Minimal Invasive Procedures in Neurosurgery

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Ever since surgery was introduced for the treatment of neurological diseases, miniaturized approaches have been considered and developed in order to limit trauma of vital and delicate structures of the central nervous system. Thus, the application of stereotactic techniques and endoscopy date back to the beginning of this century.

Stereotactic neurosurgery started with the goal of reaching target areas in the brain through a burrhole and then to guide (by the aid of landmarks on the bony skull and its radiographic image) small instruments such as needles and biopsy forceps. Moreover, ventriculograms with contrast material were used as guides to calculate coordinates for a 3-dimensional guiding-system within the brain. Coordinates for the brain's interior structures had to be taken from a theoretical average human brain as shown in a stereotactic brain atlas.

Today, imaging techniques are available for direct depiction of the individual brain and spinal cord; thus, target points within the cranial cavity are calculated from CT- or MRI-scans for classical stereotactic procedures such as tumor biopsy or implantation of radiating seeds. These methods have improved precision for target-finding to an error of plus or minus 1 mm. The disadvantage still remains, however, that these images are "historical," i.e., demonstrations of the state before the procedure. Drainage of cerebrospinal fluid of a larger cyst may change the anatomical situation and require re-imaging before further invasive procedures become possible.

Another step in the development of imaging-guides became real-time ultrasonography, the only method for direct intraoperative demonstration of diseased areas within the brain or spinal cord that has been adopted for stereotaxy.[1,2,3]

In addition, miniaturized video technology allows for simultaneous imaging through fine catheters or lens-systems, thus making stereotaxy an easier undertaking.

Endoscopic neurosurgery, too, has been used early on in the treatment of a variety of diseases.[4] However, hemorrhage in the operating field in a comparably tiny approach and the difficulty in keeping the operating area sterile made this procedure rather complicated and it thus fell into disuse, until new instruments, in conjunction with the endoscope, became available. Besides imaging with video techniques and ultrasonography, the problems of endoscopic surgery were mainly diminished by the introduction of laser energy for coagulation.

Thus, endoscopic neurosurgery has become a new area. Fitting between classical stereotactic neurosurgery and conventional neurosurgery, it uses stereotactic methods to approach a target area within the brain in order to perform miniaturized microsurgical procedures. Moreover, video- and ultrasound-imaging enable such procedures in the spinal canal, either to reach a prolapsed disc[5] or targets within the spinal cord itself.[6] In recent years, these new surgical procedures have been summarized, the same as in other surgical disciplines, under the term of minimal invasive neurosurgery.

In the following section, several examples of possible interventions will be discussed, along with the technical equipment developed and/or applied for their accomplishment.

Ultrasound-guided stereotaxy for intracranial endoscopy and other minimal invasive procedures

This discussion will be limited to intracranial ultrasound-guided procedures under video control. Although spatial resolution is limited with real-time ultrasound (the same as with other techniques), images are usually excellent with the appropriate instrumentation[7] (Figure 1).

Two different types of stereotaxy have been applied using ultrasound imaging: 1. Simultaneous stereotaxy via a small craniotomy with the probe placed onto the brain surface, while a surgical instrument is introduced into the brain under imaging control (Figure 2a).

Figure 1. Intraventricular low-grade astrocytoma.

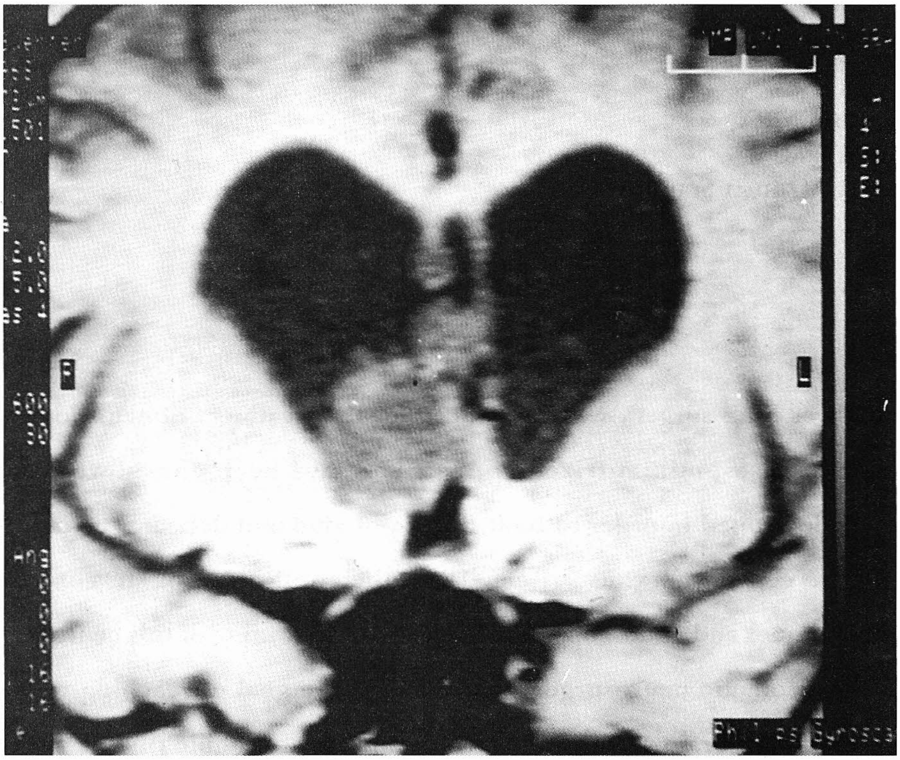

Figure 1a. Preoperative MRI, coronal section.

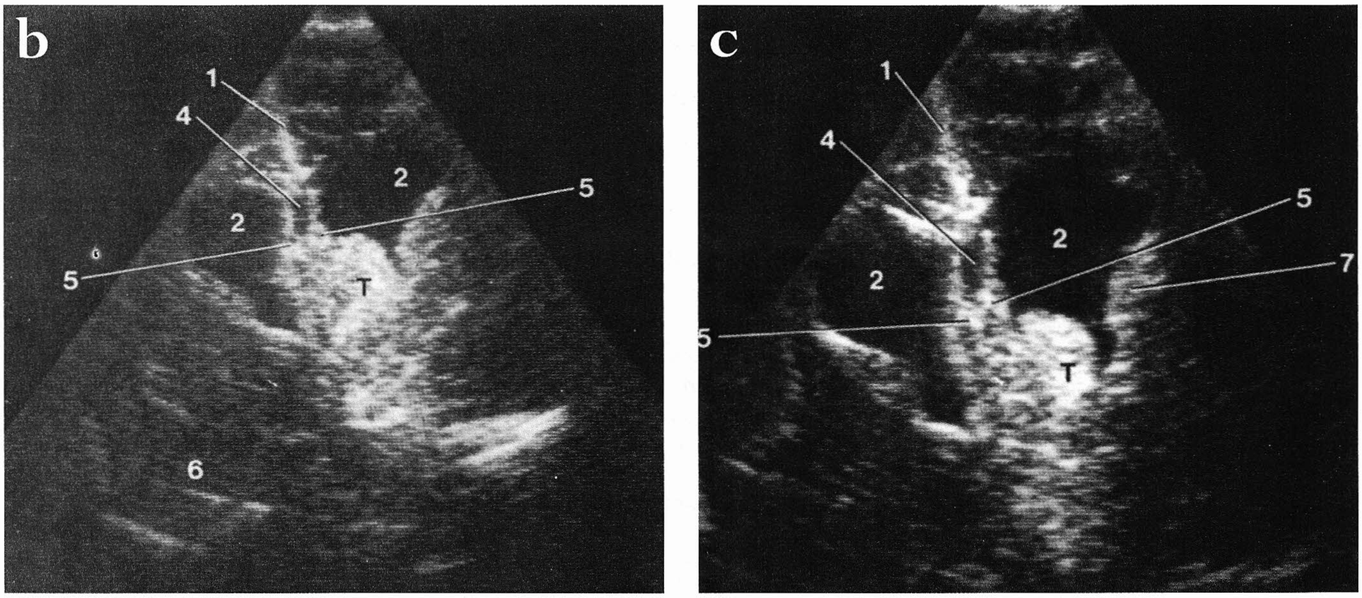

Figure 1b. and c. Intraoperative ultrasound images, coronal sections with 5 MHz ultrasound head: 1= interhemispheric fissure, 2= lateral ventricle, 3= third ventricle, 4= cavum vergae, 5= columnae fornicis, 6= left temporal fossa, 7= caudate nucleus, T= tumor.

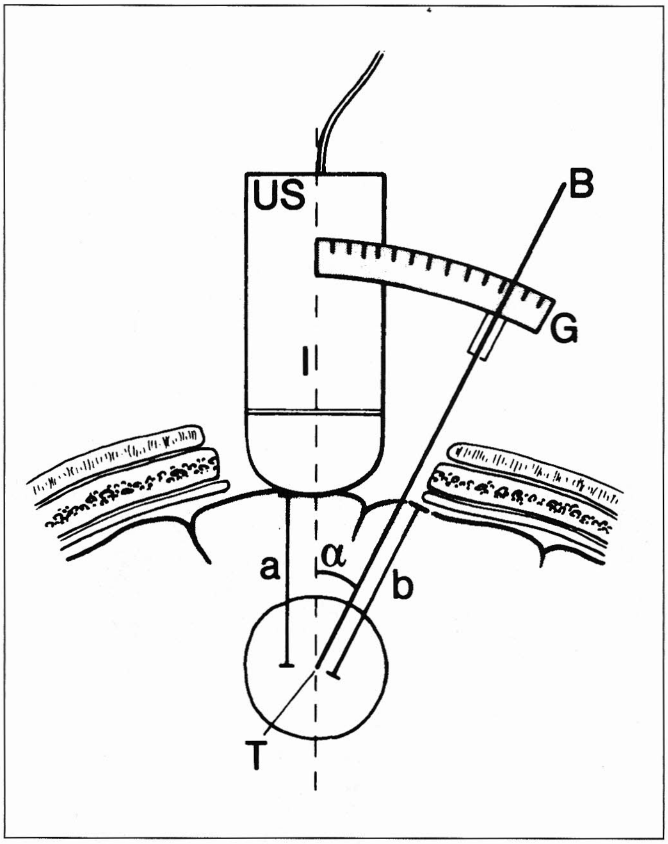

Figure 2.a. Simultaneous ultrasound-guided stereotaxy: a= distance between brain surface and target point in the depth of the brain, alpha= angle between central ray and B, b= distance between brain surface and target point along B, B= biopsy needle, G= instrument guide with indication of angle for angle alpha, 1= central ray of the ultrasound image, T= target point, US= ultrasound probe.

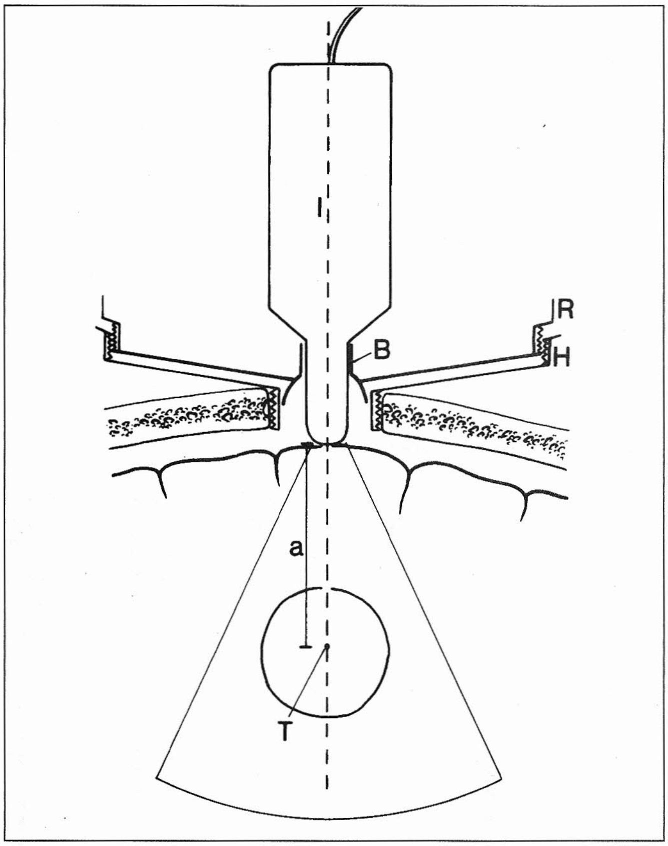

Figure 2b. Consecutive ultrasound stereotaxy: a= distance between brain surface and target point, B= ball joint, H= fixation ring for the ultrasound probe and biopsy instrument, 1= central ray of ultrasound probe, R= fixation ring, T= target point.

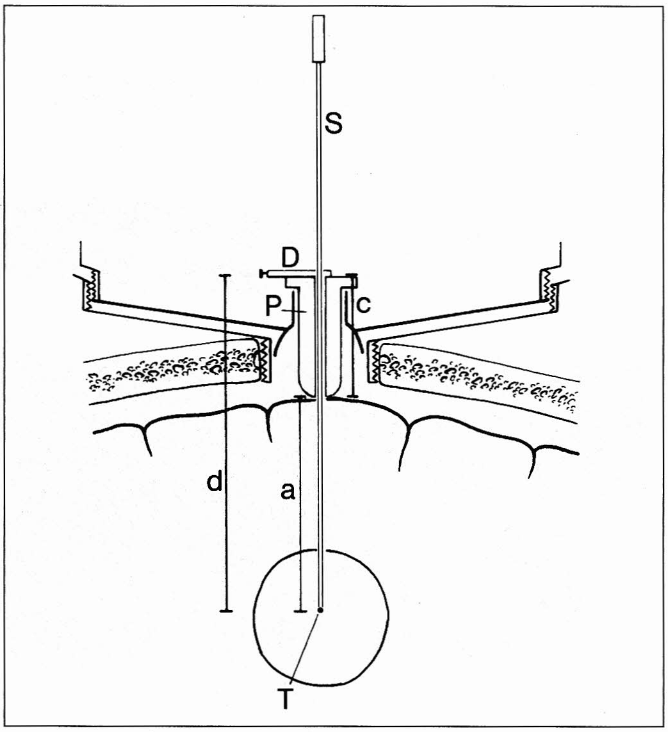

Figure 2c. Consecutive ultrasound stereotaxy for biopsy via a burrhole: a= distance between brain surface and target point, c= length of guide P, d= distance between needle guide and target point (a+c. , P= guide for biopsy needle, S= biopsy needle, T= target point.

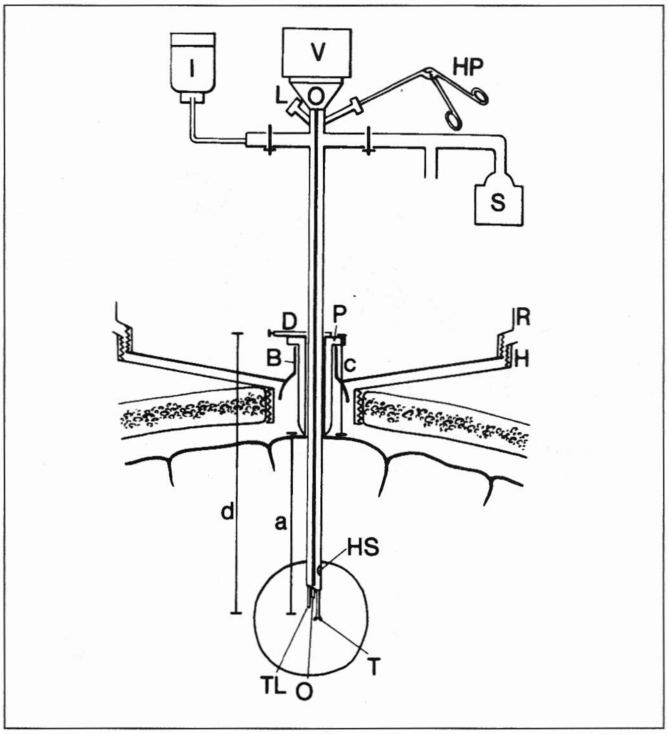

Figure 2d. Ultrasound stereotactic endoscopic microneurosurgery: H and R= fixation ring for ultrasound probe or neuro-endoscope. I= infusion system for the neuro-endoscope, L= Neodym YAG laser connector, O and V= connector for video system, S= suction system, D= tip of microbiopsy forceps, HP= microbiopsy forceps, TL= tip of microlaser tube.

2. Consecutive stereotaxy via a burrhole, where the pathway to the target is first established by aid of the ultrasound probe and then replaced by a guide-piece for a surgical instrument such as a needle, forceps or endoscope harboring instruments (Figure 2 b–d).

Both procedures exclude intraoperative complications such as hemorrhage behind the surface, which is visible by ultrasound. Likewise, at the end of an intervention, ultrasound imaging for another 15 to 20 minutes excludes hemorrhage in the immediate postoperative period. Thereafter, a drainage catheter is implanted for further control of the operating field.

Endoscopy was performed using the Storz Neuro-Endoscope (Karl Storz Endoscopy GmbH & Co., Tuttlingen, Germany). This rigid 6-mm-diameter instrument harbors channels for video imaging, irrigation, suction, laser tube and another surgical instrument (Figure 3).

A Neodymium-Yag laser (MBB, München, Germany) was used for coagulation at 20–40W through a 300-µm or 500-µm tube.

Irrigation of the operating field is performed with artificial cerebrospinal fluid; intracranial pressure is controlled by adjusting the level of the irrigation source and the outflow tube. Further technical details are indicated elsewhere.[4,7,8]

This procedure is indicated primarily

Figure 3. Instruments for neuro-endoscopy.

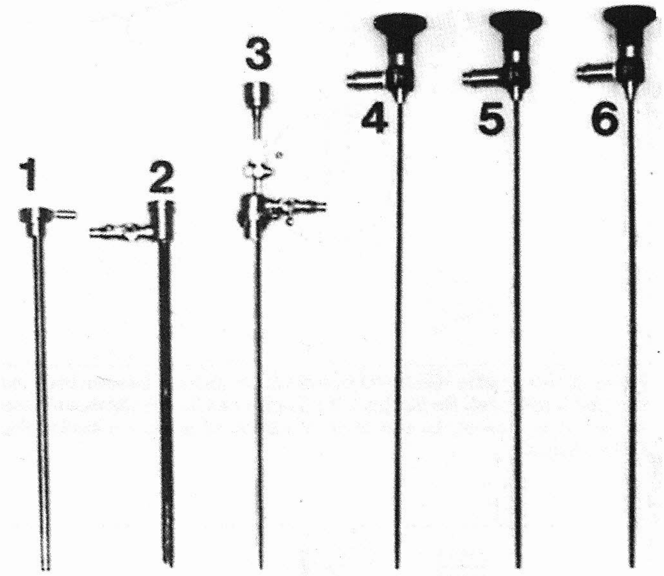

Figure3a. 1-6= parts of the endoscope.

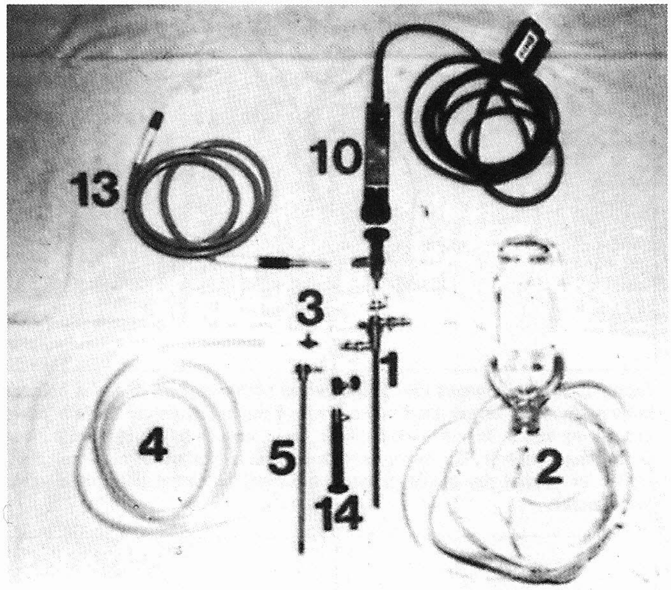

Figure3b. 1= neuro-endoscope, 2= irrigation system for the endoscope, 3 and 4= suction system, 10= video camera, 13= cable for cold light source, 14= safety handle.

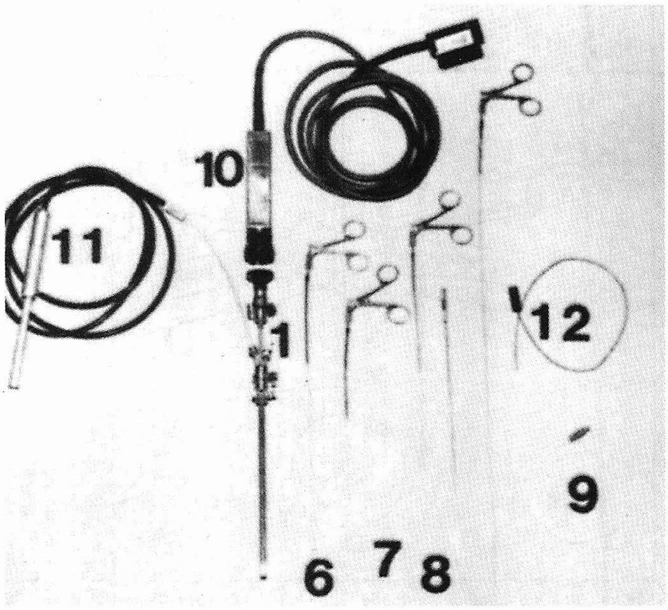

Figure 3c. 1= neuro-endoscope, 6= biopsy forceps, 7= micro-scissors, 8= forceps, 9= suction tube, 10= video camera, 11= Neodymium YAG laser tube, 12= monopolar coagulation probe, 13= cable for cold light source, 14= safety handle.

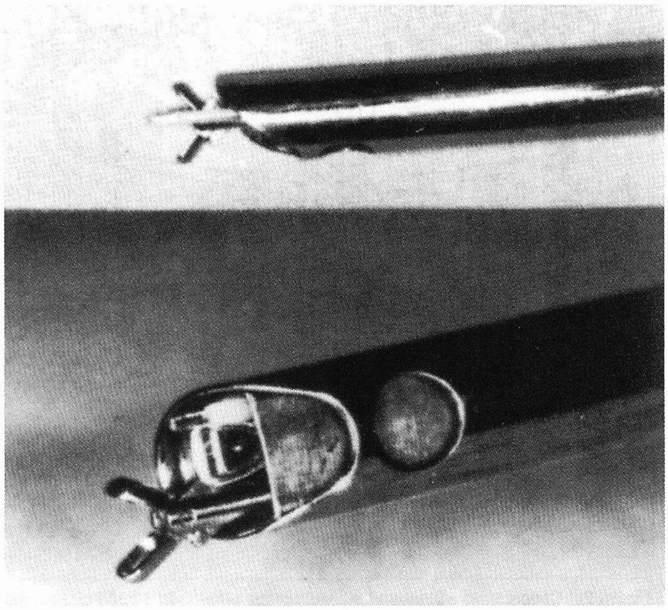

Figure 3d. Tip of endoscope with oblique end and additional suction channel, optic system, biopsy forceps and tip of laser probe.

Figure 4.

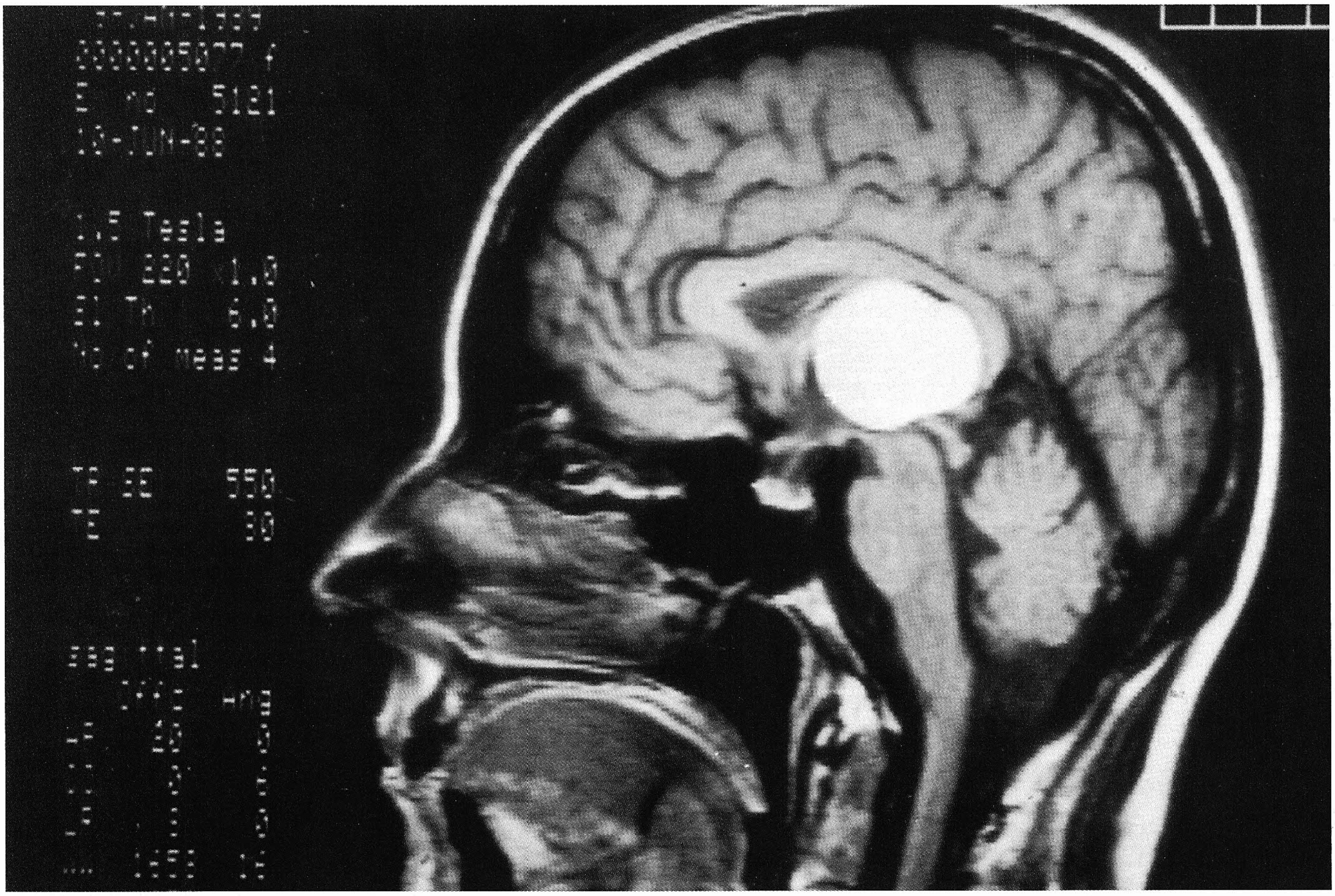

Figure 4a. (above) and 4b. (below): Colloid cyst of the third ventricle on in the preoperative MR image.

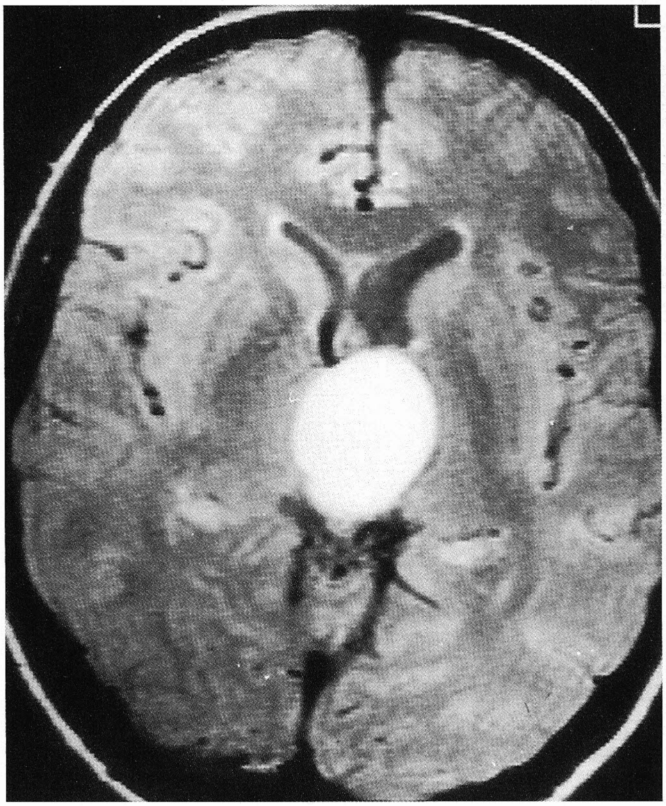

Figure 4b.

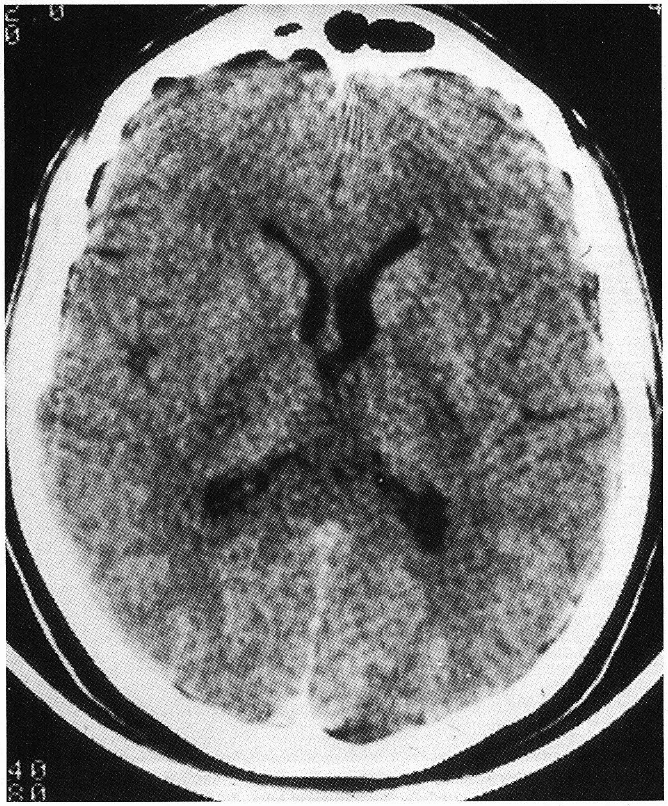

Figure 4c. Control CT following ultrasound stereotactic punction under local anesthesia and drainage of the cyst.

Figure 5. Cystic craniopharyngeoma in a 30 year old patient suffering from blockade of both foramina of Monro and chronic headache as well as attacks of vertigo and hemiparesis on the right side:

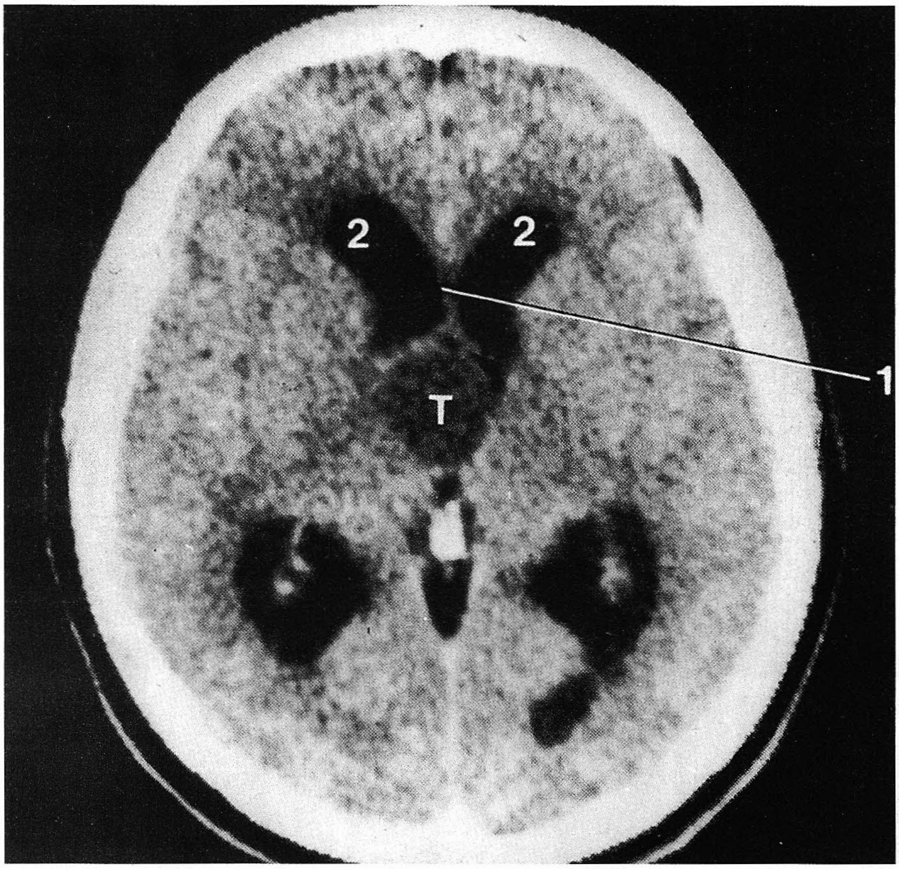

Figure 5a. Preoperative CT.

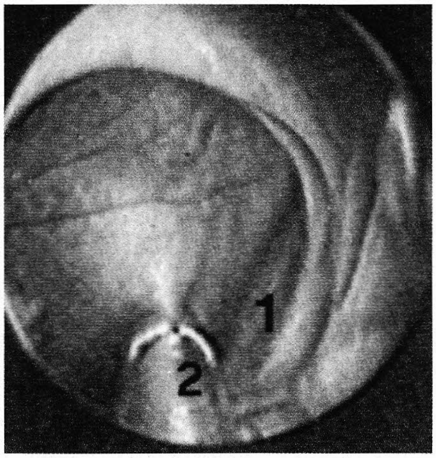

Figure 5b. Intraoperative images during ultrasound stereotactic endoscopic resection of the tumor: view into the right lateral ventricle towards the enlarged foramen of Monro on the right side; 1= vascularized membrane of the cystic tumor, bulging from the third ventricle through the foramen of Monro into the lateral ventricle, 2= choroid plexus.

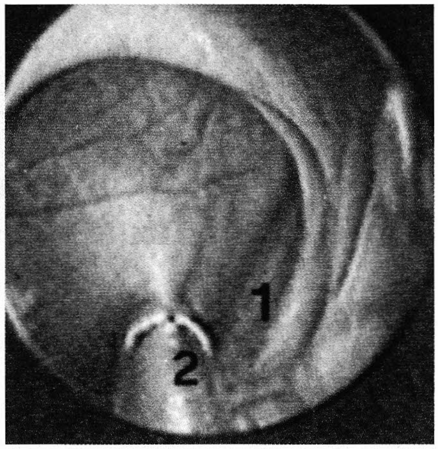

Figure 5c. View of the surface of the tumor during its opening with a microbiopsy forceps (2) following laser coagulation of the tumor surface. 1= floor of the third ventricle.

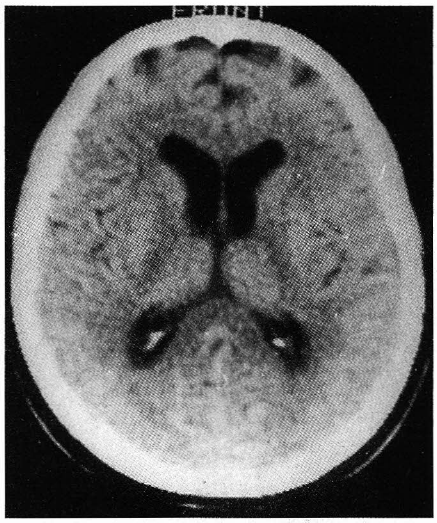

Figure 5d. Control CT one month postoperatively. Normalization of the ventricular volume, the tumor is removed.

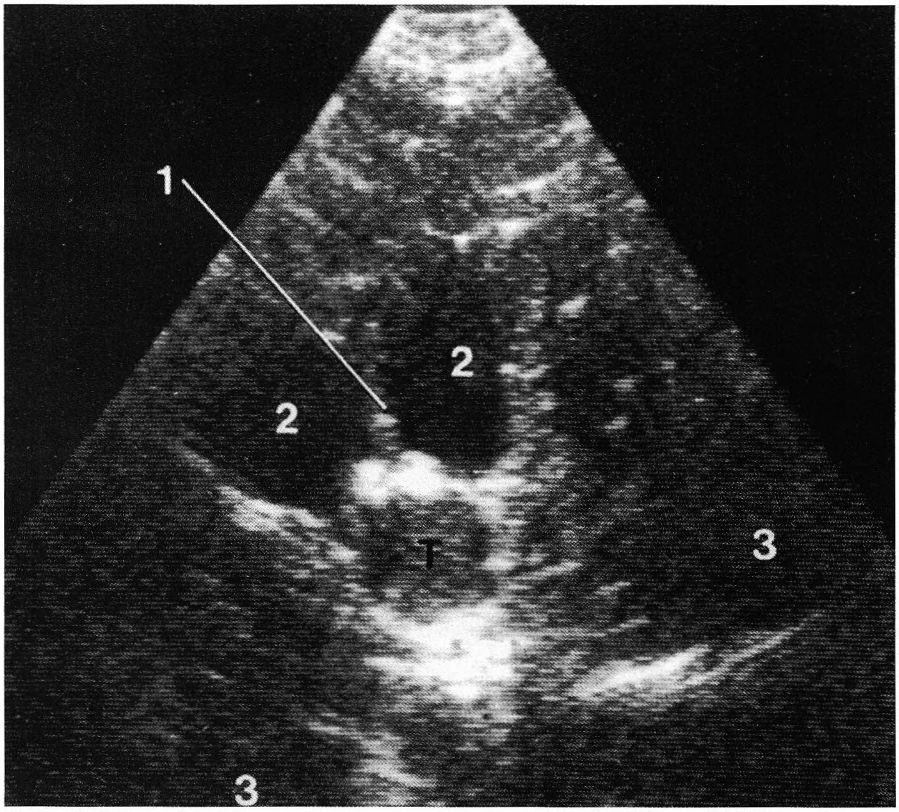

Figure 5e. Intraoperative ultrasound image, coronal section through a right frontal burrhole: 1= septum pellucidum, 2= lateral ventricle, 3= temporal lobe, T= tumor.

in cases of intraventricular diseases such as tumors (Figures 1, 4, 5) or hematomas (Figure 9 c–f), especially in cases of obstructive hydrocephalus, where reduction of the mass-lesion may prevent shunt-dependent hydrocephalus. Moreover, it may be useful in case of cystic hemispheric tumor (Figure 6) and intraparenchymal hematoma or abscess (Figure 7).

Solid ventricular tumors are biopsied transendoscopically under visual control on the video screen; oozing from the site of biopsy is controlled with the laser. The advantage of this procedure over classical stereotaxy is visual control, which enables biopsy from sites visually selected. Moreover, in some cases, further excision may be possible by the aid of stepwise coagulation, scissors and biopsy forceps. The defect from the approach through viable cerebral tissue remains much smaller than with conventional microsurgical techniques. A residual tumor may be treated depending on histology, e.g., by stereotactic implantation of a radiating seed or other radiotherapy.

Cystic ventricular tumors such as colloid cysts may be punctured and drained via a blunt needle without further instrumentation (Figure 4). Alternatively, biopsy, coagulation and

Figure 6. Astrocytoma of the left premotor area in a 23 year old male patient.

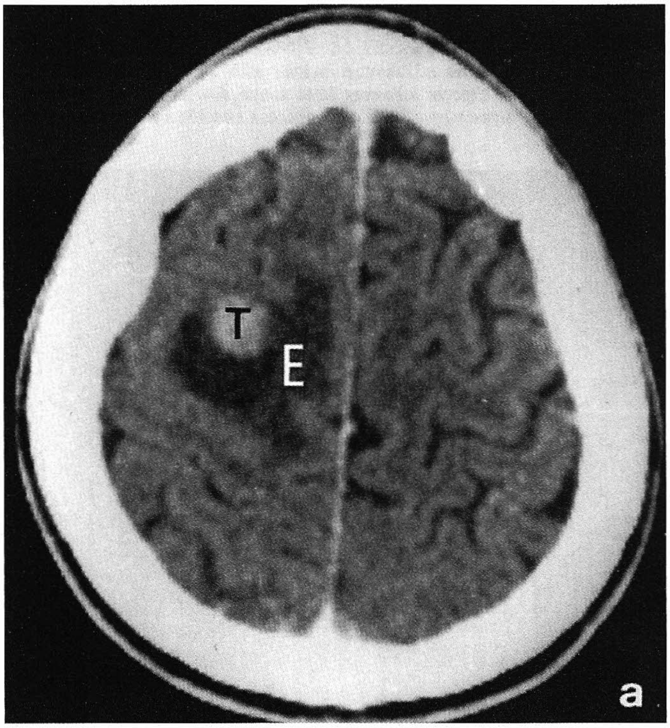

Figure 6a. Preoperative CT.

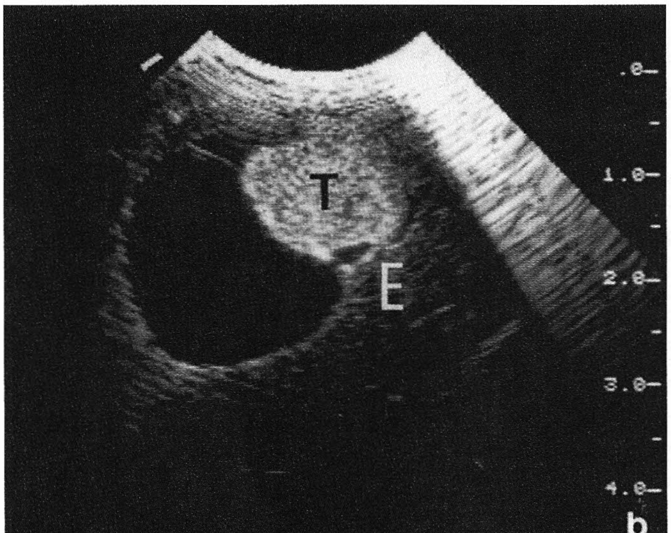

Figure 6b. Intraoperative ultrasound image with a 10MHz probe, T= solid tumor, E= edema. The ultrasound image shows the large cystic part of the tumor as dark, well defined area, the border between edema and cystic tumor is better defined on ultrasound than on CT.

Figures 7a,b,c,d. Brain abscess of the right fronto-temporal region in a 40-year old male patient.

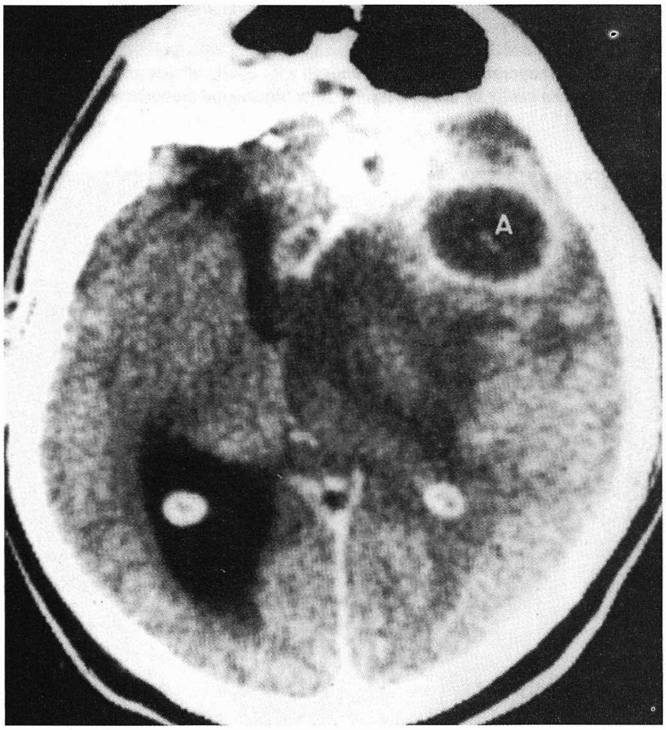

Figure 7a. Preoperative CT.

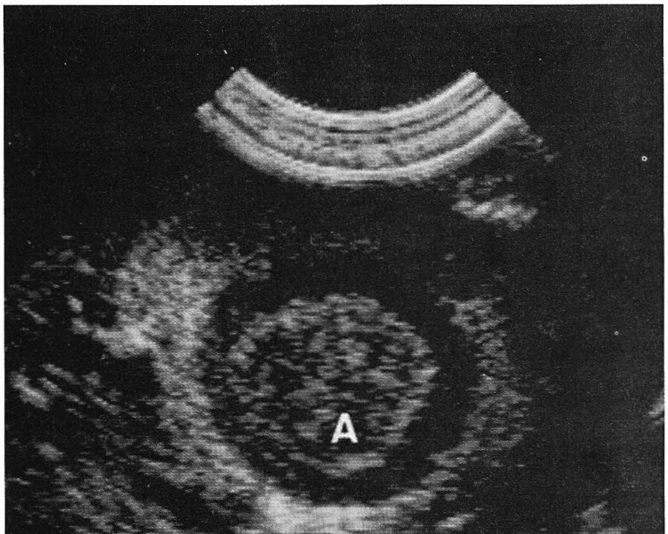

Figure 7b. Intraoperative ultrasound images with 5MHz ultrasound head: abscess before drainage,

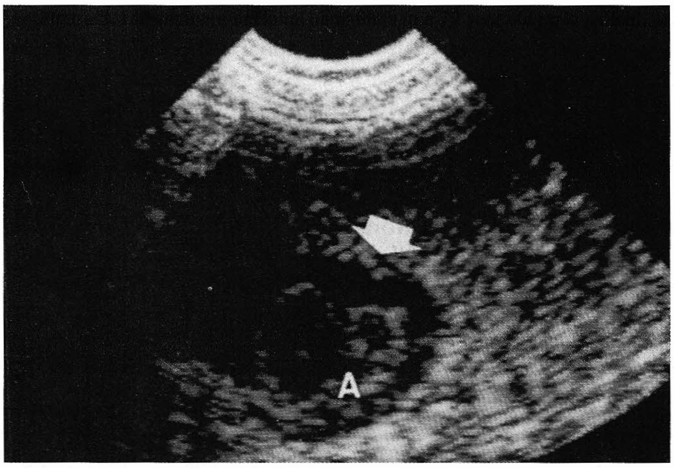

Figure 7c. Intraoperative ultrasound images with 5MHz ultrasound head: puncture of abscess cavity by aid of simultaneous ultrasound stereotaxy.

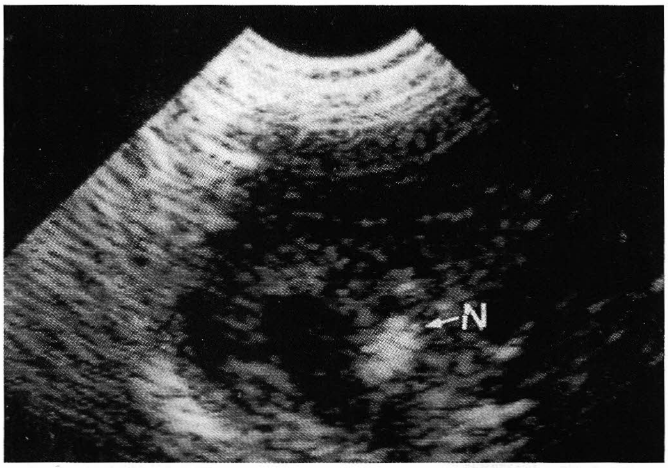

Figure 7d. Intraoperative ultrasound images with 5MHz ultrasound head: shrunken capsule of abscess following its drainage. A= abscess cavity, N= tip of biopsy needle, arrow= invagination of abscess capsule by entrance of the biopsy needle.

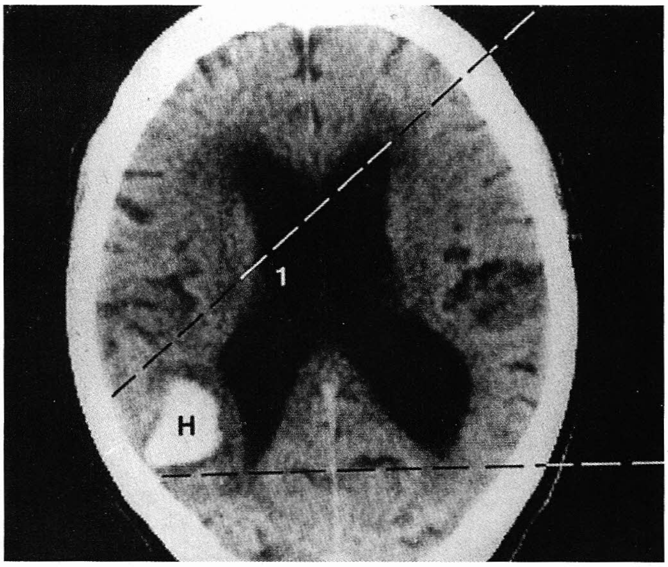

Figure 8a. Preoperative CT.

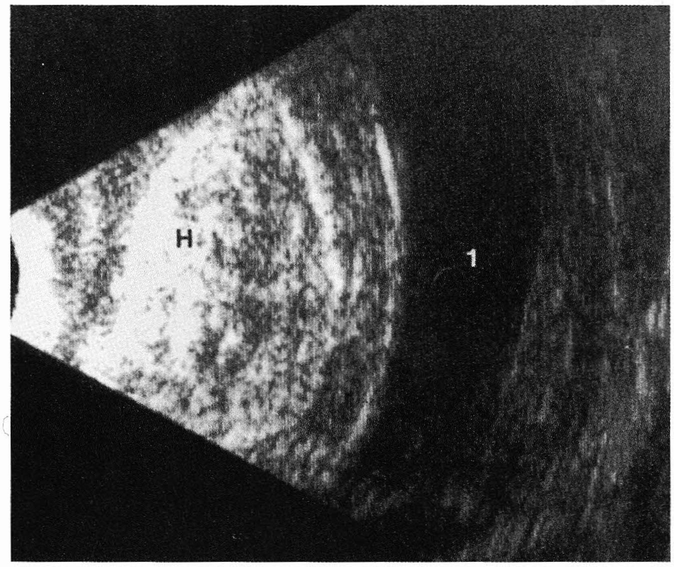

Figure 8b. Intraoperative ultrasound image with a 7,5MHz probe before evacuation of the hematoma.

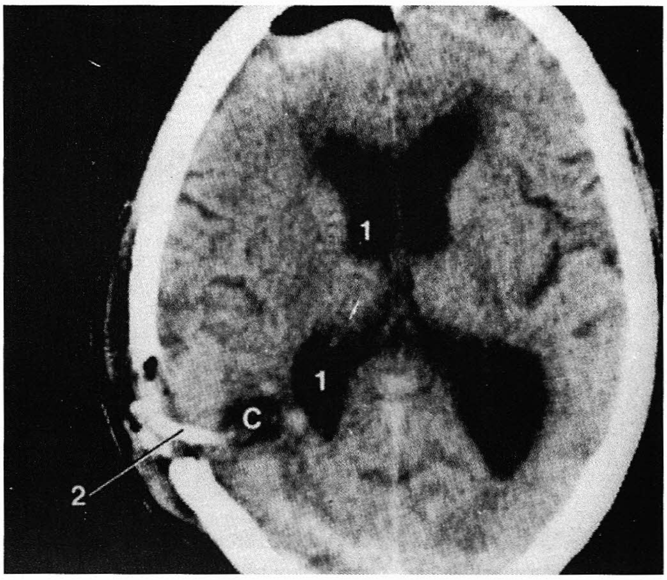

Figure 8c. Intraoperative ultrasound image following evacuation of the hematoma.

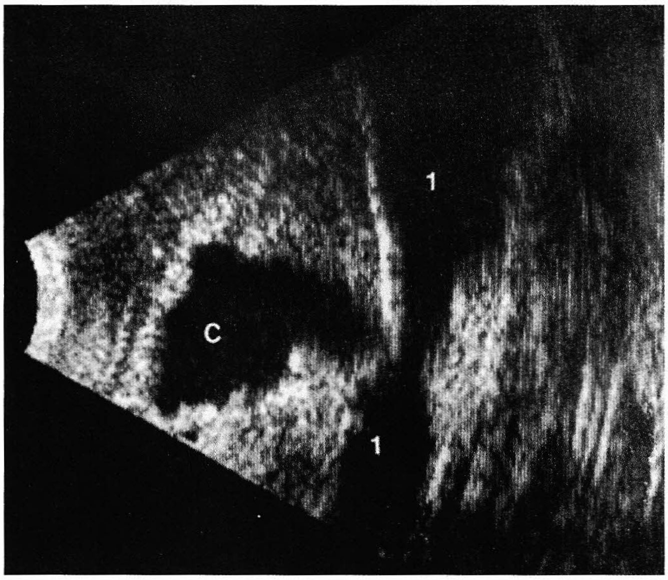

Figure 8d. Postoperative control CT: 1= left lateral ventricle, 2= drainage catheter in the empty hematoma cavity, H= hematoma, C= empty hematoma cavity.

Figure 9. Various types of intracranial hematoma before and after ultrasound stereotactic endoscopic evacuation.

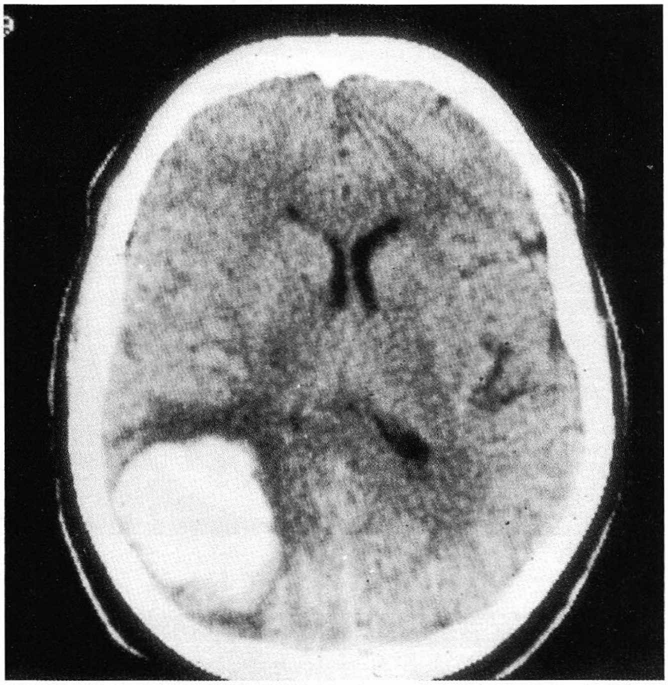

Figure 9a. Parieto-occipital lobar hematoma.

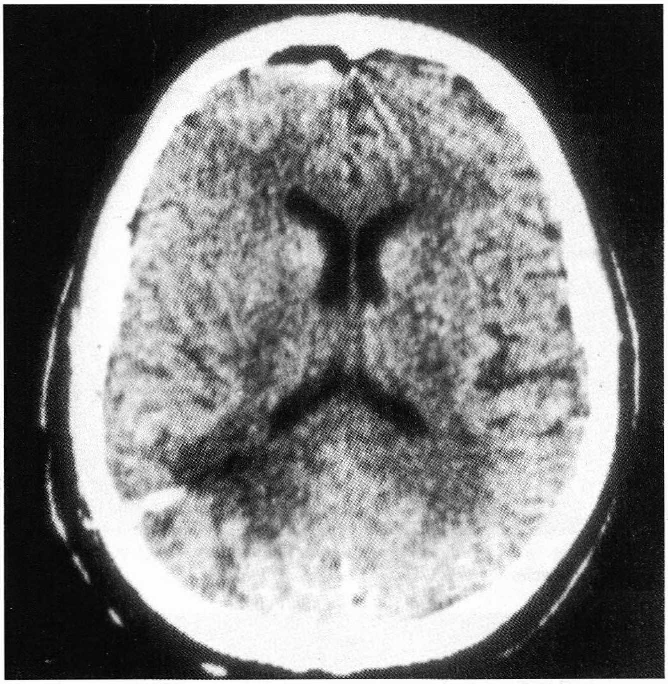

Figure 9b. Parieto-occipital lobar hematoma.

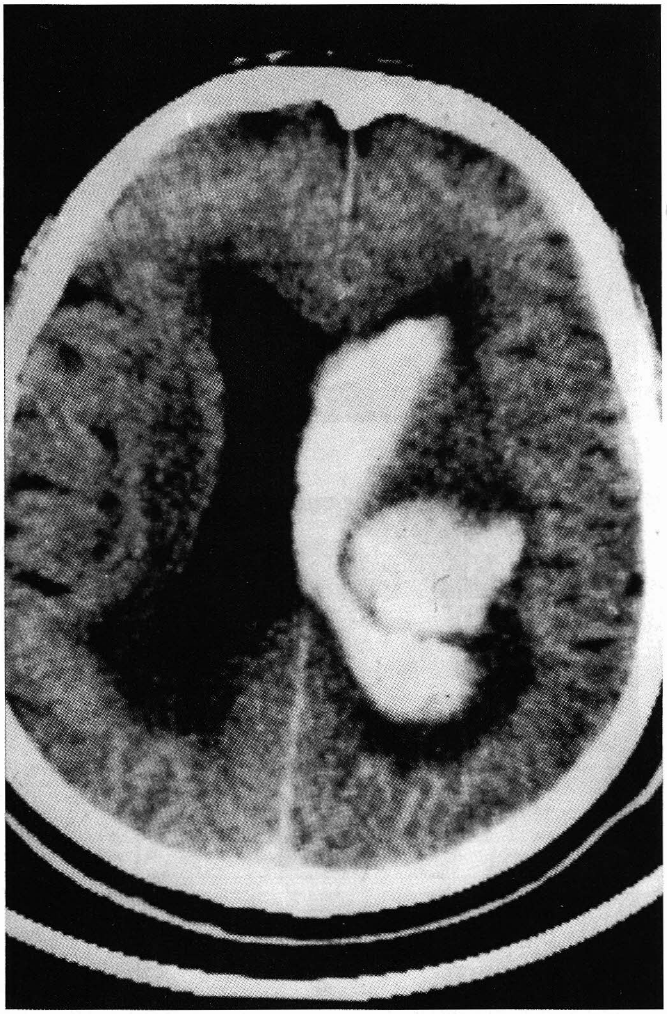

Figure 9c. Thalamic hemorrhage with rupture into the right lateral ventricle.

Figure 9d. Thalamic hemorrhage with rupture into the right lateral ventricle.

Figure 9. Various types of intracranial hematoma before and after ultrasound stereotactic endoscopic evacuation.

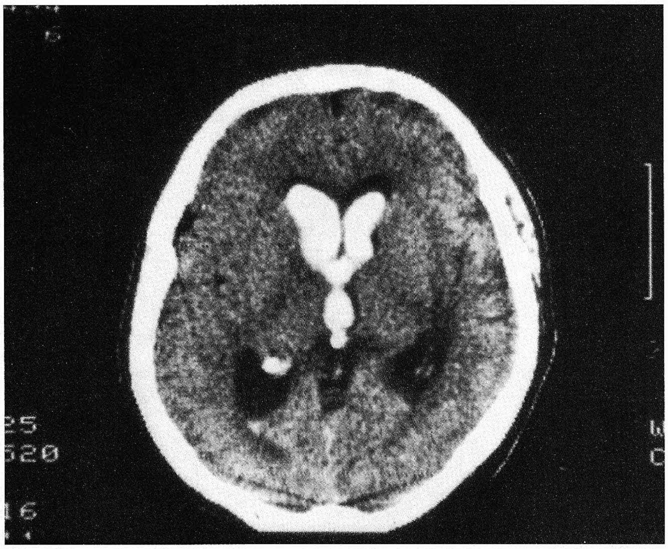

Figure 9e. - 9f. Ventricular hematoma filling both lateral ventricles and the third ventricle.

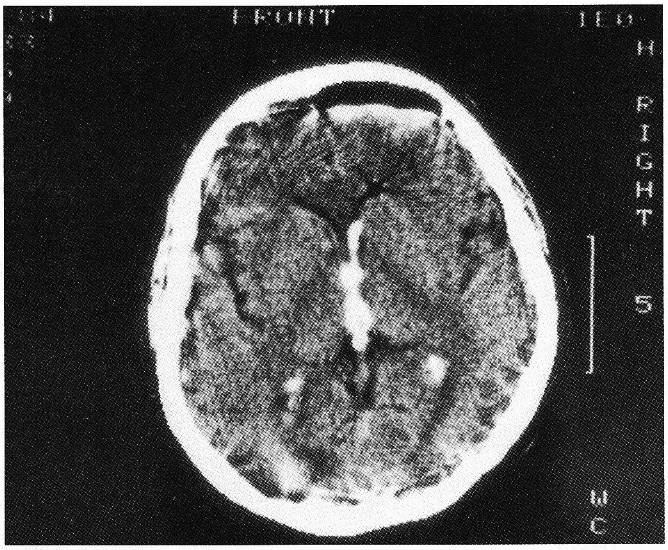

Figure 9f.

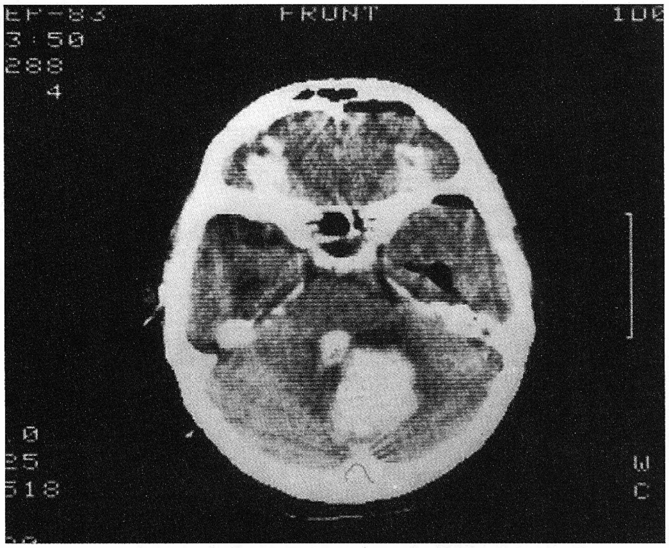

Figure 9g - h. Cerebellar hematoma.

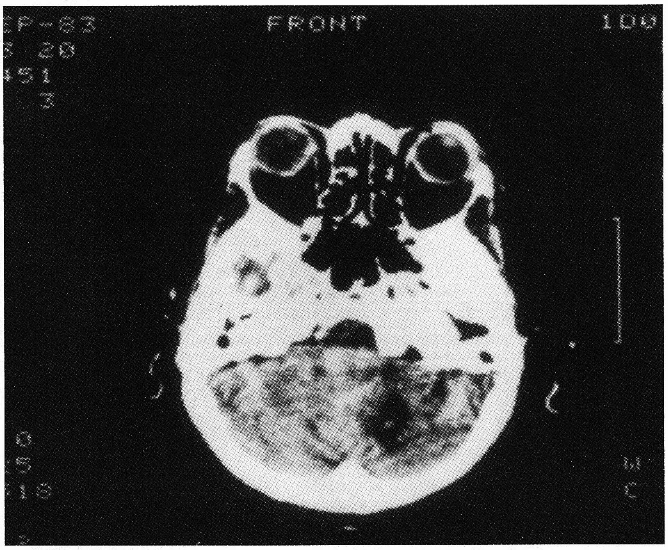

Figure 9h.

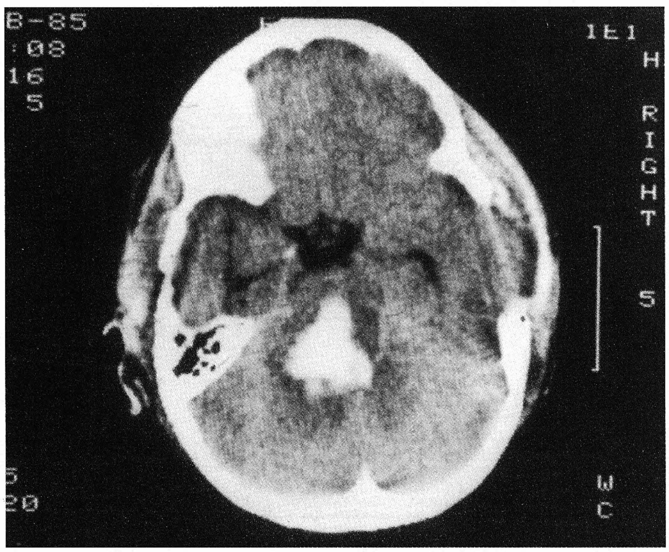

Figure 9i - j. Traumatic brainstem hematoma.

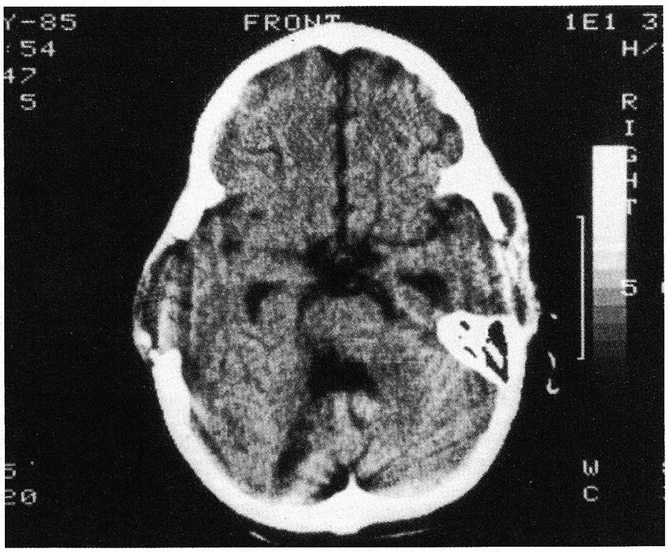

Figure 9j.

excision of the capsule may be tried transendoscopically. (Figure 5)

Ventricular hematoma has been a major problem due to the development of occlusive hydrocephalus and recurrent obstruction of ventricular drainage catheters by clots. Transendoscopic gentle irrigation and suction may allow complete evacuation, thereby preventing shunt-dependent hydrocephalus in many cases (Figure 9 c–f).

Surgical treatment of Intraparenchymal cerebral hematomas has been a matter of controversy and debate over the decades. A recent controlled study showed, however, that endoscopic evacuation of some types of hematomas improve outcome compared to conservative treatment.[9] Endoscopy is used only if simple tapping is not successful (Figure 8, 9 a–b). Cerebellar hematoma is a special neurosurgical problem and an indication for emergency operation; transendoscopic evacuation reduces the surgical trauma from suboccipital craniectomy and reduces the large opening of the dura to a burrhole procedure. (Figure 9g-h) Clearly, the evacuation of brain-stem hematomas is not able to prevent patients from neurological deficit. It may, however, save lives in selected cases (Figure 9 i–j).

Cystic hemispheric tumors may be difficult for a reliable biopsy by means of classical stereotaxy. Moreover, patients harboring such tumors sometimes decompensate rapidly and are admitted as emergencies in a poor state. The minimal procedure of transendoscopic biopsy enables specimens to be taken from specially selected areas of the cyst wall. At the same time, the cyst is drained and allowed to stepwise collapse, while laser-coagulation of the tumorous wall or solid nodules is performed (Figure 6). STI

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