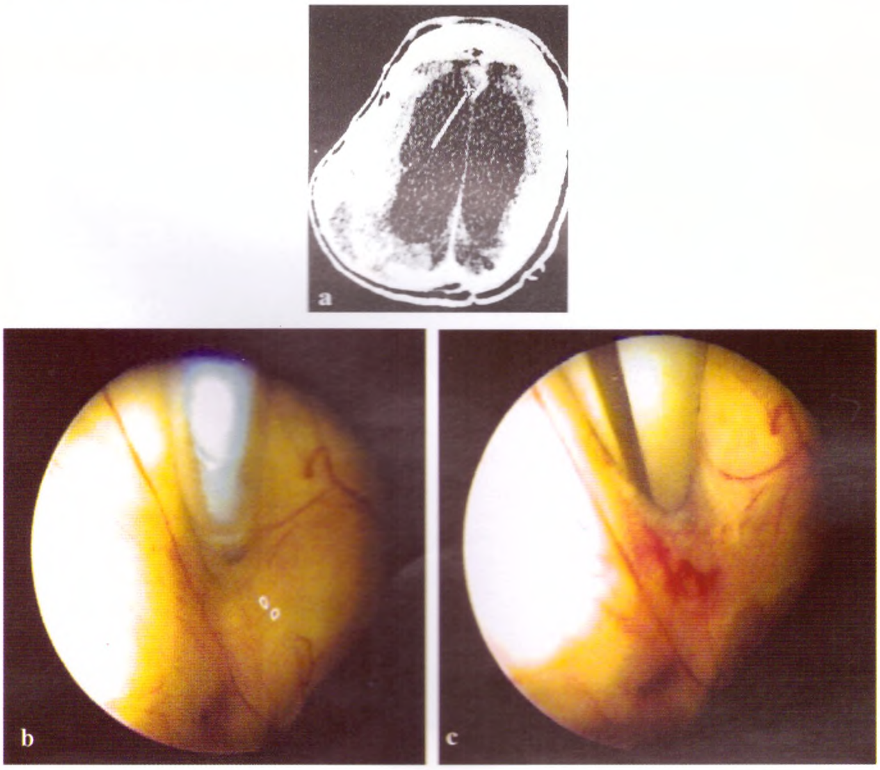


Fig. 4a,b,c. Computerized tomography scan axial with the neuronavigationally displayed tip of the endoscope (a) in a 25-year old patient with a post-traumatic abscess in the interhemispheric fissure. Endoscopically, the anteromedial ventricular wall was perforated (b) and the abscess was aspirated (c). For puncture of the small abscess, neuronavigation was required.

NEURONAVIGATIONAL AND ENDOSCOPIC ASSISTANCE IN TRANSSPHENOIDAL PITUITARY ADENOMA SURGERY

M. Marinov, V. Bussarsky, K. Romansky, A. Bussarsky, N. Stoyanchev, G. Kounin, Z. Tonchev, Y. Enchev, St. Djendov

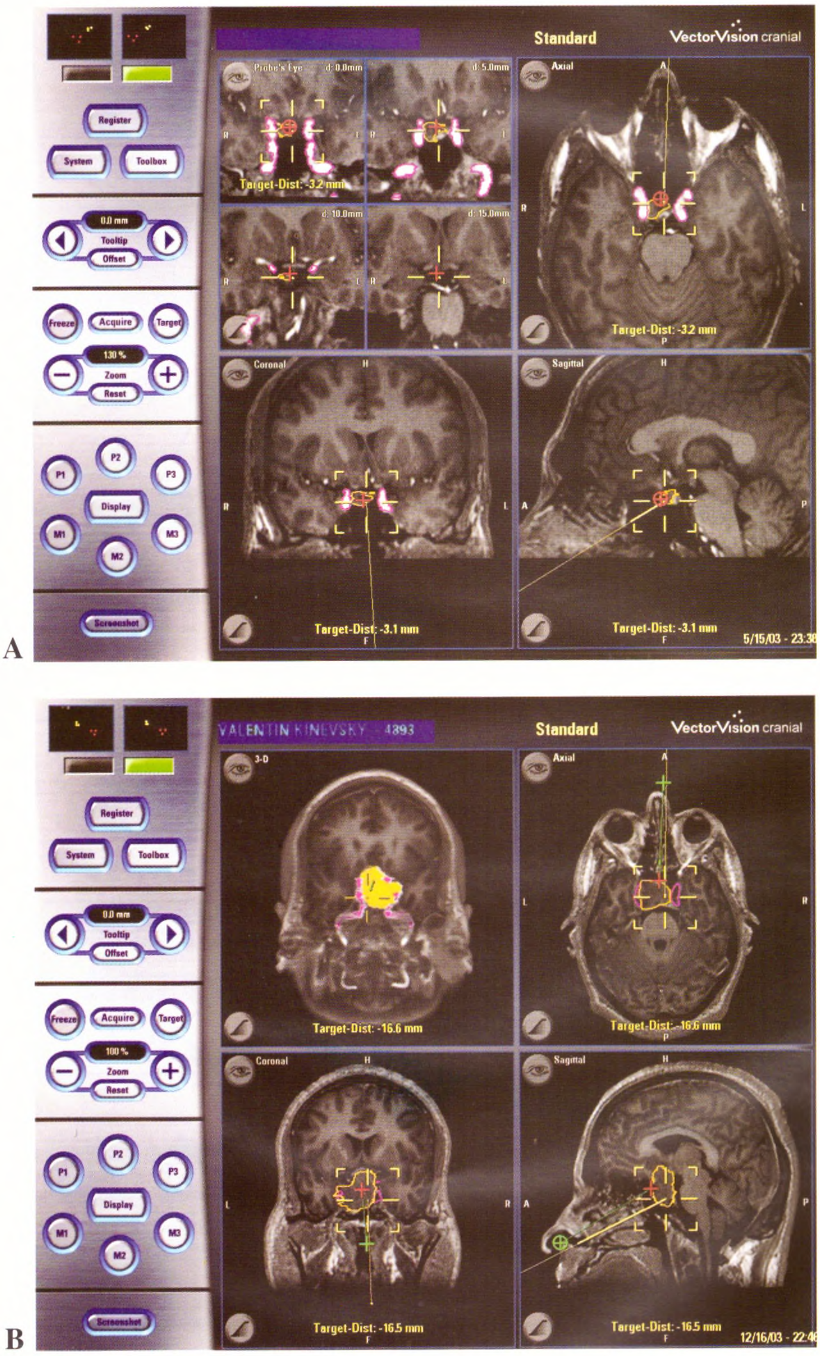


Figure 2. A typical snapshot display of the VectorVision system during surgery, while pointer has been placed on the structure of interest. Segmented PA and perisellar vascular structures;
a - case No 4 with acromegaly and excentric microadenoma and
b - case No 18 with acromegaly and macroadenoma with para/suprasellar extension.

VIRTUAL REALITY AND NEUROSURGERY: A BRIEF OVERVIEW

N. Hoess, G. Skopp, H. Wassmann

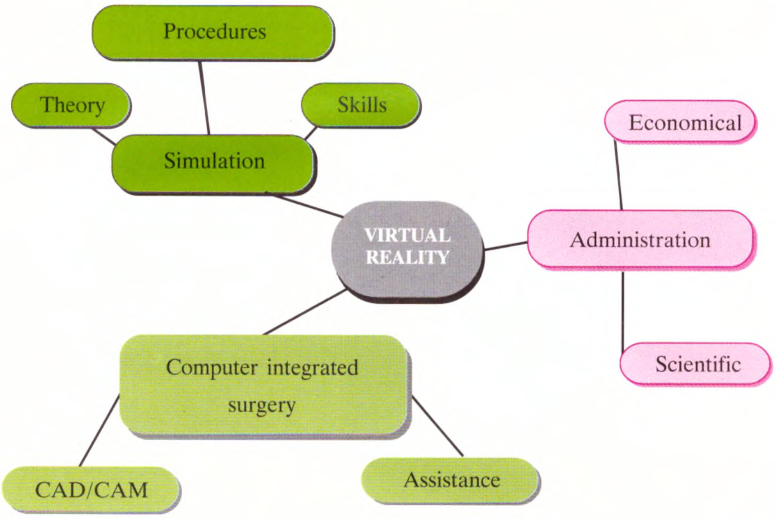


Figure 1. Applications for VR in Neurosurgery

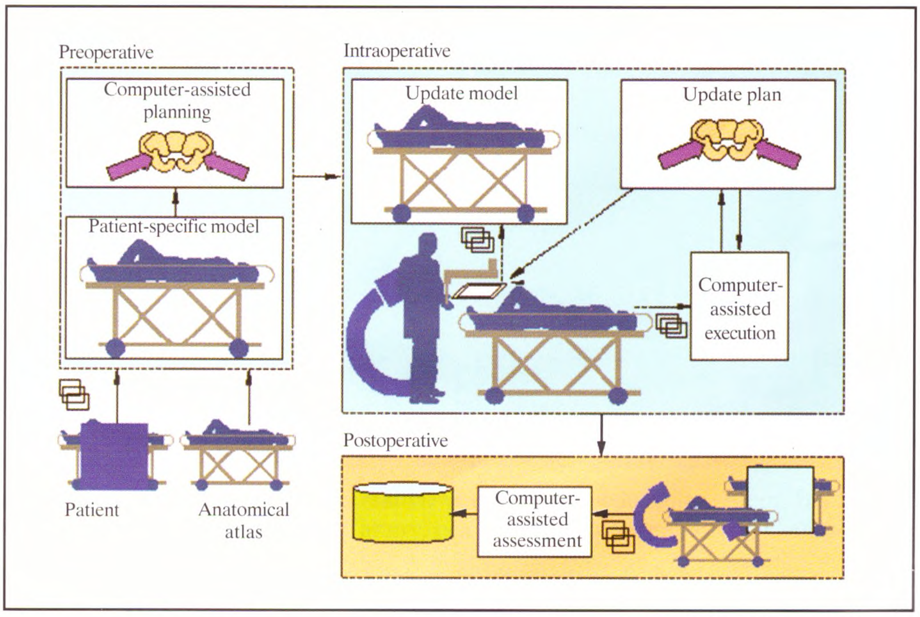


Figure 2. Modules of computer integrated surgery

VIRTUAL ENDOSCOPY FOR PLANNING ENDOSCOPIC INTRAVENTRICULAR SURGERY - OUR EARLY EXPERIENCE

A. Bussarsky, M. Marinov, R. Kalyonsky, Z. Tonchev,
V. Bussarsky, H. Wassmann

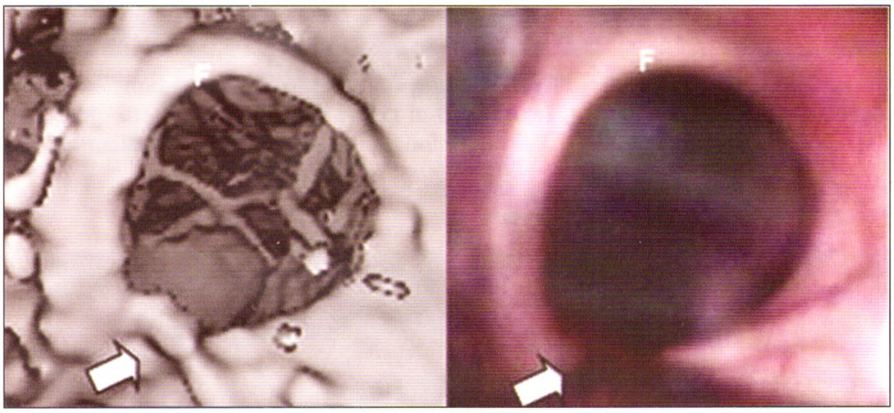


Fig. 1. Virtual endoscopic and real views of enlarged right foramen of Monro. The structures of posterior circle of Willis that are clearly seen in the VE image (left) are hidden on the real intraoperative image (right) by the membrane formed by the floor of the third ventricle and the wall of the arachnoid cyst. F- fornix, arrow - choroid plexus.

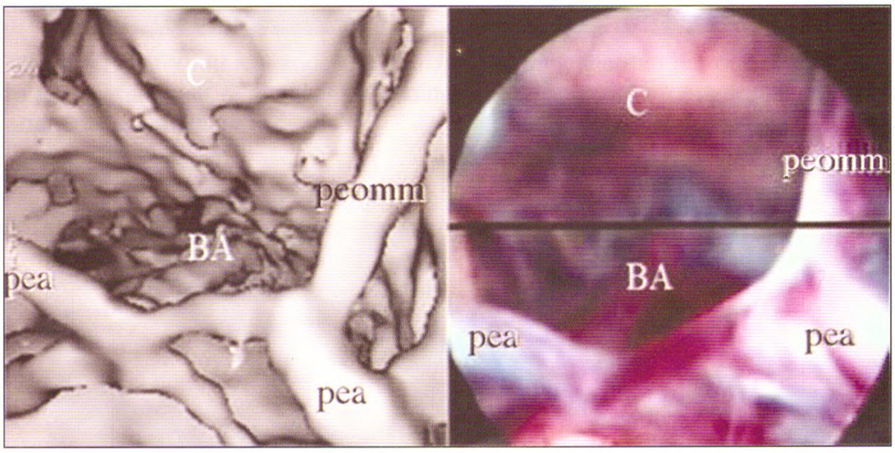


Fig. 2. Virtual endoscopic (left) and real views of the interpeduncular cistern. BA-basilar artery, p comm - posterior communicating artery, pca - posterior cerebral artery, C-clivus.

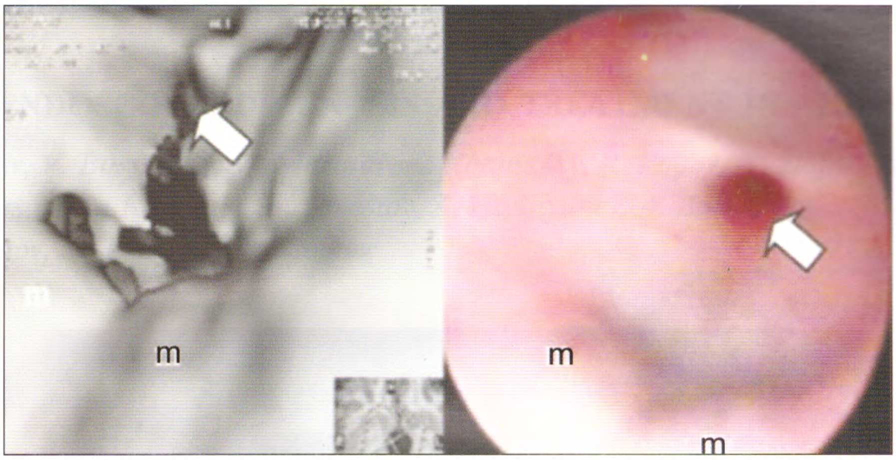


Fig. 3. VE and real views of the thick non-translucent floor of the third ventricle. Note the basilar tip showing through the defect in the third ventricular floor on the VE image (left). m- mammillary bodies, arrow- infundibular recess.

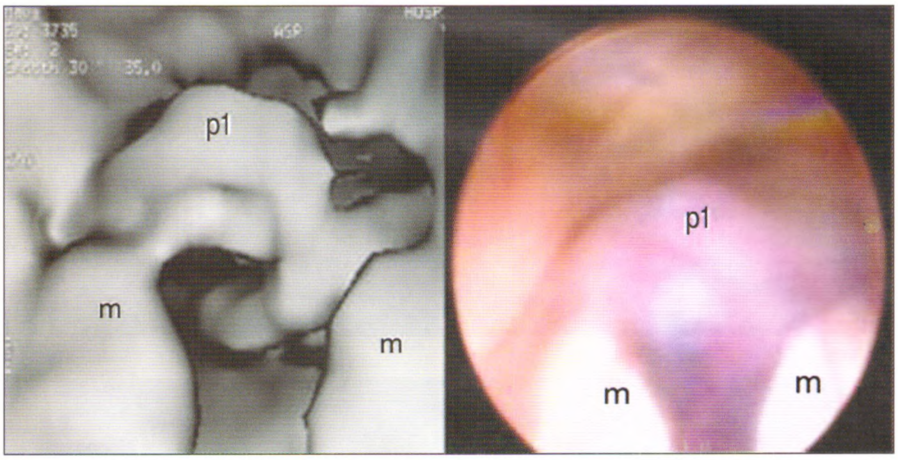


Fig. 4. VE (left) and real endoscopic images showing aberrant position of the basilar tip deviated to the right and left p_1 segment protruding into the ventricle. p_1- p_1 segment of posterior cerebràl artery, m- mammillary bodies.

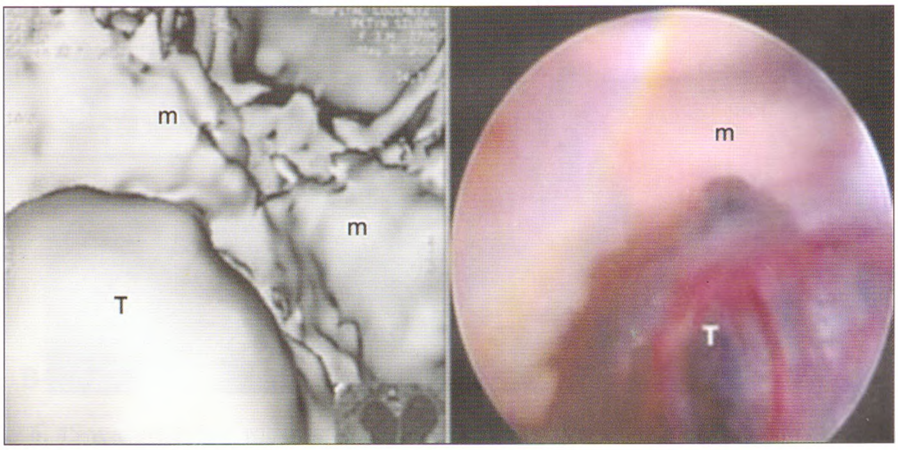


Fig. 6. VE (left) and real endoscopic views of a tumor of posterior third ventricle through the right foramen of Monro. T- tumor, m- mam-millary bodies.

NEUROENDOSCOPIC DIAGNOSIS AND TREATMENT IN ADULTS

N. Mirchev, V. Bussarsky, M. Marinov, K. Romansky, R. Popov, N. Stojanchev, V. Karakostov, G. Kounin, Chr. Christov, A. Hadjiyanev, A. Bussarsky, V. Gerganov, St. Djendov, L. Nuchev

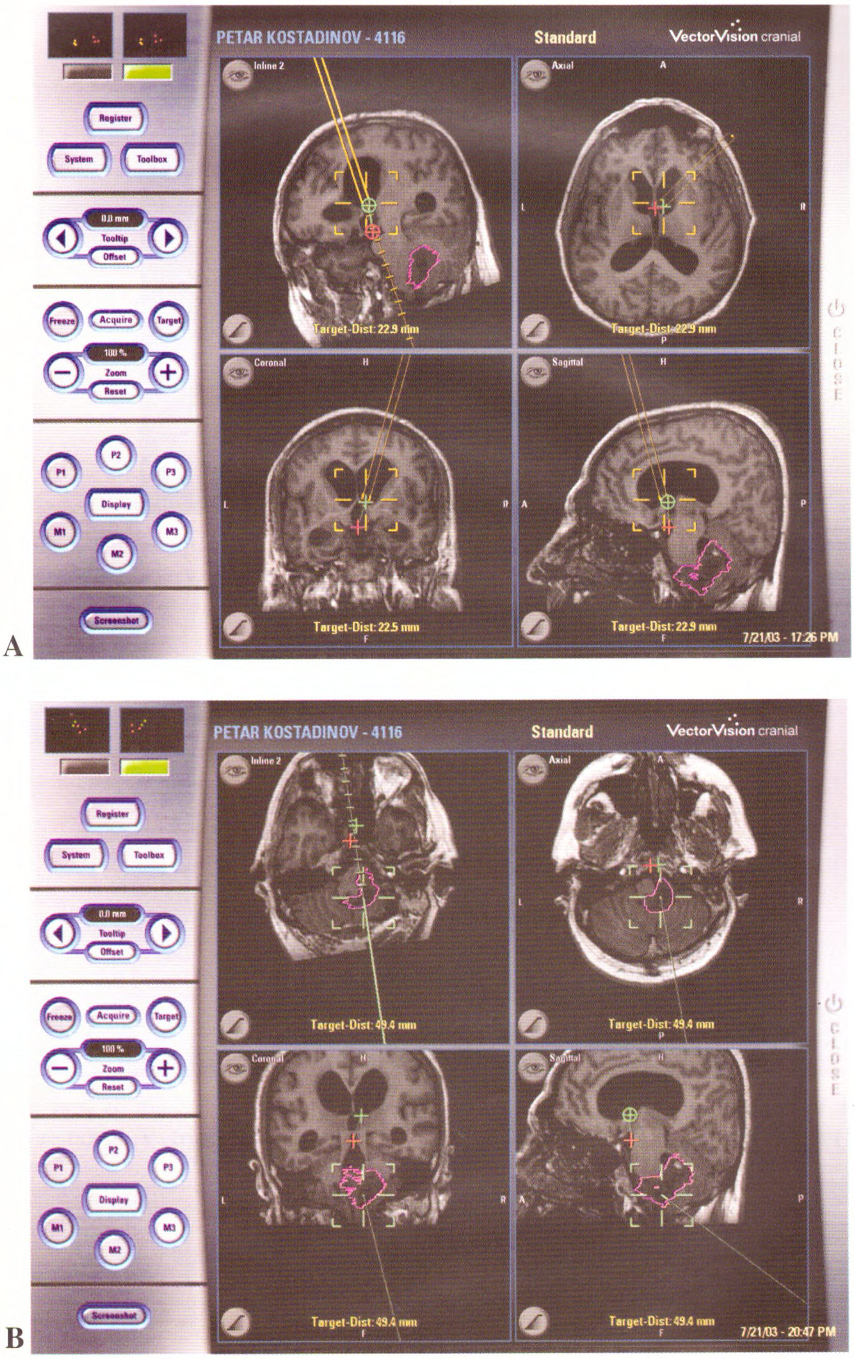


Fig. 6. 45 years old man with metastasis of the floor of the IV-th ventricle and internal hydrocephalus. Third ventriculostomy (a) followed by removal of the tumor of the forth ventricle (b). Both operations were assisted with neuroendoscopy and neuronavigation.

ENDOSCOPE - ASSISTED MICROSURGERY OF PATHOLOGICAL LESIONS AFFECTING THE POSTERIOR CRANIAL FOSSA: INITIAL EXPERIENCE

V. Gerganov, V. Bussarsky, K. Romansky

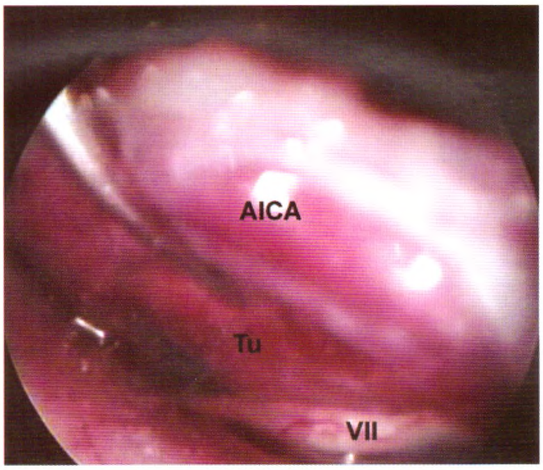


Fig.1. Endoscopic view of the anterior tumor surface. AICA- anterior inferior cerebellar artery, Tu- vestibular schwannoma, VII- facial nerve.

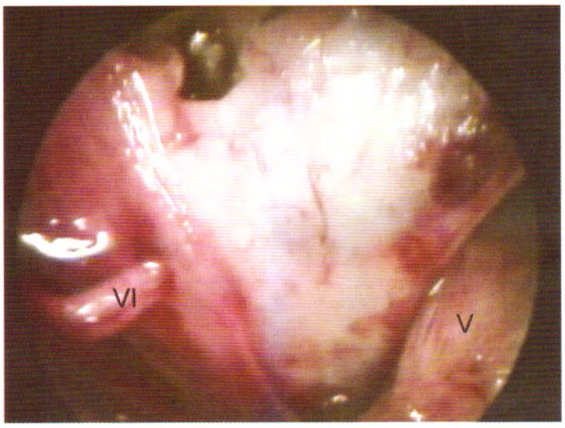


Fig. 2. Endoscopic view of the cerebellopontine angle after partial tumor removal. V- trigeminal nerve, VI- abducent nerve

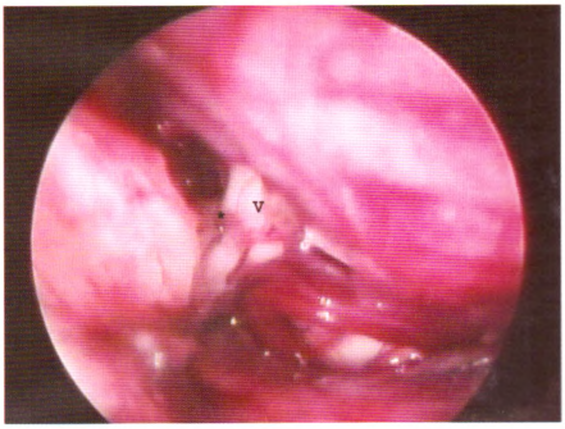


Fig. 3. Endoscopic visualization of the vascular groove (*) on the trigeminal nerve (V).

MICROSURGICAL TREATMENT OF CRANIAL RHIZOPATHIES

Chr. Ranguelov, K. Romansky, V. Bussarsky, M. Marinov

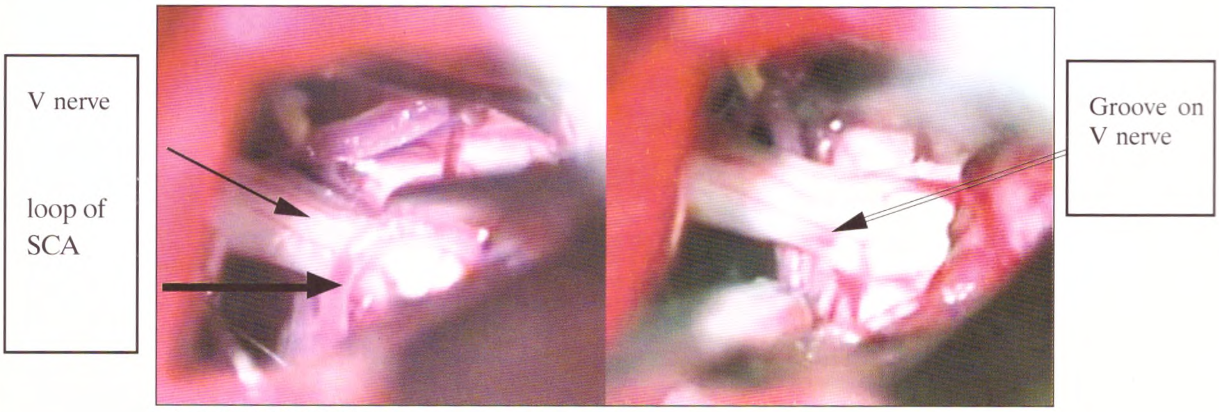


Fig.1 NVC-SCA/V nerve

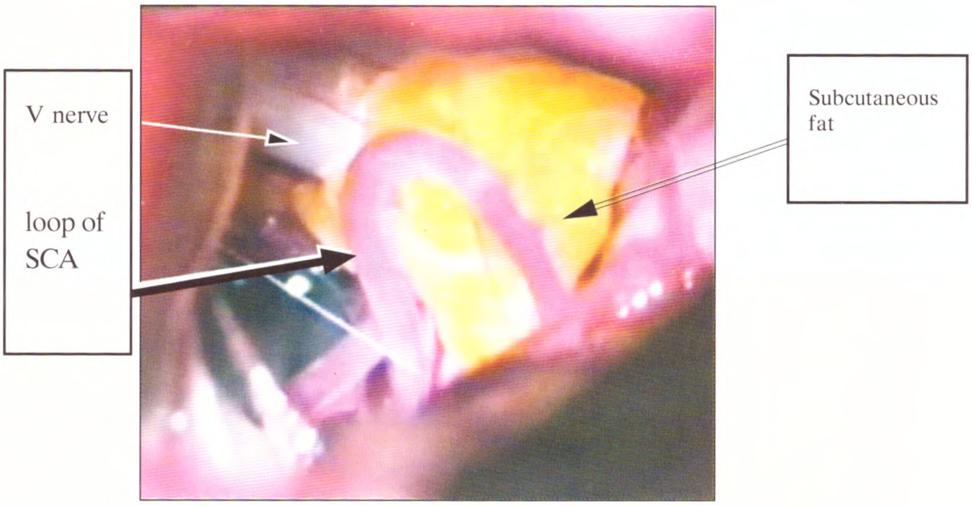
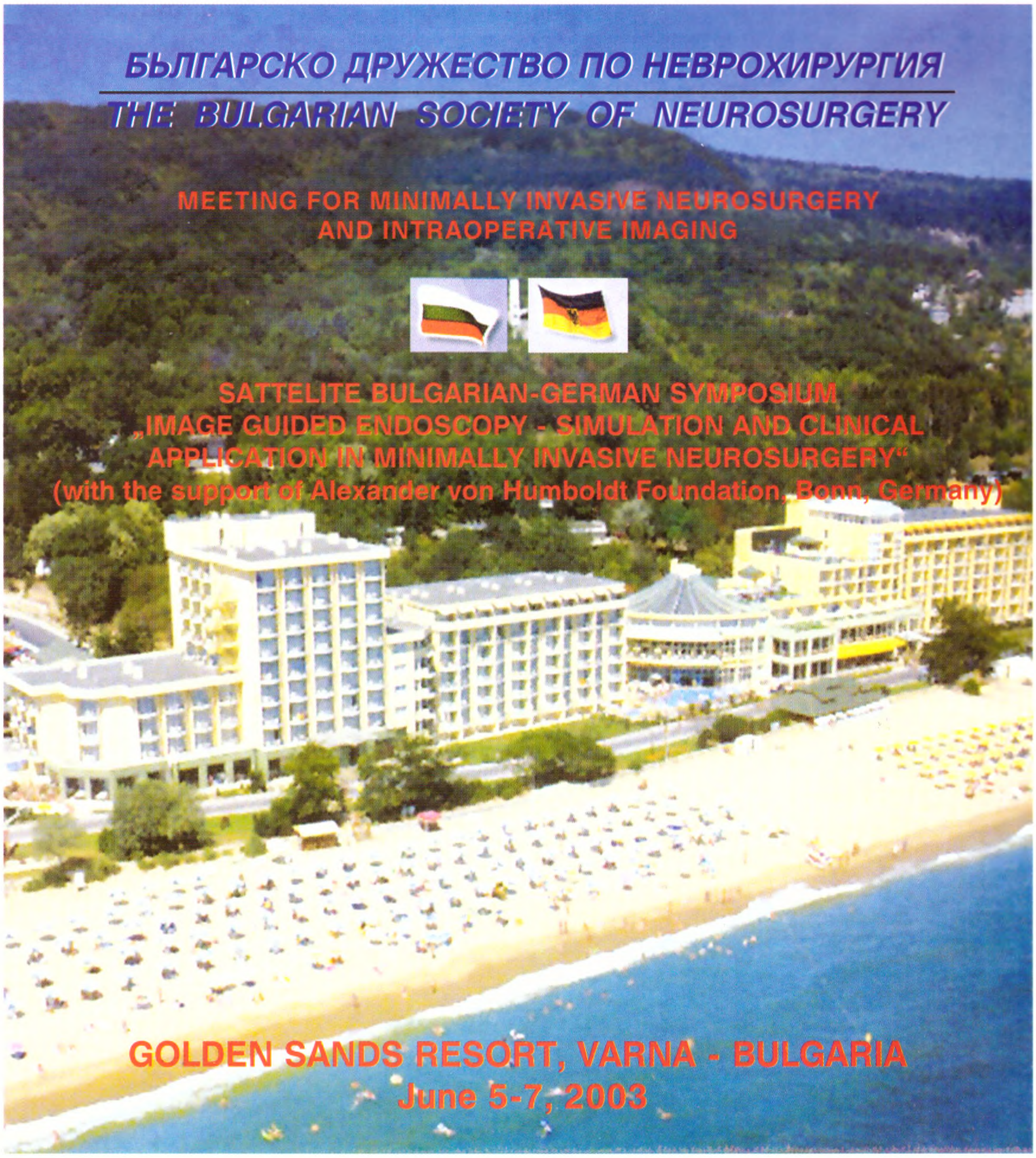


Fig. 2 MVD of V nerve with fat tissue.



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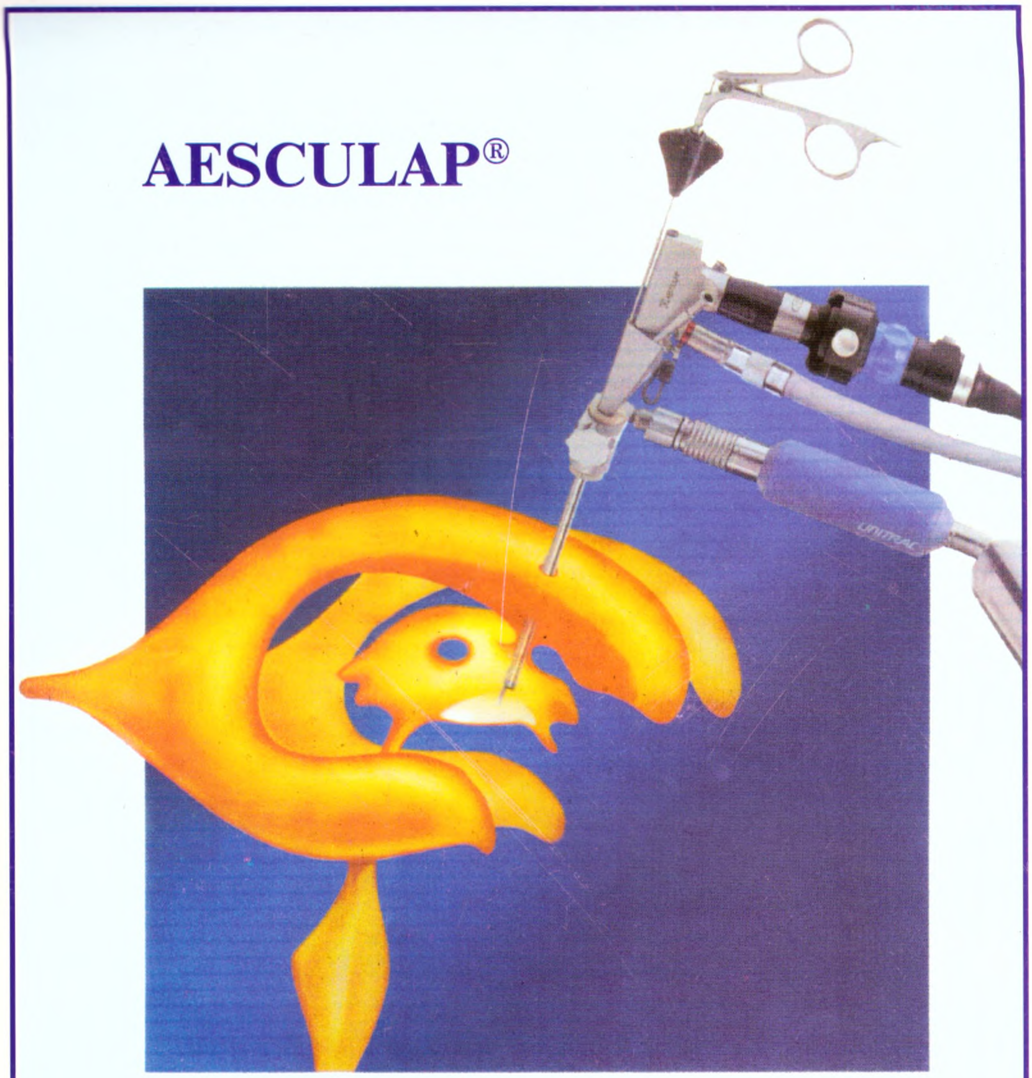
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