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Retrospective Study on Patients Treated Neuroendoscopically for Lesions in the 3rd Ventricle: Evaluation of Own Data, Basic and Elementary Principles, Review of the Literature with Current and Future Perspectives of Neuroendoscopy

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Abstract: **Introduction: Neuroendoscopic surgery can be considered as minimal invasive surgical procedure, as it can be performed with minimal damage to normal structures, carries a lower rate of complications and achieves excellent outcomes. Surgeons using an endoscope and related instruments can perform complex operations through very small incisions, which is especially useful for minimally invasive procedures for the brain and spine. Neuroendoscopic technique is nowadays performed in diverse cases such as of obstructive hydrocephalus, various intraventricular lesions and hemorrhages, hypothalamic hamartomas, craniosynostosis, skull base tumors, and spinal lesions. There is currently no randomized controlled trial evidence of benefit for neuroendoscopy versus conventional neurosurgical treatment across a variety of indications.**

Methods: The history of neuroendoscopy along with the current state and future perspectives of endoscopic surgery should be discussed briefly. Retrospective evaluation of own data along with elementary and basic principles in neuroendoscopy to be evaluated along with review of the literature.

Results: The standard indications for neuroendoscopy are the treatment of hydrocephalus, intracerebral cysts, intraventricular haemorrhages and intraventricular tumors / lesions. The advantages of neuroendoscopy-assisted microneurosurgery as an adjuvant technique were described as well. Whether endoscopy of the sellar region will gain and play more rules in the future, is as yet uncertain. Endoscopic interventions on the vertebral column and spinal cord are now routine, but controversial. The endoscopic carpal tunnel surgery is established and widely practiced.

Discussion and Conclusion: In some neurosurgical cases, the neuroendoscopic technique has become the first choice for treatment. The increasingly close links between neuroendoscopy and neuronavigation may bring promising developments for the neurosurgical management. In future, virtual neuroendoscopy may aid the planning and execution of surgical interventions.

Keywords: **Neuroendoscopy, hydrocephalus, brain tumor, lumbar disc prolapse, carpal tunnel syndrome, cerebrospinal fluid (CSF), endoscopic third ventriculostomy (ETV), endoscopy-assisted craniosynostosis surgery (EACS), subependymal giant cell tumor (SGCT), tuberous sclerosis complex (TSC), papilloma, carcinoma, lymphoma, microendoscopic discectomy (MED), intracerebral cyst, arachnoid cyst, ependymal cyst, endodermal cyst, neuroepithelial cyst, chordoid glioma, ependymoma, meningioma, craniopharyngioma, intraventricular haemorrhage (IVH), aqueductal stenosis (AS).**

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1. INTRODUCTION

Neuroendoscopy is a relatively new technique in the neurosurgical management, that cannot yet be definitely judged on the basis of scientific evidence. Large-scale, randomized controlled studies and meta-analyses are currently in progress, but no conclusive findings have yet been reported regarding the potential advantages, for various indications, of this new technique over other, established ones. [1-8, 23, 25-26, 29-39, 47-50]

In this article own data of neuroendoscopic procedures will be evaluated, neuroendoscopic techniques and their indications and results will be described and discussed along with review of the current literature. The search terms used were "neuroendoscopy," "intraventricular haemorrhages and tumors, " " hydrocephalus," "colloid cysts," "cystic brain lesions," "endoscopic pituitary surgery," " neuroendoscopy in epilepsy surgery" "endoscopic carpal tunnel surgey" and "spinal endoscopy." [3-15, 18-21, 23-27, 31-39, 43-48]

The intracranial lesions in the third ventricle can have a variety of clinical manifestations. Masses related to the anterior recesses or floor of the third ventricle may manifest as dysfunction of the hypothalamic–pituitary hormonal axis. Masses of the posterior wall of the third ventricle, foramen of Monro masses, and intraventricular masses often manifest as hydrocephalus accompanied mostly by headaches. Some congenital cysts or acquired abnormalities, such as cavum veliinterpositi cyst and ectatic basilar artery, respectively, may be incidental imaging findings but distort the normal anatomy of the third ventricle or mimic more serious disease.

Victor de l'Espinasse, a Chicago urologist, performed in 1910, the first neurosurgical endoscopic procedure for choroid plexus fulguration in two infants with hydrocephalus. Using a cystoscope, one infant was successfully treated. [4-14, 16, 21, 23, 26-29]

Walter Dandy [9-19] used an endoscope to perform an unsuccessful choroid plexectomy in 1922. The next year, Mixter [17-22] used a urethroscope to complete the first successful endoscopic third ventriculostomy (ETV) in a 9-month-old girl with obstructive hydrocephalus. In 1935, Scarff reported his initial results after using a novel endoscope equipped with a cauterizing electrode, an irrigation system to prevent ventricle collapse, and a movable operating tip to perforate the third ventricle floor [2-9, 16, 23, 25-30].

In 1952, Nulsen and Spitz [18-22] began the era of ventricular cerebrospinal fluid (CSF) shunting, marking the end of the initial era of neuroendoscopy. The period of darkness in neuroendoscopy continued until 1970s, but interest in ETV for treating obstructive hydrocephalus was renewed with the improved imaging capability of endoscopes. In 1978, Vries [22] described his experience treating five patients with hydrocephalus, in whom he demonstrated that ETVs were technically feasible using a fiberoptic endoscope. In 1990, Jones and colleagues [15] described a 50% shunt-free success rate for ETV in 24 patients with various forms of hydrocephalus. Four years later, the same group reported an improved success rate of 61% in a series of 103 patients [14, 26, 28-33]. Currently, ETV is primarily used to treat obstructive hydrocephalus due to benign aqueductal stenosis or compressive periaqueductal mass lesions. Modern shunt-free success rates range from 80 to 95% [16, 21].

Many authors have reported age limitations for ETV in pediatric populations. Many reviews have been made to find out and to examine the literature on pathological indications for ETV, age limitations to ETV and complications to date [1-10, 46-51].

Dandy reported the first third ventriculostomy using a subfrontal approach in 1922. Interestingly, Mixter performed the first endoscopic third ventriculostomy the following year, using a urethroscope to successfully treat a pediatric hydrocephalic patient. Given the bulky equipment used in endoscopy, several attempts for modified third ventriculostomy were developed. Hoffman et al. reported stereotaxic third ventriculostomy with intraoperative ventriculography using a special apparatus. Kelly et al. and Melikian et al. [55-56] described CT-guided computer-assisted stereotactic resection of brain tumors.

All cases recovered without shunting. With the development of a neuroendoscopy apparatus, larger numbers of series were reported in the 1990s.

2. EVALUATION OF OWN DATA

In the paper published in "The International Journal of Current Research", Munthir Al-Zabin et al. Vol. 9, Issue, 06, pp.51952-51959, June, 2017, detailed data was presented and discussed about neuro-endoscopic cysto-ventriculostomy and biopsy with aid of neuronavigation in patients with intraventricular lesionsin the 3rd ventricle and occlusive hydrocephalus in comparison to stereotactic technique: a series of 41 patients and review of the literature was published. 41 Patients (24 female, 17 male, age 12-82 years) with occlusive hydrocephalus due to intraventricular processes were treated by endoscopic technique with the aid of neuro-navigation. In these cases, the endoscopic cysto-ventriculostomy and biopsy of lesion has been selected as operative method. The neuro-navigation has been used for the optimization of the operation approach. For diseases in the region of the 3rd ventricle there are three variants: micro neurosurgery, stereotaxy, and endoscopic method. In patients with unclear diagnosis and other clinically limiting conditions the endoscopic guided method as a minimally invasive method should be selected. With the endoscopic method, the intraventricular processes could be visualized. A necessary hemostasis could be performed under direct vision. In addition to the biopsy extraction, the occlusive hydrocephalus could be also treated with this method in approximately 68.3 % of the patients. Postoperatively, there were no significant complications. In 70-90% of the cases, there was a reliability achieved of histopathological diagnosis in the pediatric group and in the adult group, retrospectively.

In comparison with the stereotactic method it has the same grade of accuracy (Mennel et al., 1994, Zentralblattfür Neurochirurgie). There has been no postoperative morbidity or mortality in consequence of this treatment.

In conclusion, neurovavigation-assisted, endoscopic biopsy and cystoventriculostomy has in comparison with the stereotactic method the same grade of accuracy and reliability. It has also more advantages, such as visualization of the operation area and intraoperative treatment and avoidance of complications postoperatively, especially intracranial or intracerebral haemorrhages. The hydrocephalus was also treated concurrently and successfully in the most presented cases of the study.

3. VENTRICLES OF THE BRAIN: EMBRYOLOGY AND ANATOMY

The ventricular system is embryologically derived from the neural canal, forming early in the development of the neural tube. The 3 brain vesicles (prosencephalon or forebrain, mesencephalon or midbrain, and rhombencephalon or hindbrain) form around the end of the first gestational month. The neural canal dilates within the prosencephalon, leading to the formation of the lateral ventricles and third ventricle. The cavity of the mesencephalon forms the cerebral aqueduct. The dilation of the neural canal within the rhombencephalon forms the fourth ventricle.

The lateral ventricles communicate with the third ventricle through interventricular foramens, and the third ventricle communicates with the fourth ventricle through the cerebral aqueduct. During early development, the septum pellucidum is formed by the thinned walls of the 2 cerebral hemispheres and contains a fluid-filled cavity, named the cavum, which may persist.

Tufts of capillaries invaginate the roofs of prosencephalon and rhombencephalon, forming the choroid plexuses of the ventricles. Cerebrospinal fluid (CSF) is secreted by the choroid plexuses, filling the ventricular system. CSF flows out of the fourth ventricle through the 3 apertures formed at the roof of the fourth ventricle by 12 weeks' gestation.

The largest cavities of the ventricular system are the lateral ventricles. Each lateral ventricle is divided into a central portion, formed by the body and atrium (or trigone), and 3 lateral extensions or horns of the ventricles. The central portion or the body of the ventricle is located within the parietal lobe. The roof is formed by the corpus callosum, and the posterior portion of the septum pellucidum lies medially.

The anterior part of the body of the fornix, the choroid plexus, lateral dorsal surface of the thalamus, stria terminalis, and caudate nucleus, form the floor of the lateral ventricle.

The interventricular foramen is located between the thalamus and anterior pillar of the fornix, at the anterior margin of the body. The 2 interventricular foramens (or foramina of Monro) connect the lateral ventricles with the third ventricle. The body of the lateral ventricle is connected with the occipital and temporal horns by a wide area named the atrium.

The anterior or frontal horn is located anterior to the interventricular foramen. The floor and the lateral wall are formed by the head of the caudate nucleus, the corpus callosum constitutes the roof and anterior border, and the septum pellucidum delineates the medial wall. The posterior or occipital horn is located within the occipital lobe. The fibers of the corpus callosum and the splenium form the roof. The forceps major is located on the medial side and forms the bulb of the occipital horn.

The inferior or temporal horn is located within the temporal lobe. The roof is formed by the fibers of the temporal lobe; the medial border contains the stria terminalis and tail of the caudate. The medial wall and the floor are formed by the hippocampus and its associated structures. The amygdaloid complex is located at the anterior end of the inferior horn.

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Capillaries of the choroid arteries from the pia mater project into the ventricular cavity, forming the choroid plexus of the lateral ventricle. The choroid plexus is attached to the adjacent brain structures by a double layer of pia mater called the tela choroidea. The choroid plexus extends from the lateral ventricle into the inferior horn. The anterior and posterior horns have no choroid plexus.

The choroid plexus of the lateral ventricle is connected with the choroid plexus of the contralateral ventricle and the third ventricle through the interventricular foramen. The anterior choroidal arteries (branch of internal carotid artery) and lateral posterior choroidal arteries (branch of the posterior cerebral artery) form the choroid plexus. Venous supply form the choroidal veins drain into the cerebral veins.

The third ventricle is the narrow vertical cavity of the diencephalon. A thin tela choroidea supplied by the medial posterior choroidal arteries (branch of posterior cerebral artery) is formed in the roof of the third ventricle.

The fornix and the corpus callosum are located superiorly. The lateral walls are formed by the medial thalamus and hypothalamus. The anterior commissure, the lamina terminalis, and the optic chiasm delineate the anterior wall.

The floor of the third ventricle is formed by the infundibulum, which attaches the hypophysis, the tuber cinereum, the mammillary bodies, and the upper end of the midbrain. The posterior wall is formed by the pineal gland and habenular commissure.

The interthalamic adhesions are bands of gray matter with unknown functional significance, which cross the cavity of the ventricle and attach to the external walls. The fourth ventricle is connected to the third ventricle by a narrow cerebral aqueduct. The fourth ventricle is a diamond-shaped cavity located posterior to the pons and upper medulla oblongata and anterior-inferior to the cerebellum.

The superior cerebellar peduncles and the anterior and posterior medullary vela form the roof of the fourth ventricle. The apex or fastigium is the extension of the ventricle up into the cerebellum. The floor of the fourth ventricle is named the rhomboid fossa. The lateral recess is an extension of the ventricle on the dorsal inferior cerebellar peduncle. Inferiorly, it extends into the central canal of medulla.

The fourth ventricle communicates with the subarachnoid space through the lateral foramen of Luschka, located near the flocculus of the cerebellum, and through the median foramen of Magendie, located in the roof of the ventricle. (See Figure 1 below).

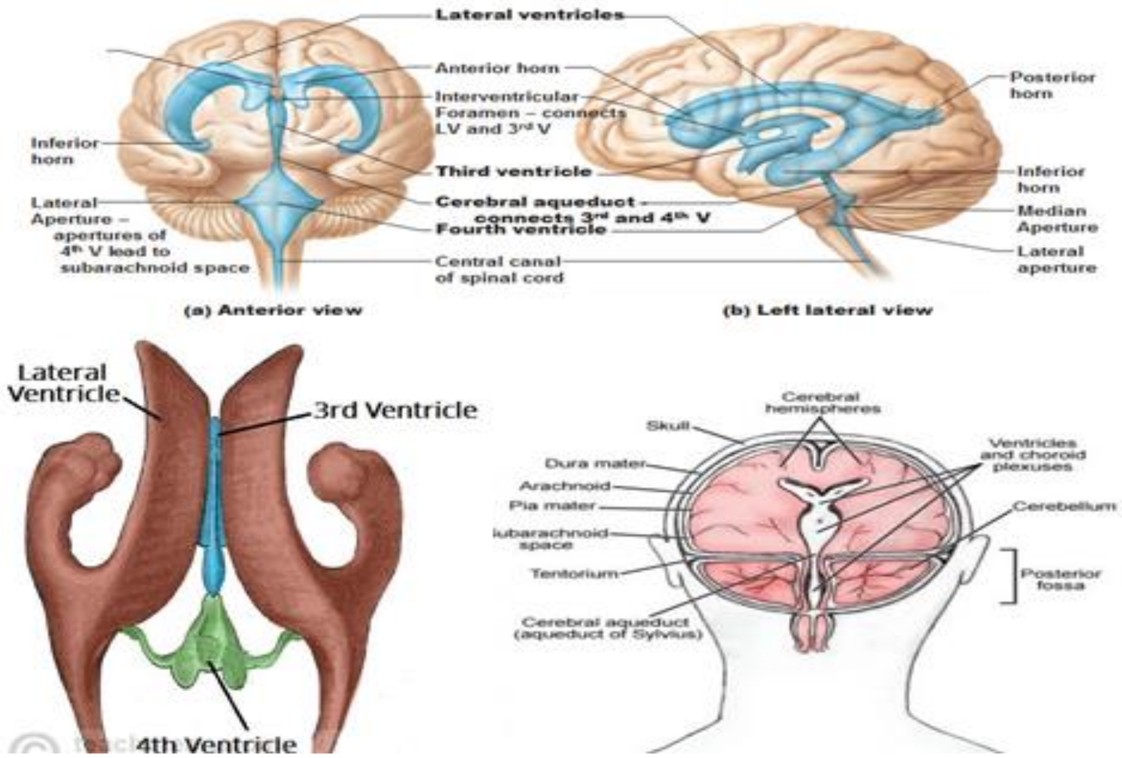

Figure 1: Ventricles of the brain.

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Most of the CSF outflow passes through the medial foramen. The cerebral aquaeduct mesencephalic contains no choroid plexus. The tela choroidea of the fourth ventricle, which is supplied by branches of the posterior inferior cerebellar arteries, is located in the posterior medullary velum.

CSF is a clear, watery fluid that fills the ventricles of the brain and the subarachnoid space around the brain and spinal cord. CSF is primarily produced by the choroid plexus of the ventricles (≤70% of the volume); most of it is formed by the choroid plexus of the lateral ventricles. The rest of the CSF production is the result of transependymal flow from the brain to the ventricles. CSF flows from the lateral ventricles, through the interventricular foramens, and into the third ventricle, cerebral aqueduct, and the fourth ventricle. Only a small amount enters the central canal of the spinal cord.

CSF flow is the result of a combination of factors, which include the hydrostatic pressure generated during CSF production (known as bulk flow), arterial pulsations of the large arteries, and directional beating of the ependymal cilia.

Hydrostatic pressure has a predominant role in the CSF flow within the larger ventricles, whereas cilia favor the movement of the CSF in the narrow regions of the ventricular system, such as the cerebral aqueduct. Immotile cilia syndrome is a rare cause of hydrocephalus in children. [13-16, 18-22, 24-29, 31-37].

The ventricles constitute the internal part of a communicating system containing CSF. The external part of the system is formed by the subarachnoid space and cisterns.

The communication between the 2 parts occurs at the level of fourth ventricle through the median foramen of Magendie (into the cistern magna) and the 2 lateral foramina of Luschka (into the spaces around the brainstem cerebellopontine angles and prepontine cisterns).

The CSF is absorbed from the subarachnoid space into the venous blood (of the sinuses or veins) by the small arachnoid villi, which are clusters of cells projecting from subarachnoid space into a venous sinus, and the larger arachnoid granulations.

The total CSF volume contained within the communicating system in adults is approximately 150 mL, with approximately 25% filling the ventricular system. CSF is produced at a rate of approximately 20 mL/h, and an estimated 400-500 mL of CSF is produced and absorbed daily. CSF absorption capacity is normally approximately 2-4 times the rate of production. The normal CSF pressure is between 5-15 mm Hg (65-195 mm H_2O) in adults.

In children younger than 6 years, normal CSF pressure ranges between 10-100 mm H_2O. CSF plays an important role in supporting the brain growth during evolution, protecting against external trauma, removal of metabolites produced by neuronal and glial cell activity, and transport of biologically active substances (e.g. hormones/neuropeptides) throughout the brain. (See Figure 2 below).

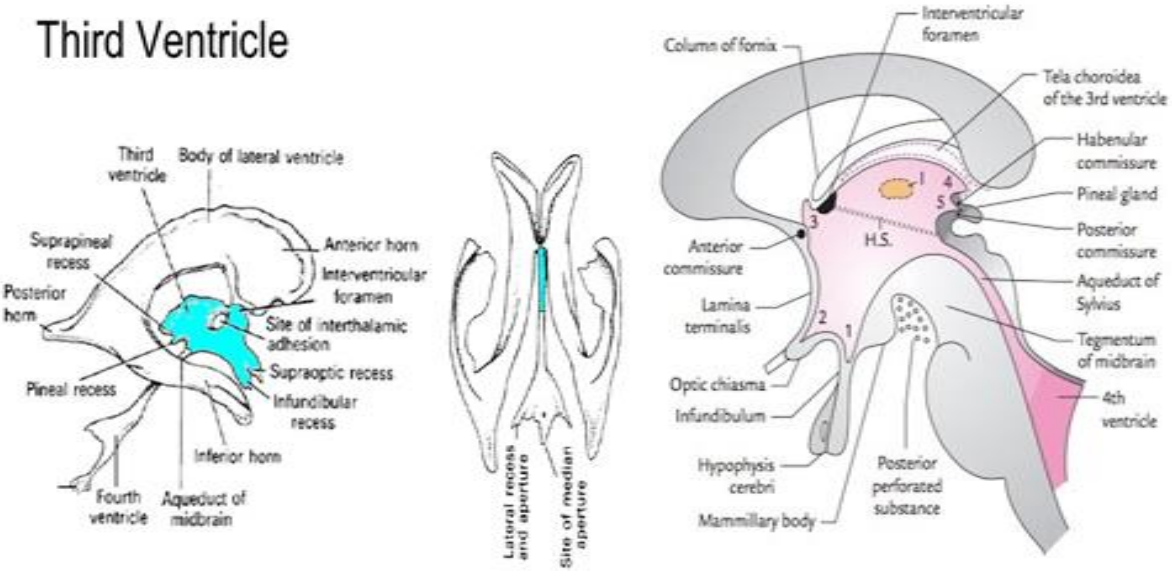

Figure 2: Anatomy of the 3rd ventricle of the brain.

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4. CURRENT STATUS OF NEUROENDOSCOPY

The field of neuroendoscopy has extended beyond ventricular procedures. Many types of endoscopes are currently used for many types of neurosurgically treatable diseases, which can be approached safely and effectively by the endoscope. [1-11, 16-22, 33-40, 50-57] These lesions or diseases can be hydrocephalus and subtypes of hydrocephalus, intracranial cysts, intraventricular tumors, hypothalamic hamartoma (HH), skull base tumors, sellar / supracellar lesions such as pituitary adenoma, craniosynostosis, degenerative spine disease, and carpal tunnel syndrome. [12-15, 23-32, 41-49]

5. INSTRUMENTS IN THE NEUROENDOSCOPIC SURGERY

Neuroendoscope: Many different types of neuroendoscope with good optical properties are now available, and improvement seems to be still needed in this area [3, 9-17, 27-31, 34, 44].

The neuroendoscope should have two working channels to enable the surgeon to work with both hands (as in conventional, non-endoscopic microsurgery), as well as a channel for irrigation and suction. A Compromise must be struck, so that the parenchymal trauma due to the insertion of the device is minimized, while the endoscope simultaneously remains optimally manipulable for surgical purposes.

The standard types of neuroendoscopes (rigid and flexible) today have a diameter of 3 to 6 mm. Diameters greater than 8 mm are not acceptable, because the use of such instruments affords no advantage over conventional microsurgery. Intraoperatively interchangeable endoscopes with different viewing angles, i.e., angulated optics, must be used to enable inspection of the operative field from a variety of perspectives (Figure 3 (i) A-C).

A special problem may arise in neuroendoscopic procedures on neonates or infants. Large-diameter adult endoscopes should not be used in such patients, as their use promotes the development of a cerebrospinal fluid fistula to the skin along the trajectory of insertion of the endoscope through the brain parenchyma. It has been found to be safer to use pediatric endoscopes of diameter 2–3 mm with two working channels and high-quality optics. Ultra-thin endoscopes have been designed and put to use as microsurgical operating instruments for endoscopically assisted microsurgery, e.g., as "seeing dissectors" in cerebral aneurysm surgery. Such instruments enable the neurosurgeon to see around corners in the operative field. Obviously, endoscopes that are designed for this purpose can be kept very thin, as they do not need to have any working channels [4-7, 8-11, 15-20, 27, 29, 33-35, 28-42].

Concept of “Oi Handy Pro TM ” Neuroendoscope: The “Oi HandyPro TM ” endoscope is the result of several years of neuroenoscopy invention. The author’s experience, as well as that of other colleagues, has formed the basis for the design of a new device with potential for improving certain features of the endoscope used in the neurosurgical field. It is a handy rigid-shaft neuroendoscope that combines several major advantages; high-resolution imaging with right illumination, mobile manipulation with “frameless free-hand maneuvering,” and a lightweight body with fine surgical instruments. This new instrument was reported and its unique features as they relate to neurosurgery were described [53].

In 1991, the newly developed flexible and steerable fiberoptic operative viewing endoscope for the intracranial use was reported and the system was described (The first Symposium on Treatment for Handrocephalus, July 1991, the paper was published in 1992 [9]). The system has been designed to be steered within the angles of +90 to -130 degree with a miniature high-resolution camera, processor and monitor. This flexible viewing fiber has also a working channel (diameter 1 mm) with a lighting guide and objective lens. Through the channel, the system can provide gentle irrigation in the ventricles with irrigation or passage of microinstruments. However, the clinical application to the various intracranial lesions has faced to limitations with disadvantages of the flexible-steerable (fiber) neuroendoscope, i.e. possibility of prion disease, poor quality of imaging compared by size, disorientation, limited instrumentations etc. To conquer these limitations of fiber endoscope, the authors have developed a new type of neuroendoscope, offering improved access to intracranial lesions and maneuverability for various micro-instruments under high-resolution imaging during neuroendoscopic surgery. The endoscope used in this model is a rigid rod of 2.0 mm diameter with an ovoid cannula of 4.0 mm diameter. The “gun-butt” holder incorporated to the neuroendoscope for use with operator’s left hand provides stability to the holder and allows the endoscope to be handled with improved control. The surgical route is protected by insertion of a 14 French peel-away sheath. Various micro-instruments can be introduced to the operative field through the upper 1/3 of the cannula. These micro-instruments are almost as long as the body of the endoscope, so that direct handling

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by the right hand of the surgeon allows fine neuroendoscopic surgical maneuvering to be much more readily achieved. The main technical advance with this “Free-hand Maneuver” of the “Handy Small Diameter Rigid-rod Neuroendoscope is one’s ability to hold the endoscope comfortably with one hand and maneuver instruments in and out the field with the other. The results of early clinical experiences, with 0% mortality and morbidity, indicate the utility of these new concepts in both neuroendoscope and neuroendoscopic surgery. [J. Neurosurg (Pediatrics 1) 120: 113 ─ 118, 2005].

Operative instruments: At the beginning, there was no uniform instrumentation set for neuroendoscopy, but it has now been clearly established which instruments are minimally required for such procedures: Bipolar cutting and coagulating microinstruments (Figure 3 (i) and Figure (ii)), microscissors, and grasping and biopsy forceps [5-7, 8-12, 17-21].

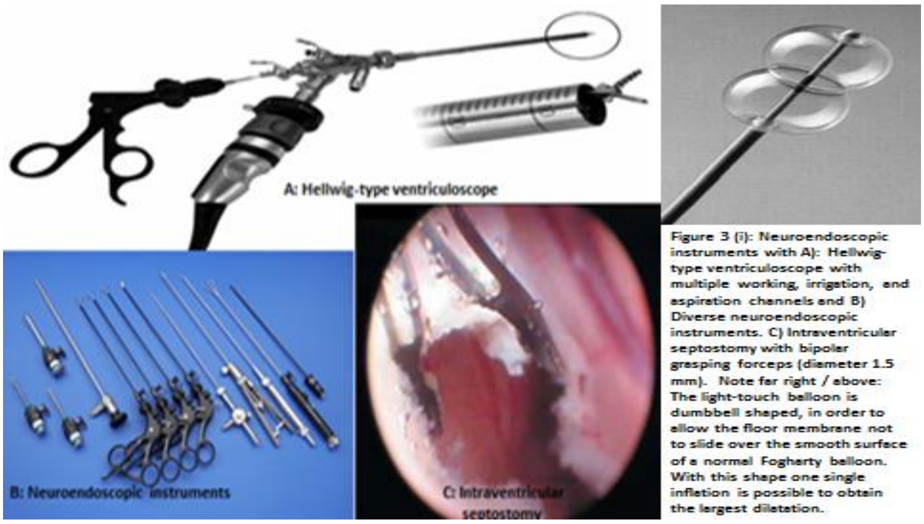

Figure 3 (i): Neuroendoscopic instruments with A): Hellwig-type ventriculoscope with multiple working, irrigation, and aspiration channels and B) Diverse neuroendoscopic instruments. C) Intraventricular septostomy with bipolar grasping forceps (diameter 1.5 mm). Note far right / above: The light-touch balloon is dumbbell shaped, in order to allow the floor membrane not to slide over the smooth surface of a normal Fogharty balloon. With this shape one single inflation is possible to obtain the largest dilatation.

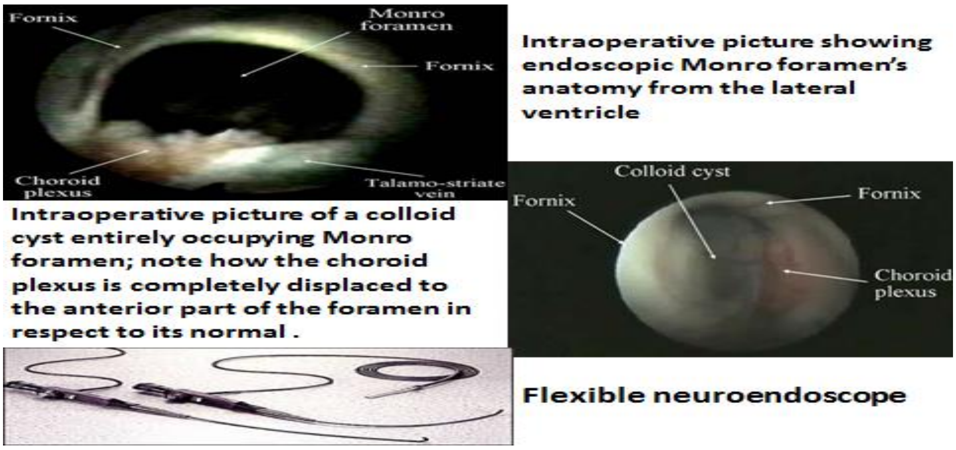

Figure 3 (ii): Anatomy of the Foramen of Monro during endoscopy; flexible neuroendoscope.

6. PLANNING OF NEUROENDOSCOPIC APPROACH

The precise, three-dimensional planning of the neuroendoscopic approach, i.e., the determination of the burr hole site, approach trajectory, and target, can be carried out either with stereotactic neurosurgical technique [6, 28, 34, 38-44, 47-50] or with the aid of neuronavigation [7, 19, 41-47, 49-50]. The advantage of neuronavigation over stereotaxy is the surgeon's greater freedom in the manipulation of the endoscope when it does not need to be attached to a stereotactic frame.

A combination of neuroendoscopy and neuronavigation is currently the operative standard (Figure 4). Neuronavigation is always unnecessary in the endoscopic treatment of severe hydrocephalus, because entering the ventricular system is unproblematic and adequate intraoperative orientation can be acquired from the visible anatomic landmarks. The situation is different, if the venricle size is small; neuronavigation is in this situation very useful.

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So-called virtual ventriculoscopy [8, 39, 41-44, 53-57] is a new imaging technique that is currently in the process of development. It enables three-dimensional planning of neuroendoscopic procedures so that they can be "performed" preoperatively in a virtual environment (figure 4).

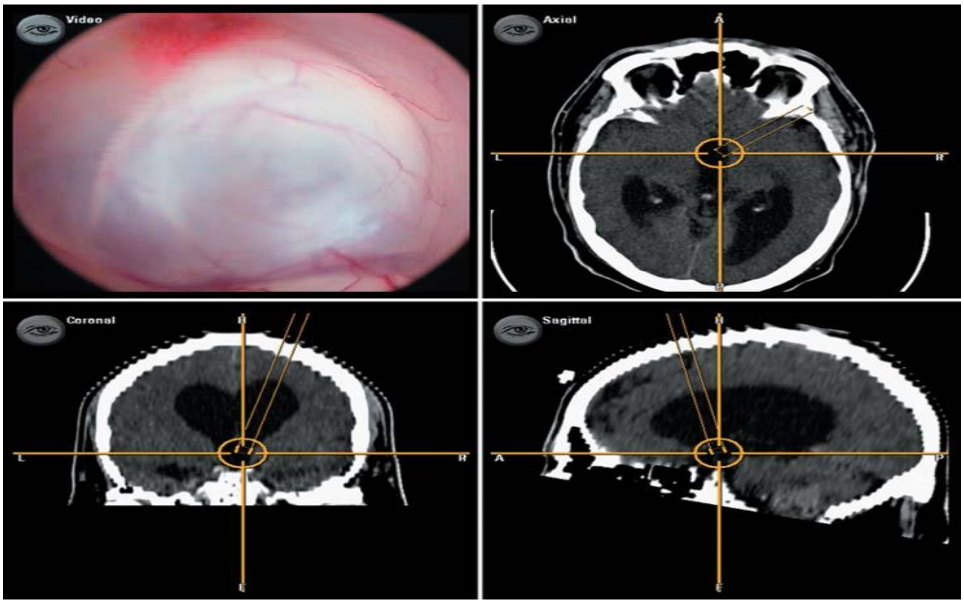

Figure 4: Navigation-assisted neuroendoscopy. Determination of the trajectory to the target and intraoperative three-dimensional check of the approach to a colloid cyst in the foramen of Monro

The indications for intracranial neuroendoscopic operations have been standardized in the last few years. In general, neuroendoscopy is used for procedures in preexisting or pathologically formed cavities in the central nervous system [9, 28, 35, 37-40, 42-44].

In the following chapters, the main fields of the neuroendoscopical treatment are described.

6.1. NEUROENDOSCOPIC SURGERY IN CHILDREN:

In pediatric patients, the use of an endoscope to treat hydrocephalus has become a well-established technique that emerged in the early 20 century when Sir Walter Dandy began treating hydrocephalus by endoscopically cauterizing or removing the choroid plexus. In the past two decades, introduction of new instruments including rod lenses, Hopkins optic devices and high-resolution cameras has led to a huge increase in the number of neuroendoscopic procedures performed in specialized neurosurgical centers. Neuroendoscopy is particularly useful as an adjunct tool in the treatment of hydrocephalus. It is an attractive method owing to its simplicity, durability and because it does not require lifelong implanted hardware. Historically, endoscopic third ventriculostomy (ETV) always seemed to be a promising technique and can be considered nowadays a standard procedure for obstructive hydrocephalus. However, data published in the medical literature is both extensive and conflicting when they come to the role of patients' age and etiology of the hydrocephalus in the success rate (SR) of endoscopic procedures.

How young can ETV become applicable? In recent articles, ETV success rate in adults was 83%, including for tumor, long-standing overt ventriculomegaly, Chiari malformation Types I, II, aqueduct stenosis and IVH. In the secondary group (shunt malfunction), ETV was successful in 67%. According to a study of ETV in children <6 months old, ETV was successful in 57% of patients who experienced regression of signs of intracranial hypertension. Balthasar et al. reported that optimal timing should be ≥ 4 months after birth for ETV from the analysis of 12 cases. Gorayeb et al. reported that in patients <1 year old (mean, 4.7 months), the success rate was 64% and complications mainly involved meningitis. Early postoperative CSF leakage was the most common complication, followed by late postoperative restenosis of stoma. Complication rate varied significantly with the etiology of hydrocephalus, with patients showing Chiari type I malformation and tumor displaying no or very low complication rates. The risk of complications was significantly higher for repeat endoscopic procedures (55.5%) than for the first procedure (10%; $P = 0.0001$). Cinalli et al. reported on alterations in ICP after ETV in non-communicating hydrocephalus in pediatric patients. ICP was continuously recorded for an average of 7 days in 64 children who underwent 68 ETVs for obstructive triventricular hydrocephalus of various etiologies. After 31 procedures (45.6%), ICP remained normal (<20 mmHg) for the entire duration of monitoring. After 37 procedures (54.5%), ICP was persistently high on Day 1 (mean, 29.7 mmHg) and decreased very slowly in subsequent days, remaining high for 2-9 days (mean, 4.5 days). In 13 patients (19.1%), ETV failed and a ventriculoperitoneal shunt was implanted. After four procedures, the stoma became obstructed and the patients were treated to reopen the stoma. Postoperative ICP was not significantly higher in patients in whom ETV failed. Post -ETV infection was one of the most awful complications, occurring in 8.08% / ETVs. This complication usually occurs within the first 2 weeks after ETV. In an article on ETV with previous shunt operation, a total of 131 patients were identified as comprising 86 patients who underwent ETV as a primary procedure and 45 patients who received ETV at the time of shunt malfunction. Serious complications after ETV occurred more frequently in patients who presented with shunt malfunction (14 of 45 patients, 31%) compared with patients who underwent primary ETV (7 of 86 patients, 8%). Previously shunted patients with a history of two or more revisions and who experienced serious complications at the time of ETV were more likely to require shunt replacement. In a case of complex shaped hydrocephalus, identifying anatomical structures is sometimes difficult. Hayashi et al. reported a transparent sheath composed of a thin polypropylene outer tube and an obturator. The sheath measures 10 cm in length, 5.2 mm in outer diameter, and 4.7 mm in inner diameter J. Neuroendoscopy, Vol. 1, No. 1, 2010). It provides excellent visibility without troublesome bleeding from tissues surrounding the foramen of Monro during rigid endoscopic procedures. In response to ETV, ventricular volume falls to a value lower than preoperatively, but higher than the normalized value for age and sex. All patients appeared to have supranormal volumes in the long term, with volume stabilizing at 3-6 months.

Constructive interference in steady-state, 3-dimensional, Fourier transformation (CISS) magnetic resonance imaging in the endoscopic management for 11 of 15 procedures provided better brain tissue/cerebrospinal fluid contrast, allowing better understanding of the cause of hydrocephalus and the nature of the cysts. CISS is useful to determine the results for ETV. Malfunction of ETV can be diagnosed by detecting flow void from the stoma on MRI with T2 sagittal fast spin echo (FSE).

The study, which was presented by Luciano Lopes Furlanetti, Marcelo Volpon Santos, Ricardo Santos de Oliveira, about Neuroendoscopic surgery in children: An analysis of 200 consecutive procedures in Arq. Neuro-Psiquiatr. vol.71 no.3 São Paulo in March 2013, the results were presented of neuroendoscopic operations performed in children during the past ten years in the same institution. [54]

A total of 177 patients were studied. There were 78 male patients (44%) and 99 female patients (56%) ranging in age from 11 days to 18 years (mean age 5.1±1.06 years). The mean follow-up period was 65 months (ranging from 10 months to 9 years).

The etiology of hydrocephalus was as follows: Out of the 177 patients, cystic malformations were found in 45 (25%), tumors in 40 (23%), aqueductal stenosis (AS) in 33 (19%), cerebral malformation in 30 (17%), meningitis or ventriculitis in 8 (5%), intraventricular hemorrhage in 6 (3%), isolated ventricle in 3 (2%) and other etiologies in 12 out of 177 (7%) patients. In 114 patients (64%), ETV was performed as a single and straight forward procedure.

In 29, (16%) endoscopic cyst fenestration was performed. In 18 (10%), two procedures were associated (i.e. ETV + cyst fenestration), in 11 (6%) a ventricular catheter was placed guided by endoscopy and five patients (2%) underwent ETV + tumor biopsy.

The basic indication for endoscopic-assisted catheter placement was complex multiloculate hydrocephalus. Six of these patients were younger than six months and seven were pre-term children. Sixty-six procedures (33%) were performed in patients under one year of age.

In 166 patients, the main goal of the endoscopic intervention was to restore the cerebrospinal fluid (CSF) flow pathways. The overall SR for CSF circulation restoration was 77% (127/166). According to the age group, it was observed, that a 46% (12/26) SR in Group A; 68% (17/25) in Group B, and 85% (98/115) in Group C (p=0.001) (Figures and Tables in information boards A and B below).

Table 1 shows the distribution of patients with respect to their hydrocephalus etiology and SR per group of age according to the CSF restoration. Hydrocephalus etiology and SR: In Group A, the etiology of hydrocephalus was related to

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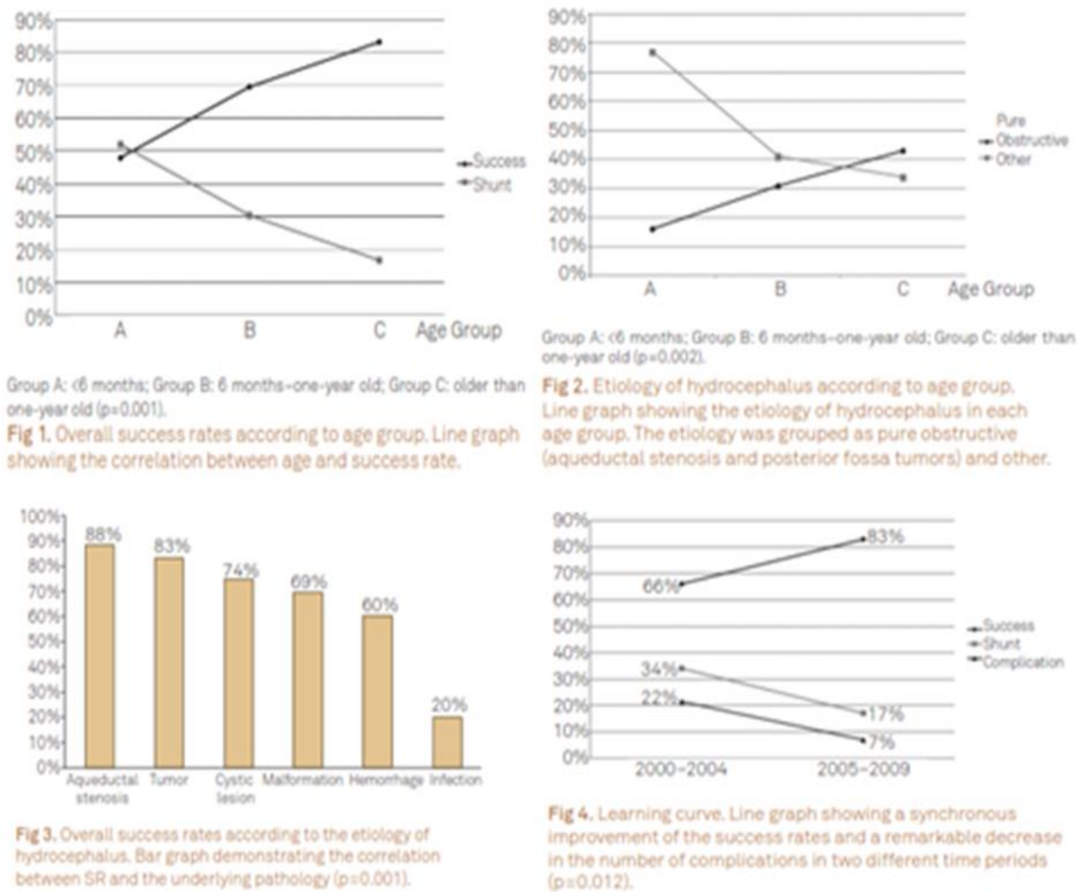
complex cystic lesions or arachnoid cysts in 15 out of 26 (58%) cases, whereas brain or spinal malformations (such as spinal dysraphism, Dandy Walker Cyst, Chiari malformation) were noted in four (15%), and hemorrhage and ventriculitis in two cases (3.8%). AS was observed in five patients (19%).

Out of the 25 patients in Group B, cystic lesions were found in 6 (24%), malformations in 5 (20%), AS in 4 (16%), posterior fossa tumors in 3 (12%), hemorrhage in 2 (8%), and infection in only one case. In Group C, an obvious predominance of pure obstructive hydrocephalus (i.e. posterior fossa tumors and AS) was observed in comparison to the other groups (19% (5/26), 28% (7/25) and 53% (61/115) respectively (p=0.002).

The overall analysis according to etiology showed a success rate of 88.1% (29/33) in AS, 83% (33/40) in hydrocephalus associated to posterior fossa tumors and 74% (32/43) in cystic lesions. Lower success rates were observed in cases of myelomeningocele, intraventricular hemorrhage and ventriculitis (p=0.001). Poorer outcomes were more frequent in premature infants compared to their full-term counterparts (56 and 77% of SR respectively, p=0.042).

The overall success rate of ETV ranged from 33 to 86.4%. ETV alone showed the best overall outcome, with 80% of good results (91/114), followed by 69% (20/29) success rate with cyst fenestrations. Among patients with AS, there was no statistical difference between the age groups: Group A – 60% (3/5), Group B – 75% (3/4) and Group C – 92% (22/24) (p=0.104). The overall outcome of ETV in patients with previous intraventricular hemorrhage or infection was 44%. There was no statistical significance between age groups (p=0.709). The mean length of time between ETV and failure was four months (ranging from 15 days to 9 months). In the presented series, reoperations due to failure of the first attempt of endoscopic procedure were observed in 11.5% of cases. The success rate was 74% after a second procedure.

These results were similar to other series. Therefore, despite the fact that some patients suffering from re-occlusion of the stoma might have to undergo shunting, several authors consider well worth trying to repeat ETV.



Information board (A): Overall success rates according to age, etiology of hydrocephalus, overall success rates according to etiology of hydrocephalus and learning curve. (Study of Luciano Lopes Furlanetti et al).

Table 1. Cerebrospinal fluid circulation restoration procedures in 166 patients and success rate calculated according to the number of patients and procedures.

Underlying pathology	n	SR*			Complication rate
		Group A	Group B	Group C	
Tumor	40	0	2/3 (67%)	31/37 (84%)	6/40 (15%)
Aqueductal stenosis	33	3/5 (60%)	3/4 (75%)	22/24 (92%)	2/33 (6%)
Cystic lesions	43	6/15 (40%)	5/6 (83%)	21/22 (95%)	4/43 (9%)
Brain malformations	29	2/4 (50%)	3/5 (60%)	16/20 (80%)	5/29 (17%)
Hemorrhage/CSF infection	9	0	1/ 3 (33%)	3/5 (40%)	3/9 (33%)
Other	12	0	1/4(25%)	6/7 (86%)	4/12 (33%)

n: Values represent the number of patients (%) unless otherwise stated; SR: success rate; CSF: cerebrospinal fluid; *assortment of the SR by "underlying pathology" did not reveal any statistically significant differences among these groups.

Table 2. Summary of data of the neuroendoscopic pediatric series published in the medical literature*.

Authors and year/ reference	n	Overall SR	SR <2 yrs old	SR <1 yr old	SR <6 mos old	Mean follow-up (mos)	Complication rate
Bognar et al. (2005)	221/247	63%	N/A	63%	34%	32	N/A
Warf et al. (2005)	284*	N/A	N/A	47%	N/A	19	~2%
Peretta et al. (2006)	450/495	N/A	N/A	N/A	N/A	62	8.1%
Oertel et al. (2009)	126/134	72% (81/112)	56% (15/27)	N/A	N/A	12-72	~22%
Kulkarni et al. (2009)	618†	67% (305/455)	N/A	64.1%	44.9%	>6	N/A
Warf et al. (2010)	1406	55.6% (388/979)	58% (64/109)	41% (60/146)	34% (143/421)	6-36	N/A
Sacko et al. (2010)	165	66% (109/165)	71% (27/38)	N/A	32% (7/22)	47 (6–106)	~10%
Naftel et al. (2011)	136/151	68% (93/136)	N/A	N/A	N/A	39.4	9.3%
Durnford et al. (2011)	181*	64.5%	N/A	N/A	N/A	28.6	6%

*Only pediatric series with more than 100 neuroendoscopic cases were included; SR: success rates; N: values represent number of patients/procedures; NA: data not available; ETV: endoscopic third ventriculostomy; yr: year; mos: months; *: ETV alone; †: Multicentric analysis.

Information board (B): CSF restoration procedures and summary of data of neuroendoscopic pediatric series published by Luciano Lopes Furlanetti et al,

In general, neuroendoscopic techniques provide very good results for a wide number of indications in children. Tumor-related CSF circulation problems and AS seem to be particularly well suited to neuroendoscopic treatment regardless of the patient's age. Intraventricular hemorrhage, previous CNS infection and myelomeningocele showed very high failure rate in infants under six months of age. The reduction of complication rates occurred as a result of accumulated surgical experience over the years. Every effort should be made to optimize the selection of surgical candidates on the basis of the underlying pathology.

6.2 TREATMENT OF HYDROCEPHALUS:

In the treatment of hydrocephalus, neuroendoscopic techniques can be used to reconstitute or recreate the natural pathways of cerebrospinal fluid (CSF) flow, and thereby to obviate the need for the insertion of a shunt system (foreign body in the brain!). [4, 9, 18-20, 33, 45]

Endoscopic third ventriculostomy (ETV) has come to new life as a concept for the treatment of occlusive hydrocephalus [10, 26-31, 39-45] because of the complications commonly associated with the implantation of shunts to treat hydrocephalus, including shunt malfunction, thrombosis, infection, overdrainage, and slit-ventricle syndrome. It is the first-line approach in cases of aqueductal stenosis, with a success rate above 60%. ETV is equally effective in treating hydrocephalus due to tectal plate lesions (8, 24). The results of ETV in patients are influenced by hydrocephalus etiology and patient age. Congenital hydrocephalus and that combined with myelomeningocele are not satisfactorily treated in very young children, but success rates are better in older children and adolescents (>70%). [8, 16].

In patients with midline posterior fossa tumors, preoperative ETV is considered in severe hydrocephalus requiring urgent management. ETV is also suitable for postoperative hydrocephalus as an alternative to shunt insertion [16, 21, 45, 47, 50-53, 55-57].

In occlusive hydrocephalus, the CSF resorption mechanisms remain intact, and "internal shunt methods" such as ventriculostomy can, therefore, be used (box). Recent publications have shown that patients, whose hydrocephalus has been treated with shunts and who have suffered multiple episodes of shunt malfunction, can be successfully treated with neuroendoscopy, so that they can do without a shunt from then onward [13, 19, 28, 33, 40, 43-48].

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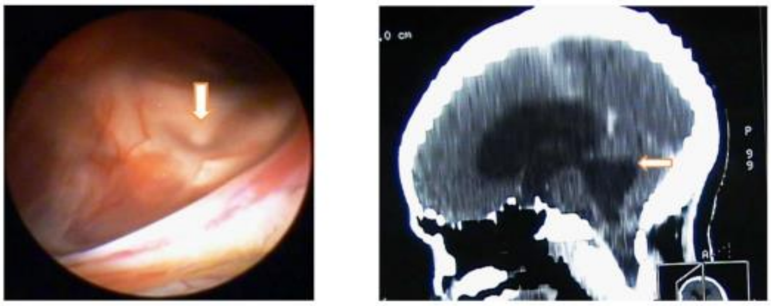
Patients are considered to be at elevated risk of complications from surgical shunt revision, including those with post-hemorrhagic and post-meningitic hydrocephalus [14] should have an endoscopic procedure instead of insertion of CSF diversion device. Since the advent of endoscopy, the old clinical rule "once a shunt, always a shunt" thankfully no longer applies.

In special cases of aqueductal stenosis, particularly when there is an isolated fourth ventricle, a so-called aqueductoplasty can be performed. In this procedure, the pathway of CSF flow is reconstituted by the endoscopic insertion of a stent from the third to the fourth ventricle, and the implantation of a shunt is thereby avoided. Aqueductoplasty is thus an alternative to ventriculoplasty when the latter would be technically difficult [4, 9, 11-13, 15-16, 26-30, 38, 43-45].

Not all types of hydrocephalus are amenable to neuroendoscopic treatment. There is as yet no predictive test for the success of endoscopic ventriculostomy. The best outcomes to date have been documented for occlusive hydrocephalus due to tumorassociated aqueductal stenosis or fourth ventricular displacement, followed by idiopathic aqueductal stenosis [9, 11].

The success rate in post-meningitic and post-hemorrhagic hydrocephalus is markedly lower, as it is, too, in normal-pressure hydrocephalus (NPH). Gangemi et al. [16] treated 25 NPH patients with endoscopic third ventriculostomy and achieved a success rate of 72%; in particular, these patients' gait disturbance was improved. (See figure 5).



(a) (b)

Figure 5: Etiologies of hydrocephalus. (a) Endoscopic view of an aqueductal stenosis. The rostral aperture of the aqueduct is replaced by a fold (arrow). (b) Head CT scan of stenosis of foramina of Luschka and Magendie, sagittal reconstruction. Note the round shape apex of fourth ventricle instead of sharp angle (arrow).

Use of the endoscope has also been explored for other complicated forms of hydrocephalus. Septostomy or septum pellucidotomy can be performed endoscopically to treat isolated lateral ventricles. Fenestration of loculated ventricles due to various causes can also be performed by neuroendoscopy. [16, 19, 21, 28-35]

Aqueductoplasty was recently reported for the treatment of trapped fourth ventricle syndrome. Applied neuroendoscopic techniques have been extended to foraminoplasty of the foramens of Monro and Magendie, as well as endoscopic fourth ventriculostomy (Figure 6).

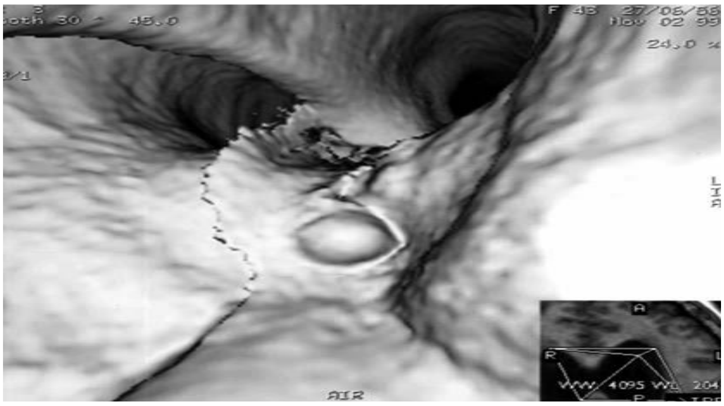


Figure 6: Preoperative imaging of the operative site with so-called virtual neuroendoscopy.

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BOX

Facts on the neuroendoscopic treatment of hydrocephalus

- A stoma in the floor of the third ventricle should be between 4 and 6 mm in diameter, depending on the anatomical situation.
- The rate of closure of ventricular stomata is ca. 2%. A closed stoma can often be reopened in a second endoscopic procedure (11).
- The long-term success rate of third ventriculostomy (i.e., shunt independence) lies between 70% and 90% (12).
- The morbidity and mortality of neuroendoscopic treatment, and the rate of stoma closure, are no higher in infants and young children than in adults. The etiology of hydrocephalus is the most important factor guiding the decision to treat with neuro-endoscopy. In occlusive hydrocephalus, third ventriculostomy is always indicated (13).
- Patients who were initially treated with a shunt and subsequently had multiple shunt-related complications can be treated with neuroendoscopy.

Box 1: Facts on the neuroendoscopic treatment of hydrocephalus.

6.3 TREATMENT OF CYSTS AND INTRAVENTRICULAR TUMORS IN THE REGION OF THE 3RD VENTRICLE:

Intracranial cysts are particularly suitable for neuroendoscopic treatment. Colloid, arachnoid, and pineal cysts can be endoscopically aspirated and fenestrated or removed. For the treatment of cystic craniopharyngiomas, dysontogenetic tumors, gliomas, and metastases, neuroendoscopy can be used in combination with microsurgical resection, radiotherapy, and adjuvant chemotherapy. Third ventriculostomy involves creation of a perforation in the tuber cinereum to allow communication of the third ventricle with the prepontine cistern and is used to treat third ventricle obstruction. It is performed by means of a trajectory through one of the lateral ventricles and foramen of Monro, avoiding the fornix and caudate nucleus.

Acquired Masses of the Third Ventricle: For better understanding of the variety of pathologic processes that may involve the third ventricle and to allow creation of a useful imaging differential diagnosis, we categorize such processes according to one of five locations with respect to the ventricle (Tables 1 and 2). Lesions may be found at or involve the anterior aspect of the third ventricle, at the posterior aspect of the ventricle, at or below the ventricle floor, at the foramen of Monro, or within the third ventricle. Entirely intraventricular lesions other than colloid cysts at the foramen of Monro are uncommon, but there is a long imaging differential diagnosis with differentiation often possible on the basis of MR imaging or CT features. When masses distort or invade the third ventricle, they most frequently arise in relation to the anterior aspect of the ventricle and can be broadly grouped into sellar-suprasellar masses and hypothalamic-chiasmatic masses. For creation of a useful differential diagnosis, the anterior third ventricle lesions can be further divided into pediatric or adult pathologic processes (Table 2). Of the different pathologic entities that may arise in the sellar or suprasellar region and in the hypothalamus or optic chiasm, some lesions such as germinoma, lymphoma, pituitary macroadenoma, craniopharyngioma, and meningioma may rarely arise entirely within the anterior recesses of the third ventricle. [16, 17]

Table 1: Differential Diagnosis for Lesions Distorting or Invading the Anterior Third Ventricle by Age Group.

Pediatric patients
Germinoma
Pilocytic astrocytoma
Craniopharyngioma
Langerhans cell histiocytosis
Adult patients
Lymphoma
Pituitary macroadenoma
Craniopharyngioma
Metastases
Granulomatous disease (eg, sarcoidosis)
Sellar meningioma

Endoscopic procedures include cyst fenestration, tumor biopsy, tumor removal, and metastatic disease assessment. Suprasellar or quadrigeminal arachnoid cysts presenting with hydrocephalus are good candidates for endoscopic fenestration.

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Most patients with intraventricular cyst or tumors have concomitant hydrocephalus. This makes endoscopic surgery particularly advantageous, as simultaneous procedures can be performed for both CSF diversion and tumor management. (2-4, 6-7, 10, 13, 15, 17, 19-23).

Endoscopic tumor biopsy is a well-established method for intraventricular brain tumors. It has a high diagnostic yield (>90%) and low risk (<3.5%). Germ cell tumor, infiltrative hypothalamic/optic pathway glioma, and Langerhans cell histiocytosis are addressable with endoscopic biopsy. [15-21, 30-41] Endoscopic excision is suitable for colloid cysts or tumors that are also pedunculated at the ependymal surface. Colloid cysts, because of their intraventricular location, are a classic indication for neuroendoscopy. [17, 35, 40, 42-46]

Patients with symptoms of occlusive hydrocephalus are treated operatively. For asymptomatic patients, an operation is indicated when the cyst is large enough to threaten an acute occlusion of the foramen of Monro, which would cause acute occlusive hydrocephalus.

Of the pediatric tumors, Langerhans cell histiocytosis most commonly occurs in children under the age of 2 years, whereas the prevalence of germinoma peaks at around 10–12 years. The prevalence of both hypothalamic-chiasmatic pilocytic astrocytoma and craniopharyngioma peaks between the ages of 5 and 15 years.

Germinoma arises at the anterior third ventricle less commonly than at the posterior aspect of the ventricle, but in both cases it tends to have high attenuation at CT and intense solid enhancement at MR imaging.

CSF spread should be carefully sought on gadolinium-enhanced MR images. In contrast, hypothalamic-chiasmatic pilocytic astrocytoma tends to have only mild enhancement and may be seen to extend locally along the optic tracts and nerves. In adult patients with anterior third ventricle masses, it is often difficult to differentiate these entities and the final diagnosis frequently depends on direct biopsy or CSF sampling. [21, 22]

Pituitary macroadenoma is the most common of the adult pathologic processes affecting the anterior third ventricle and most often displaces rather than invades the ventricle. (See Tables 1 & 2). Papillary (adult-type) craniopharyngioma rarely has the calcifications seen in adamantinomatous (pediatric-type) craniopharyngioma and is more often a homogeneous solid mass. [20, 23-24]

Lymphoma, metastases, and granulomatous disease may appear identical at CT and MR imaging. With any of these entities, it is important to look for evidence of CSF dissemination or additional brain or skull lesions that might allow narrowing of the differential diagnosis. Sellar meningiomas extending superiorly to deform the anterior third ventricle can be distinguished by means of their dural base and sclerosis of the adjacent skull base, if present.

Table 2: Differential Diagnosis for Third Ventricle Masses by Location. Note.—SGCT = subependymal giant cell tumor, TSC = tuberous sclerosis complex.*Papilloma, carcinoma, or lymphoma. †Arachnoid, ependymal, endodermal, or neuroepithelial cyst. ‡Chordoid glioma, ependymoma, meningioma, or craniopharyngioma.

Anterior masses
Sellar-suprasellar masses
Hypothalamic-chiasmatic masses
Posterior masses
Pineal mass
Tectal mass
Inferior thalamic mass
Inferior masses
Hypothalamic hamartoma
Basilar artery ectasia or aneurysm
Arachnoid cyst
Foramen of Monro
Colloid cyst
SGCT with associated TSC
Subependymoma
Intraventricular masses
Primary neoplasm of the choroid plexus*
Metastasis or lymphoma to the choroid plexus or the ventricle proper
Vascular malformation of the choroid plexus
Congenital intraventricular cyst†
Solid neoplasm not of the choroid plexus‡

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A preventive operation is justified in view of the reports of sudden death in previously asymptomatic patients with colloid cysts. [18, 28, 30, 38, 41-44]

The postoperative results of neuroendoscopic surgery for colloid cysts are at least as good as those of microsurgery in terms of morbidity, mortality, and recurrence rates.

Endoscopic excision of a colloid cyst is technically feasible through the lateral ventricle in most cases unless the cyst is very large, which increases the risk of venous injury at the foramen of Monro [21, 25, 35, 39-41]. Transventricular endoscopic tumor cyst decompression can temporarily or permanently alleviate obstructive hydrocephalus or visual loss. It can be employed in patients with craniopharyngioma, hypothalamic/chiasmatic astrocytoma, and suprasellar or pineal germ cell tumors. Total removal of the solid tumor is limited due to the inadequacy of compatible endoscopic instrumentation and limited bleeding control.

The success of endoscopic tumor removal depends on tumor size, density, and vascularity [21, 24-28, 33-38]. Extraventricular arachnoid cyst located at the Sylvian fissure or interhemispheric fissure and posterior fossa can be treated with endoscopic approaches. Endoscopic fenestration can be safely performed from inside of the cyst into the surrounding subarachnoid space [6, 8-15, 19-23, 55-57].

Posterior Masses:

The majority of posterior third ventricle masses are of pineal origin, with the most common neoplasm being a germinoma. However, results of pathologic analysis range from benign and typically asymptomatic cysts to pineocytomas (WHO grade II), pineoblastomas (WHO grade IV), other germ cell tumors, and teratomas [26, 48-50]. A recent article highlights the key imaging and clinical features that help distinguish these entities [23, 50]. Most pediatric pineal tumors manifest as third ventricle obstruction and hydrocephalus when the tumor is still small [20, 26-33]. Pineal masses in children or adults can also manifest as mass effect on the tectal plate, causing Parinaud syndrome (paralysis of upward gaze). Masses of the tectal plate itself, or less commonly of the inferior thalamus, may also distort the posterior third ventricle contour, resulting in aqueduct obstruction (Figure 7). Pineocytomas (WHO grade II) are slow-growing tumors composed of mature cells and most often occur in teens and young adults. They may mimic a cyst or appear aggressive, thus mimicking a pineoblastoma. Pineoblastomas (WHO grade IV) are highly malignant primitive tumors and typically arise in children or teens. The main differential diagnosis for these lesions is the more common germinoma, which has a significantly better prognosis.

Masses of the Ventricular Floor:

Masses arising in the floor of the third ventricle are uncommon. The most frequently seen lesion is a hamartoma of the tuber cinereum (hypothalamic hamartoma). These nonneoplastic masses consist of heterotopic neurons and glia and typically manifest in childhood as central precocious puberty or gelastic seizures [27]. At MR imaging, these lesions are isointense to gray matter on T1-weighted images and slightly hyperintense on T2-weighted images, with no enhancement on gadolinium-enhanced images. Extrinsic masses may also distort the floor of the third ventricle. Upward displacement of the floor can occur from dolichoectasia of the basilar artery, a basilar artery aneurysm, or a dermoid, epidermoid, or arachnoid cyst of the prepontine cistern (Figure 7).

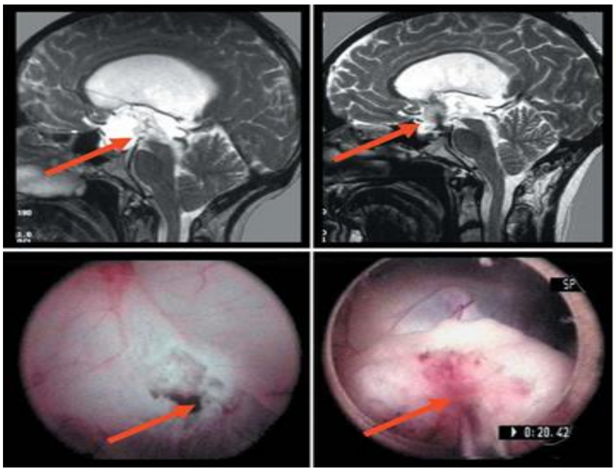

Figure 7: Low-grade astrocytoma in the posterior portion of the third ventricle.

(a) The T2-weighted preoperative MRI scan shows that the tumor is causing obstructive hydrocephalus;
(b) Endoscopic biopsy of the tumor;
(c) Immediately after biopsy, a third ventriculostomy is performed to treat the occlusive hydrocephalus;
(d) The postoperative MRI shows a prominent flow void at the floor of the third ventricle, indicating flow of CSF into the interpeduncular fossa.

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Foramen of Monro Masses:

Masses arising at the foramen of Monro frequently manifest as obstruction of the lateral ventricles. The most common true mass of the foramen of Monro is a colloid cyst, a benign lesion that occurs predominantly in adult patients [(30)]. This well-defined round cyst may be from several millimeters to 3 cm in size and attaches to the anterior superior aspect of the third ventricle roof. Often hyperattenuating at nonenhanced CT, it has variable signal intensity at MR imaging and is often hyperintense on T1-weighted and FLAIR images. Peripheral gadolinium enhancement is rarely seen. Ninety percent of colloid cysts are asymptomatic and stable, while 10% are reported to enlarge or cause hydrocephalus. Rapid enlargement has been associated with coma and death. [(31, 44, 51-57)]

In the publications of Hellwig, D. et al, [(2-3, 5-9)], among 32 patients with colloid cysts, who were treated by neuroendoscopic surgery, the majority had a subtotal removal of the cyst, yet only 1 patient had a recurrent cyst after 12 years of follow-up. It should be noted, however, that only a few endoscopically treated patients have been followed postoperatively for more than 10 years. It therefore remains possible that endoscopic colloid cyst evacuation and partial resection of the cyst wall actually does lead to a higher recurrence rate than complete microsurgical cyst resection. Solid intraventricular tumors, too, can be treated with neuroendoscopy. Such tumors are preferably biopsied with neuroendoscopic guidance, rather than "blindly" by stereotaxy. Biopsy under direct vision is particularly advantageous in the area of the foramen of Monro, as well as for pineal tumors in the posterior portion of the third ventricle. The operative approach can be chosen to spare ventricular vessels and functionally important structures, because endoscopy, unlike stereotaxy, offers the neurosurgeon a direct visual check.

If the tumor is causing occlusive hydrocephalus (e.g., because of its location in the posterior portion of the third ventricle), a third ventriculostomy can be performed at the same sitting, or, alternatively, a stent can be inserted between a lateral ventricle and the third ventricle, or between the third ventricle and fourth ventricle. (See Figure 7 above and Figure 8 below). The most common pediatric lesion of the foramen of Monro is an SGCT associated with TSC. It is found in up to 20% of patients with TSC and typically occurs in patients younger than 20 years [(32)]. Subependymal nodules or hamartomas may occur anywhere along the ventricular surface in patients with TSC, but a nodule that enlarges over time and is greater than 1.3 cm raises concern about a neoplasm [(33)]. SGCT is a low-grade astrocytoma (WHO grade I) that appears as a lobulated, heterogeneous, enhancing mass at the foramen of Monro and extends into the lateral or third ventricle. It may result in obstruction of the foramen. Cystic change, calcification, or hemorrhage may be present.

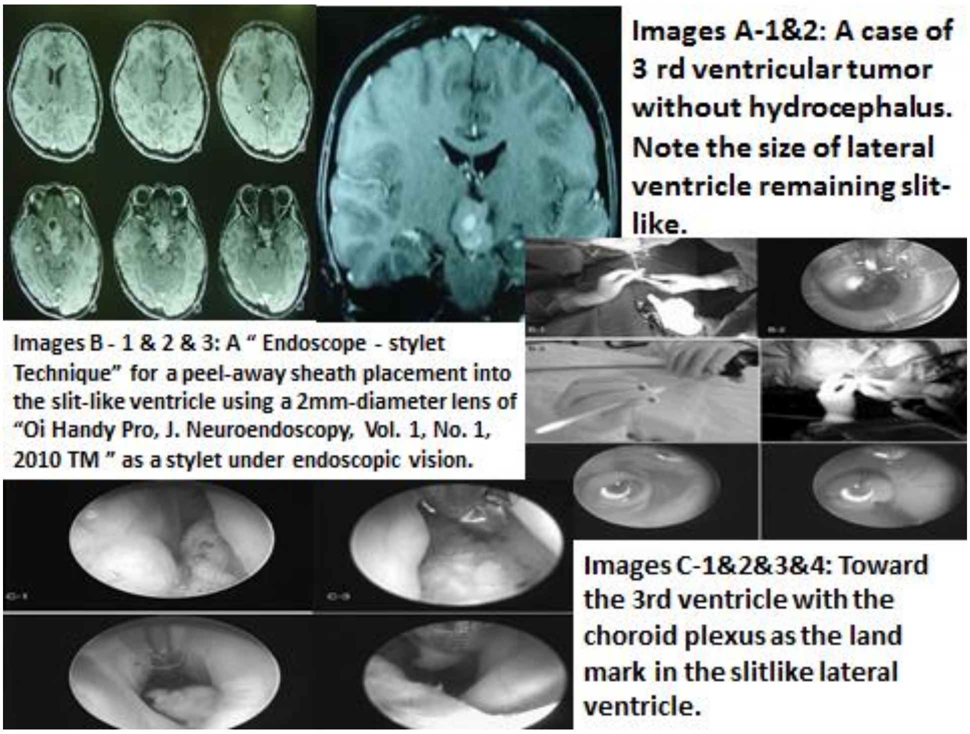

Figure 8: Neuroendoscopic surgery of a 3rd ventricular tumor

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Subependymoma (WHO grade I) is a rare slow-growing tumor that most commonly occurs in the fourth ventricle in middle-aged to elderly patients. In the supratentorial brain, it favors the foramen of Monro and appears as a small (<2 cm), lobulated, well-defined lesion with minimal to moderate enhancement. It protrudes into the lateral ventricles more often than into the third ventricle [34, 35]. It may be an incidental finding or may obstruct the lateral ventricles. It is important to note that a key differential diagnostic point at MR imaging for all foramen of Monro lesions is CSF flow artifact.

Intraventricular Masses:

Purely intraventricular lesions of the third ventricle are rare. Intraventricular third ventricle masses are most often lesions of the choroid plexus (eg, primary choroid plexus papilloma [CPP] or choroid plexus carcinoma), a vascular malformation of the plexus, or a metastatic neoplastic or infectious lesion (eg, tuberculosis) seeding the plexus. [14, 18-24, 25-29, 36–39]

Choroid plexus cysts are incidental benign neuroepithelial cysts in most patients but are of importance during fetal imaging. When they are found in association with other markers for chromosomal abnormality, amniocentesis should be considered [39]. Primary lymphoma of the choroid plexus and secondary lymphoma seeding the plexus have been described. However, these entities are all relatively rare in the third ventricle, with choroid plexus masses being more common in the lateral ventricles and fourth ventricle.

Less commonly than choroid plexus lesions, intraventricular cysts (including congenital lesions and infectious entities such as neurocysticercosis) occur in the third ventricle. Rarely, purely intraventricular neoplasms such as meningioma, craniopharyngioma, and intraventricular glial neoplasms may be found (Table 1) [40–45].

Choroid plexus papilloma (CPP) is a benign papillary neoplasm (WHO grade I) derived from choroid plexus epithelium. Up to 50% of CPPs occur in patients younger than 10 years; these lesions are most often found in the lateral ventricle. In adults, CPP is most often located in the fourth ventricle, but up to 5% of cases arise in the third ventricle [36, 37]. CPP is associated with hydrocephalus due to CSF overproduction, mechanical obstruction, and impaired CSF resorption with hemorrhage. In the absence of clearly invasive features, it is difficult to distinguish CPP from choroid plexus carcinoma with imaging alone [16, 19, 22-26, 33-38].

CPP of the third ventricle in a 55-year-old man with a history of headaches for several months. (a) Axial nonenhanced CT image shows dilatation of the lateral ventricles and anterior third ventricle along with a subtle round mass (arrow), which is isoattenuating relative to the thalami. (b) Sagittal FLAIR image shows the small intraventricular mass (arrow) in the posterior third ventricle. The mass is separate from the pineal gland and appears to obstruct the aqueduct. Contrast-enhanced imaging showed solid enhancement. At surgery, the mass was found to be a CPP.

Chordoid glioma is a rare, slow-growing, noninvasive neoplasm (WHO grade II) containing both glial and chordoid histologic elements. It arises from the anterior third ventricle and is frequently adherent to the hypothalamus. At MR imaging, chordoid glioma appears as a well-defined ovoid mass that is isointense on T1-weighted images and enhances intensely with gadolinium. Cystic changes may be present, but calcification is rare [40, 42, 44, 47-49]. Complete resection appears to be curative, although it is often difficult to achieve due to the anatomic relationships of the tumor [15-19, 21-25, 30-36, 39-41].

Uncommonly, other neoplasms may arise entirely within the third ventricle, such as ependymoma, ganglioglioma, and glioblastoma multiforme [18-25, 29-33, 42–45]. Metastatic seeding of the third ventricle by an intracranial neoplasm may also manifest as an intra-ventricular mass distinct from the choroid plexus [13-18, 20-24, 32-39, 41-46]. The likelihood of complete tumor resection via neuroendoscopic surgery is a function of tumor size. Neuroendoscopy is excessively time-consuming if the tumor exceeds 2 cm in diameter.

Hellwig et al [2-11] demonstrated in many publications the advantages of neuro-endoscopic cysto-ventriculostomy and biopsy with aid of neuronavigation in patients with intraventricular lesions in the 3rd ventricle and occlusive hydrocephalus in comparison to stereotactic procedures. It was shown, that in the majority of such cases, the treatment of the occlusive hydrocephalus was possible in the same sitting. (See box 1 above and Figure 9 below).

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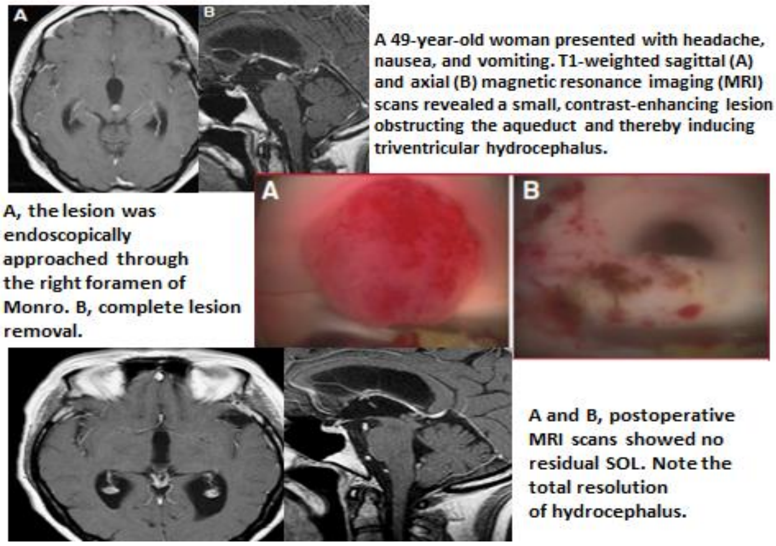

Figure 9: Endoscopic excision on intraventricular SOL and treatment of the associated hydrocephalus.

6.4 ENDOSCOPIC REMOVAL OF INTRAVENTRICULAR HAEMATOMA:

The primary aim of the acute management of intraventricular hematoma (IVH) is the faster removal of intraventricular blood and the rapid reversal of ventricular dilation with normalization of intracranial pressure.

The conventional treatment of IVH consists of external ventricular drainage with or without fibrinolysis. The method, however, is not without its drawbacks; it's efficacy is not immediate, and satisfactory drainage of blood could take several days [16-23]. Bilateral craniotomy and microsurgical evacuation are obviously limited to the aspiration of the casting clots of the lateral ventricles and, partially, of the third ventricle. All the goals of effective IVH treatment may be achievedusing a neuroendoscopic approach, possibly with a lower complication rate than that associated with external ventricular drainage (EVD). Intraventricular blood clots casting the ventricles are less consistent than intraparenchymal ones, and they can be reached throughout the ventricular system with a fexible endoscope. The use of combined intravascular embolization and endoscopy should be considered among the treatment options in patients presenting with IVHs from bleeding aneurysms, to assure fast and safe management of both the IVH and the ruptured aneurysms. (See Figure 10 below).

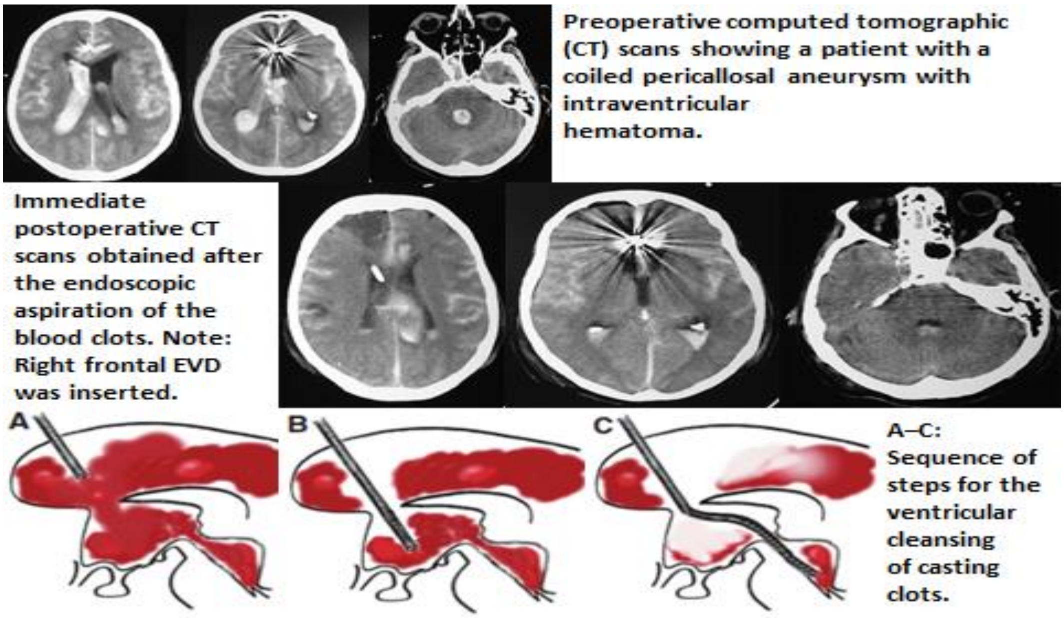

Figure 10: Endoscopic removal of IVH.

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6.5 ENDOSCOPIC COAGULATION OF HYPERPLASTIC CHOROID PLEXUS:

Bilateral choroid plexus hyperplasia is a rare congenital condition that is clinically characterized by early onset of severe communicating hydrocephalus and poor neurodevelopmental prognosis [40, 48]. The management of the hydrocephalus in these patients is still a matter of debate. Extrathecal shunting procedures are conditioned by the high CSF production rate [48], and both ventriculoperitoneal shunts [40, 48] and ventriculoatrial shunts [40] are burdened by very high failure rates. Even temporary external ventricular drainage exposes the patient to the risks of cardiovascular and electrolytic disturbances [48]. Primary open surgical excision is associated with a high intraoperative bleeding risk with a significant mortality rate and demands a double surgical procedure [40]. Endoscopic coagulation of the hyperplastic choroid plexi [40], by itself, only occasionally leads to sufficient control of the CSF production rate [10, 48], but it can help to reduce the bleeding at the time of the craniotomic choroid plexus excision that can be planned as a one-stage procedure with a reduced operative transfusion rate [48].

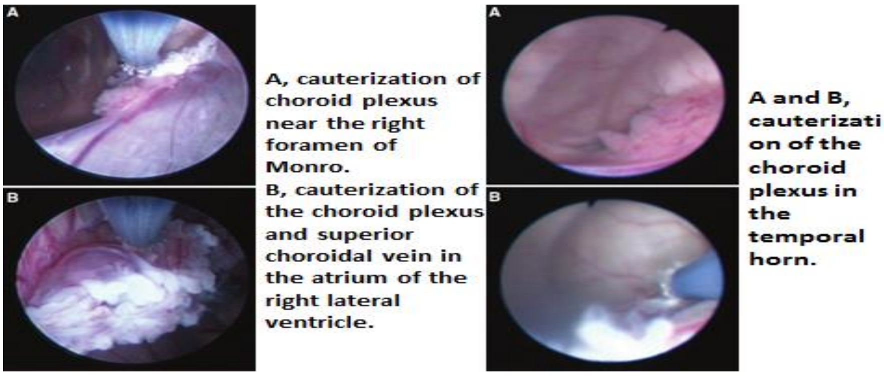

Figure 11: Endoscopic cauterization of the choroid plexus.

6.6 ENDOSCOPIC PITUITARY SURGERY:

Guiot, in 1962, was the first to use an endoscope in pituitary surgery [20]. In recent years, the use of endoscopy in adenoma resection has markedly increased but has not yet become standard. The operative approach is simple and fast and has few complications. As of now, adequate instrumentation is available to allow the neurosurgeon to work effectively through a narrow opening. It is important, however, that the neurosurgeon performing endoscopic pituitary surgery should also be well-versed in conventional transsphenoidal microsurgery, so that he or she can switch to the other technique if anatomical or other technical difficulties are encountered. The literature does not yet provide long-term results of endoscopic adenoma resection; therefore, this technique cannot yet be definitively assessed.

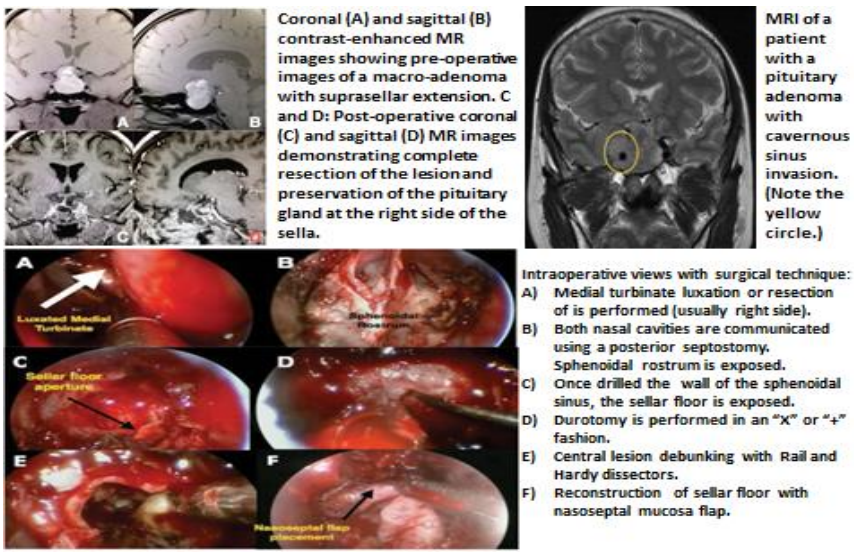

Figure 12: Endoscopic technique for excision of pituitary adenoma

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The following conclusions can be drawn: Endoscopic pituitary surgery is associated with shorter operative times, reduced operative trauma, rare intra- and postoperative complications, and a shorter postoperative period of bed rest.

6.7 TREATMENT OF HYPOTHALAMUS HAMARTOMA:

Hypothalamus Hamartomas (HH) are rare non-neoplastic congenital malformations arising from the inferior hypothalamus and associated with gelastic seizures, precocious puberty, and cognitive problems. All patients except those with precocious puberty require surgical treatment. Single or combination treatment should be used according to HH type (classified by Delalande and Fohlen [3-5, 7-11, 15-19, 21-30] or Choi et al. [2-3, 13-19, 21-24]. The transcallosal craniotomy approach is preferred for large HHs. Gamma knife surgery is an option for small lesions. Stereotactic radiofrequency thermocoagulation has been safely applied for small- or medium-sized HHs with good short-term results. Endoscopic resection assisted with stereotactic navigation has been attempted to surgically remove small HHs, but parts of the tumors remained.

Surgeries to resect HHs are typically performed in multiple steps. Nevertheless, recent reports indicate that endoscopic disconnection of HHs seems to be safer and more effective than other modalities [3, 20, 22-24, 27-33, 37-39].

In most cases, navigation assistance is recommended because lateral and third ventricles have normal sizes in these patients.

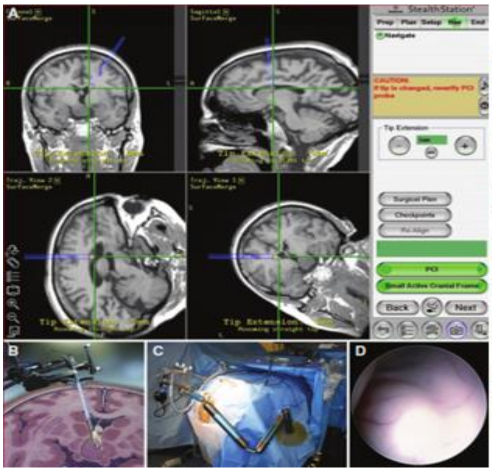


Figure 13 : Endoscopic approach to the hypothalamic hamartoma

6.8 TREATMENT FOR SKULL BASE LESIONS:

Neuroendoscopy for skull base tumors began with Carrau and colleagues [1], who reported their original experience of endonasal transsphenoidal hypophysectomy at the University of Pittsburgh. de Divitiis and colleagues [4-7, 11-16. 18-23, 27, 29, 33, 41] expanded the scope of this approach to include other lesions of the sellar and parasellar regions.

The bilateral endonasal endoscopic approach now allows for visualization of tumors at the anterior skull base up to the crista galli and down to the level of C2. The endoscopic endonasal technique has been applied for surgical excision of pituitary adenoma and craniopharyngioma with encouraging results and low morbidity. The route of the endoscopic approach for sellar or suprasellar tumors should be based on the extent of lesion. Supradiaphragmatic lesions can be removed via the endonasal route, and suprasellar prechiasmatic preinfundibular lesions can be removed with the transtuberculum-transplanum sphenoidale approach [11-16, 17-21, 23, 27, 29, 31, 34-39, 41-44].

Endoscopic treatment has been applied for the treatment of CSF rhinorrhea, which commonly occurs as the result of trauma and iatrogenic disruption of the skull base and secondary to inflammatory, neoplastic, and pseudotumor syndromes. Skull base defects can be repaired with endoscopic remodeling of tissue planes and complete separation of the cranial space and sinonasal cavities to perform a multilayered reconstruction. Small bony defects can be closed with a single layer of autologous fat or fascia, followed by tissue sealant. Larger skull base defects with a high-volume intraoperative CSF leaks require multilayered closure. This can be achieved with an autologous fat graft in the bony defect followed by fascia lata, bony buttress, and tissue sealant.

These larger skull base defects can be supplemented with a gasket seal closure [21, 23, 27-33, 39-41, 43, 47, 49].

6.9 ENDOSCOPIC SURGERY FOR CRANIOSYNOSTOSIS:

Jimenez and colleagues [12, 13, 15, 18, 22, 27, 30-34, 41-44] pioneered minimally invasive surgical treatment of craniosynostosis. This condition can be corrected with endoscopy-assisted craniosynostosis surgery (EACS) before the age of 6 months combined with postoperative helmet molding therapy.

The optimal age for EACS is 3 months. The procedure is essentially strip craniectomy and can be performed with a standard armamentarium and a 0° endoscope with a working shaft used for endoscopic facial lift surgery without irrigation.

The authors reported a low complication rate and good success rate. A separate aspirator parallel to the endoscope is used for blood aspiration.

In scaphocephaly, the craniectomy is performed from the anterior to the posterior fontanelle. The bone is cut with strong scissors. The removed strip should be 4-5 cm wide and 11 cm long. Lateral barrel stave osteotomies or wedge-shaped osteotomies can be added behind the coronal suture and in front of the lambdoid sutures. This endoscopic approach has a low reported complication rate and good success rate.

Furthermore, only 9% of 139 patients required blood transfusion in their most recent publication. The children wear a helmet within 3 weeks postoperatively for 10 months. Special attention is paid for possible pressure ulcerations or eczema, but skin complications are rare [12, 13, 21].

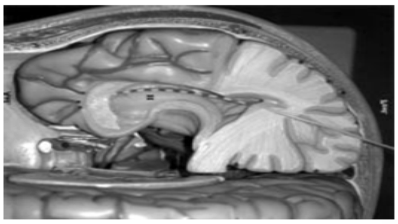
6.10 NEUROENDOSCOPY IN EPILEPSY SURGERY:

Epilepsy surgery has constantly evolved in various fields of knowledge. Surgical criteria have shifted from standard procedures to individualized forms of treatment, depending on physiological tests and specific imagenology findings in an individual patient. New instruments and applications based upon older instruments have been described in the treatment of epilepsy surgery, including the use of endoscopes. Frequent indications of neuroendoscopy in epilepsy surgery have been mostly to assist in open procedures, particularly when fluid-filled spaces are present within the surgical field, such as cystic parasites, tumors, arachnoid, or other types of cysts. Other indications certainly include cases of temporal lobe epilepsy, where ventricular exploration precedes intraventricular electrode placing as a tool to localize epileptogenic zones. Although described several years ago, there has been a recent trend in performing endoscopy-assisted section of the corpus-callosum in patients with generalized seizures. As neurosurgical instruments and techniques continue their progress, endoscopy will be included more frequently as part of the armamentarium in epilepsy surgery.

In the World Journal of Neuroscience, 2016, 6, 114-118, Oscar Humberto Jimenez-Vazquez et al. described the useful function of neuroendoscopy in the diagnosis and treatment of various intracranial cystic lesions, as well as in the assistance of open intracranial procedures as an aid in the treatment of lesions associated with epilepsy [51-52].

Intraventricular monitoring for temporal lobe epilepsy was reported by Song, JK, Abou-Khalil and Konrad, PE, in J Neurol Neurosurg Psychiatry 2003;74:561–565. [51-52]

The authors described endoscopically placed temporal horn, intraventricular electrodes provide an alternative to transcortical depth electrode placement.



Model representation of placement of intraventricular electrode. Demonstration of intraventricular electrode seen in a cutaway view of the left temporal lobe in a brain model in which the residual left hemisphere is viewed from above. Note relative position of the IVE along the lateral margin of the hippocampus in the temporal lobe.

Selected EEG recording obtained from intraventricular electrode showing seizure onset. Depicted is an ictal onset only seen in the left intraventricular electrode (arrowhead). LD, left depth (IVE); LF, left foramen ovale; RD, right depth (IVE); RF, right foramen ovale.

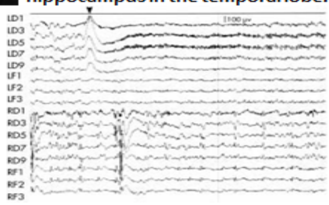


Figure 14: Endoscopically aided placement of intraventricular electrode

6.11 SPINAL ENDOSCOPIC SURGERY:

Many different techniques in the category of minimally invasive endoscopic spinal surgery have been developed in recent years, and some have already been described in this journal. Thus, the development of neuroendoscopy now means that Krämer's assertion, made in 2002 [22-24], is no longer true: "If the anulus fibrosus has been perforated, sequestrated material is pressing on the nerve root, and corresponding neurological manifestations are present, an open operation is necessary." A number of endoscopic systems are now available that enable the removal, through the intervertebral foramen, of subligamentous, freely sequestrated, intraforaminal, mediolateral, and medial disk fragments, as well as fragments that have become cranially or caudally displaced within the spinal canal. In certain situations, e.g., when there is a displaced fragment and the site of perforation of the anulus fibrosus is covered, the intervertebral space need not be completely emptied of disk material after the prolapse is removed. Removal of the fragment alone is considered adequate treatment and has been shown to yield comparable results. [22-24, 47, 49]

A further endoscopic method for the treatment of disk prolapses and spinal canal stenosis is so-called microendoscopic discectomy (MED), which makes use of a posterior or posteromedial approach through the interlaminar window. It is not yet clear whether endoscopic spinal techniques yield better long-term results than conventional microsurgery.

In the last decade, the neuroendoscope has been increasingly used in the surgical management of both intra- and extradural spinal diseases. Fenestration of intradural arachnoid cysts can be easily performed with the endoscope. In the 1990s, it was popular to dissect the septations of multiloculated syringomyelia cavities, but their clinical and radiological benefits were limited. [1-11, 13-18, 20-24]

The neuroendoscope is an important part of the minimally invasive spine surgery movement. Endoscopic approaches have expanded to thoracoscopic sympathectomy, discectomies, lumbar laminotomies, anterior approaches for spinal reconstruction, and resection of tumors and cysts. Endoscopic discectomy is increasingly performed in both the thoracic and lumbar regions. Epiduroscopy is used in patients with peridural fibrosis after spinal procedures, but it’s success and usefulness must be examined further. [6-10, 21-26, 47-49]

6.12 NEUROENDOSCOPIC TREATMENT OF INTRAPARENCHYMAL LESIONS:

Improved illumination and vision of endoscopes has led to the possibility of working in the brain parenchyma. The concept of a keyhole craniotomy combined with a selected trajectory enables the endoscopic approach of intraparenchymal lesions with an assisted navigation system. Endoscopic resection is then performed by introducing instruments through the sheath, and various instruments such as suction tubes, tumor forceps, microscissors, and monopolar or bipolar coagulation can be used for lesion resection. To ensure efficient operation under a good endoscopic view, it is very important to maintain good intraoperative irrigation and drainage. [21, 39-44] Partial or total lesion removal may be achieved depending on the nature of tumor. Selected cases for this endoscopic surgery remain limited but include cavernous angiomas, intraparenchymal hematomas, cerebellar infarctions, and brain abscesses. This technique was demonstrated to be accurate and safe and possibly will be expanded to remove other intraparenchymal lesions in the future. [21, 23, 40-45, 48-50] Endoscopes can be used as auxiliary tools in microsurgery, particularly in operations for cerebrovascular aneurysms, microvascular decompression, and lesions of the cerebellopontine angle. Endoscopes of different designs are available for different uses. They provide the important ability to look around corners or behind the lesion in question. In aneurysm surgery, for example, the optimal position of the clip can be confirmed, while in microvascular decompression the vascular loop impinging on the trigeminal nerve can be inspected from all sides. [16-21, 24-28, 31-33, 35-39]

6.13 NEUROENDOSCOPY-ASSISTED MICROSURGERY:

Many neurosurgeons have recently used the neuroendoscope to assist with “traditional” skull base microsurgery. The endoscope has already been reported as a useful adjunct to the microscope in anterior skull base surgeries, posterior fossa approaches, and aneurysm surgery. The microscopic approach makes dissected structures visible in a straight line with the great advantages of high resolution, excellent color fidelity, and stereoscopic vision. For working “around a corner,” the endoscope is applied to reduce retraction and skull base drilling.

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In endoscope-assisted microsurgery, most of the procedure is performed under a microscopic view due to better image quality. However, endoscopic approaches are used in certain steps. The endoscope is mostly used to look around bony or dural corners, as well as neurovascular structures, to avoid retraction and extensive skull base drilling. Frequently, the endoscope is simply used freehand for inspection. However, when bimanual dissection is required, the endoscope is fixed to a self-retaining holding device, and the surgeon has both hands free for manipulation [1-21, 38-42, 45-50]. The endoscope-assisted technique has proven useful in skull base surgery for tumors (pituitary tumor, craniopharyngioma, acoustic neuroma, epidermoid), aneurysm clipping, and trigeminal microvascular decompression. [17-21, 23-24, 27-33, 38-41]

6.14 ENDOSCOPIC FENESTRATION ON INTRACRANIAL ARACHNOID CYSTIC LESIONS:

Fenestration of arachnoid cysts or intratumoral cystic cavities is an advanced technique in the neuroendoscopic surgery. Arachnoid cysts are benign cystic dilatation containing cerebrospinal fluid (CSF) -like fluid that does not have communication with the ventricular system. They arise from duplication of arachnoidal membranes and were first described by Bright in 1881. Intracranial arachnoid cysts are relatively seen frequently during the routine neurosurgical practice, especially after widespread use of CT scanning and MR imaging, which had shown a higher incidence of such lesions in the literature that was approximately, presumed to be 1% of all intracranial lesions [19, 31, 36, 57]. (See Figure 15).

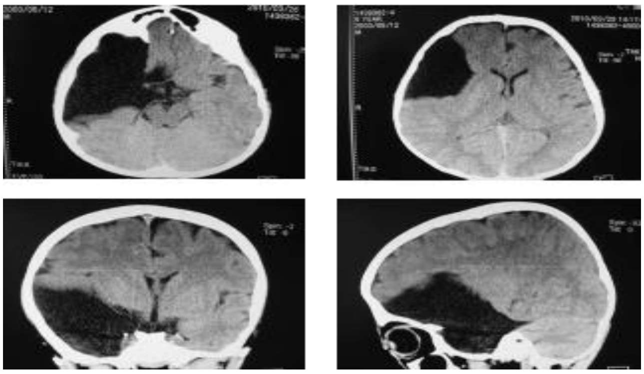

Figure 15: Endoscopic fenestration of a middle fossa arachnoid cyst

Ahmed Zaher et al. described a series 13 cases of posterior fossa arachnoid cysts, which were treated endoscopically. They considered the treatment of the arachnoid cyst as a minimally invasive alternative to traditional surgical modalities of such entity. The authors recommended the endoscopic method as an effective and safe technique that carries minimal morbidity as a first treatment option for symptomatic posterior fossa arachnoid cysts and cystoperitoneal shunts could be reserved only for residual or recurrent cases. (See figure 16).

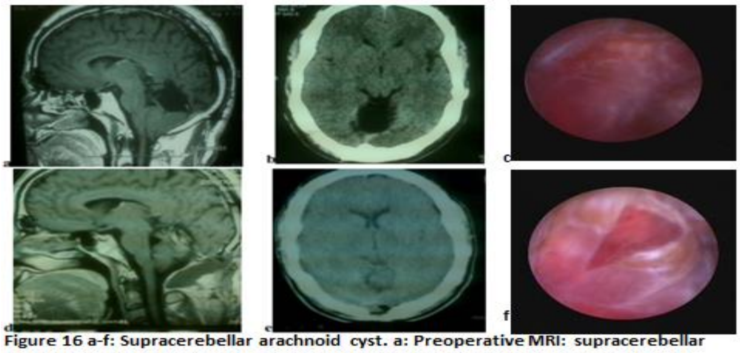

Figure 16 a-f: Supracerebellar arachnoid cyst. a: Preoperative MRI: supracerebellar cyst with cerebellar tonsil descent into the foramen magnum; b: Preoperative CT scan of the same patient; c: Intraoperative endoscopic view of the anterior wall of the cyst d: Postoperative MRI showing remission of cyst and improvement of tonsillar herniation; e: Postoperative CT scan with remission of the cyst; f: Endoscopic view after fenestration of the anterior wall of the cyst.

6.15 ENDOSCOPIC CARPAL TUNNEL SURGERY:

Endoscopic carpal tunnel surgery is now part of standard practice and is used as an alternative to conventional macrosurgical techniques. A number of different companies now offer complete endoscopic surgical kits for carpal tunnel surgery, some of which are quite expensive. Surgeons can also put together all of the necessary apparatus for carpal tunnel

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surgery more cheaply by themselves. Two kinds of approaches can be used for endoscopic surgery in the palm site of the hand: the uniportal approach (insertion of the endoscope proximal to the wrist joint) and the biportal approach (second skin incision).

Endoscopic splitting of the flexor retinaculum is indicated in all patients with clinically and electrophysiologically documented carpal tunnel syndrome. The procedure is contraindicated if the carpal tunnel is too narrow or if the patient has previously undergone carpal tunnel surgery on the affected side. Although few data from randomized studies are available to date, and although the use of endoscopy for carpal tunnel surgery faced criticism [25, 28] because of a higher complication rate than that associated with the traditional, open technique, endoscopy in this area seems to provide the following advantages: A better cosmetic result, earlier use of the operated hand, and less postoperative pain.

7. FUTURE PERSPECTIVES FOR THE NEUROENDOSCOPY

The endoscopic operative procedures achieved good results as of now with the configurations included third ventriculostomies for noncommunicating hydrocephalus, fenestration of septation of the hydrocephalic ventricle or septum in isolated ventricles (isolated unilateral ventricle), fenestration of arachnoid cysts and tumors, placement of ventricular tubes in ventricles or intratumoral cystic cavities, biopsies of intraventricular tumors and other advanced techniques. [3-15, 19-24, 51-57]

The history of neuroendoscopic surgery is essentially linked to developments in the approach instrumentation. The first attempts at intracranial endoscopic surgery were performed using cystoscopes early in last century. [17-29, 33-51]

Since then, the rigid type of endoscope had been the main instrument in this field, though many type of flexible viewing devices have been developed, for example those used in the upper and lower gastrointestinal system and upper respiratory tract.

The quality of lighting guides and objective lenses has improved and microinstrumentation has further developed for this rigid type of neuroendoscope. [21-33, 45-57]

Through the straight working channel, this system can accommodate relatively complicated instruments. (See Table 3 below).

Table 3: Future aspects of the research subjects on neuroendoscopic surgery and realistic indications

Possible indications	Critical points	Future aspects of the research	Realistic indication if confirmed following
Ventriculostomy -> non-communicating hydrocephalus	• Hydrocephalus : completely arrested postoperatively (?)	• ICP dynamics	• Definitely postoperative arrested hydrocephalus
	• Subarachnoid CSF dynamics: intact preoperatively (?) • Hydrocephalus completely arrested postoperatively (?)	• Preoperative estimation of postoperative CSF circulation	• Definitely postoperative arrested hydrocephalus
Choroid plexus coagulation -> communicating hydrocephalus	• High CSF protein: Harmful to homeostasis of the normal brain metabolism (?)	• CSF formation / absorption rate	• Safety of reduced CSF circulation to the brain metabolism
(not likely acceptable)	• Reduction of CSF formation: satisfactory (?)	• Disturbed brain matabolism and development • Preoperative estimation of postoperative CSF circulation	
Shunt manipulation -> shunt placement and / or revision	• Stylet maneuvering shunt placement : best technique (?)	• Brighter operative field and high resolution of image	• Best positioning of shunt tube in the ventricle
Tissue biopsy / resection -> Intraventricular lesions	• Biopsied tissue : enough amount of material for pathological diagnosis. (?)	• Mobility of the instruments of brighter operative field	• Less-invasive tissue diagnosis
Tumor resection -> deep-seated intraparenchymal lesions	• Endoscopy : Just an assisting tool in microsurgery (?)	• Micro-neuro-endoscopic surgery	• Endoscopy-assisting microneurosurgery
Cyst fenestration -> arachnoid cyst	• Long-standing opening of the fenestrated window with maintained CSF flow (?)	• Prevension of postoperative symptomatic giant subdural hygroma : Selection of transventricular ventriculo-cystostomy route	• Application of the finest neuroendoscopy via small or slit-like ventricle

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Over 85 years have passed since the first clinical trials of endoscopic ventriculostomy for hydrocephalic patients. Indications for endoscopic third ventriculostomy (ETV) have been expanded to the treatment of not only obstructive hydrocephalus, but also some types of communicating hydrocephalus.

While successful results have clearly been obtained for non-communicating hydrocephalus in recent clinical research, the pathological states which for ETV is effective remain enigmatic. ETV has also developed with advances in equipment and techniques. Following the evolution of ETV, complications have also changed and reduced in number.

The future of neuroendoscopic surgery is likely to be bright. The field will benefit from further miniaturization of cameras and optical technology, innovations in surgical instrumentation design, the introduction of new navigation or robotics systems, new technological advances such as multiport endoscopic surgery, and an enhanced ability to perform endoscope-assisted microsurgery with bimanual microdissection.

With ongoing development of endoscopic instruments and advanced surgical techniques including multiport approaches, endoscopic surgery will be expanded beyond intraventricular and skull base lesions to intraparenchymal brain lesions. These advances will be important for the future of endoscope-assisted microsurgery. [11-19, 24-30, 36-46]

Other goals are telemanipulated neurosurgery with supervisory-controlled robotic systems, shared control systems, and even fully robotic telesurgery. Nanotechnology developments are needed to address future indications for minimally or even ultramicro-access neurosurgery.

In the future, neuroendoscopy is expected to become routine in modern neurosurgical practice. Institutions should develop training programs for young neurosurgeons.

8. CONCLUSIONS

Neuroendoscopy is already recognized as a minimal invasive technique for the treatment of many different lesions affecting the nervous system. It has relatively less intra- and postoperative complications and it, obviously, does not cause more postoperative mortality / morbidity rate than other operative procedures.

For a precise management, the preoperative planning with aid of neuronavigation is required, and that can optimize intraoperatively the neuro-endoscopic procedure, which can minimize the intra- and postoperative complications.

There are advantages for the neuro-endoscopic cysto-ventriculostomy and biopsy with aid of neuronavigation in patients with intraventricular lesions in the 3rd ventricle and occlusive hydrocephalus in comparison to stereotactic procedures. It was also demonstrated, that in the majority of such cases, the treatment of the occlusive hydrocephalus was possible in the same sitting without insertion of CSF diversion device (such as VP shunt system).

In the next few years, the advantages and disadvantages of neuroendoscopy in comparison with another, established neurosurgical techniques will need to be critically assessed for a number of the indications for which it is currently performed.

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