Minimally Invasive Neurosurgery

ALBERT H. CAPANNA, M.D., F.I.C.S., F.I.C.P.S.
CLINICAL PROFESSOR OF NEUROSURGERY AND PEDIATRICS
THE UNIVERSITY OF NEVADA SCHOOL OF MEDICINE
CHIEF, DEPARTMENT OF NEUROSURGERY, UNIVERSITY MEDICAL CENTER
SUNRISE HOSPITAL MEDICAL CENTER
VALLEY HOSPITAL MEDICAL CENTER
DESERT SPRINGS HOSPITAL
LAS VEGAS, NEVADA

The use of the operating microscope revolutionized neurosurgery. The illumination and magnification allowed visualization of the desired area of the brain with much less retraction on normal brain. Microinstrumentation flourished. Various lasers and ultrasonic aspirators were adopted.

Endoscopic Cranial Surgery

We have been doing endoscopic cranial surgery for 9 years, initially starting with a prototype flexible endoscope (Codman & Shurtleff, Inc., Randolph, Mass.). Over the years we have used numerous systems, both flexible and rigid, and to date have not found one totally acceptable. The neodymium yttrium aluminum garnet (Nd:YAG) laser and endoscopic instrumentation are the best adjuncts to date. The explosion of information on neuroendoscopy is witnessed by the publication of textbooks on the subject.[1,2]

We have done numerous septoplasties, removal or lysis of arachnoid cysts, tumor biopsies, ablation of arteriovenous malformations and third ventricular colloid cyst excisions (Figs.1, 2). Third ventriculostomy has eliminated the need for some shunting procedures.

A 14-year-old female presented with obstructive hydrocephalus secondary to bilateral tuberous sclerosis of the thalami obstructing the foramina of Monro. The patient's mother adamantly refused ventriculoperitoneal shunting. Bilateral endoscopic transfrontal transventricular approaches and the Nd:YAG laser allowed us to open the foramina of Monro. One week post-op the patient developed edema, which resolved with dexamethasone. The patient did well and remains symptom free six years later.

INTERACTIVE IMAGE-GUIDED SURGERY (IIGS)

Advances in technology have allowed the development of image-guided frameless, stereotactic systems. An interactive image-guided surgical device was developed at Dartmouth, by Roberts[3] in 1986, when he correlated an operating microscope to the surgical field using sonic localizing technology. Watanabe in Japan, in the mid 1980s, developed an articulated arm localizer attached to a personal computer he called the NeuroNavigator.[4] A floor-standing articulated arm-based system was developed by Schlondorff, in Germany, in the mid-1980s.[5]

In interactive image-guided surgery the system displays, on a monitor, the corresponding computerized tomographic (CT) or magnetic resonance (MR) image, with a cross-hair indicating the probe tips position, which is constantly updated on the monitor as the probe moves. Images orthogonal to the acquired image are interactively reformatted and displayed. Image information along the axial, coronal, and sagittal planes at the indicated position reveal the location of surrounding hidden structures. Trajectory images along the probe allow for evaluation of different approaches. The system functions as a planning and navigational aid by allowing the surgeon to precisely locate the target, proximal critical structures, and alternative approach both preoperatively and intraoperatively.

Several systems have been reported to date.[6-11] We are currently using the Viewing Wand® (ISG Technologies, Inc., Mississauga, Ontario, Canada) which has been reported on by several authors.[12-14] The Viewing Wand® was used in tumors, vascular malformations, cysts, and hematomas. IIGS was particularly useful for intraventricular lesions and in

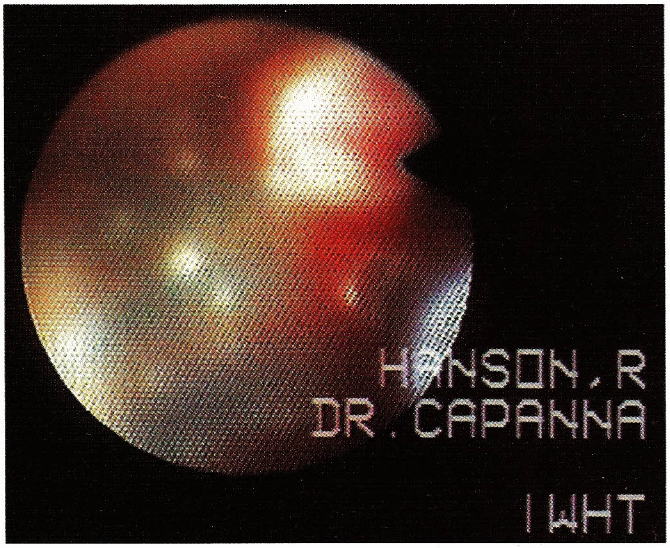

Figure 1. Colloid cyst of third ventricle. Endoscopic view with Nd:YAG laser contacting at 4 o'clock.

Figure 2. Colloid cyst wall being removed with endoscopic forceps.

transsphenoidal pituitary surgery. We feel that the IIGS systems allow for more precise surgery, shorter operating time because of more limited exposures and fewer complications. The IIGS allows surgeons interactive imaging data correlated directly to the patient's position on the operating table. We expect this technology to be greatly expanded and more simplified and useful in the future.

SPINAL SURGERY

Microdiscectomy

Mixter and Barr's classic paper on discectomy[15] began the current situation of over 400,000 discectomies per year performed in the United States of America today. Yasargil[16] performed laminectomies using the microscope, and Caspar[17] modified instruments for the procedure, but laminectomy was the procedure of choice until Williams and Capanna developed the microdiscectomy procedure.[18,19,20-32] This was possible by using the operating microscope and new instrumentation, and has led to microdiscectomy becoming the current gold standard. Since that time, several other series have been reported.[33-37]

Microdiscectomy significantly decreased the pain postoperatively and the length of stay to over night or out patient surgery. The technique led to less postoperative scar tissue formation and therefore, a higher cure rate than standard laminectomy.

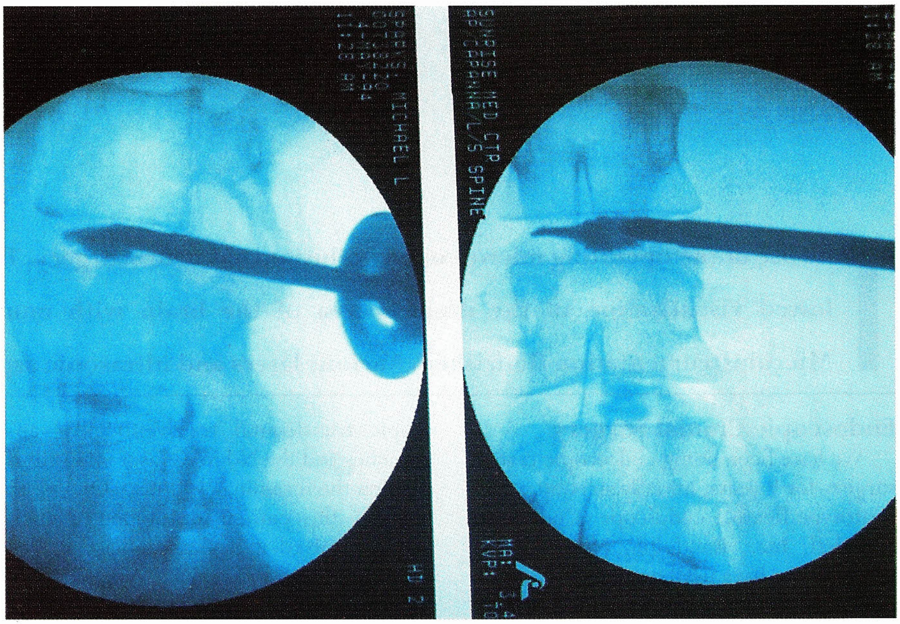

Figure 3. Intraoperative discogram at the conclusion of a lumbar arthroscopic discectomy.

Percutaneous Discectomy

In 1964, Smith[38] suggested that dissolution of the nucleus pulposus with chymopapain could relieve the pressure of a herniated disc on the nerve root. The development of chemonucleolysis offered the promise of minimally invasive surgery in a percutaneous fashion. The procedure gained in popularity until several reactions were noted and long term follow up studies demonstrated a relatively low cure rate. McCulloch and Macnab[39] present a review of the entire subject in their book.

The low cure rate and potential for complications led to the development of other percutaneous procedures not using chemicals (automated, laser, endoscopic, arthroscopic, laparoscopic, and thoracoscopic).

Valls,[40] Ottolenghi,[41] and Craig[42] developed the posterolateral approach to the spine for biopsies, the same approach later used for discography, chemonucleolysis, and discectomies. Hijikata[43] worked on percutaneous nucleotomy in Japan, while Kambin and Gellnan[44] worked in the United States. Friedman[45] reported using a 40-French chest tube and speculum. Schreiber and Suezawa[46] used discoscopy and a biportal approach, while Monteiro[47] used a posterolateral hole. Gary Onik, et al[48] introduced an automated evacuation instrument.

We have performed discectomies using all of these various techniques. Our initial results comparing percutaneous nucleotomy with microdiscectomy[49] showed only a difference in a faster return to work with the nucleotomy procedure. The use of lasers for the decompression of the disc causes many patients significant pain during the procedure and greatly adds to the cost of the operation.

Whether done via nucleotomy, endoscopy, or arthroscopically (Fig. 3) the results appear similar in our series.[50-58] The principal advantages of the percutaneous approaches are: (1) outpatient surgery, (2) a more rapid return to normal activities because of less concern about recurrent herniation through the annular opening and, (3) future scar formation is not a problem because the procedure is done outside the neural canal.

Laparoscopic Discectomy

Obenchain[59,60] reported success with retroperitoneal and transperitoneal laparoscopic discectomies. We have limited experience with the procedure, but feel it is best for L5-S1 herniations. It also seems easier to see posterior annular tears in the annulus and remove free fragments than the current percutaneous procedures.

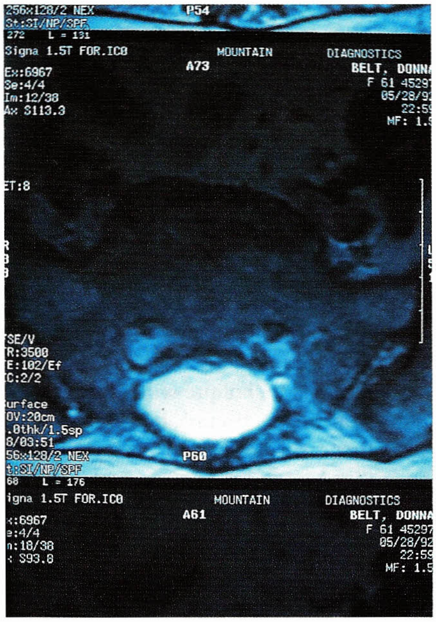

Figure 4. Preoperative MR of large sacrococcygeal cyst.

Thoracoscopy

Thoracic discectomies and fusions have been reported.[61] Endoscopic fusions of the thoracic spine are possible.[62] The current techniques are slow, but should improve as new instruments are developed.

Endoscopic Spine Surgery

The idea of a spine endoscope or "myeloscope" is not new.[63-65] However, until recent technical advances endoscopes offered few advantages. Endoscopes are currently being used to evaluate an anatomical situation such as the completeness of disc removal anteriorly and in the foramina after discectomy[66,67] and visual exploration of the pathology before and after surgery.[68] Endoscopic discectomy is reviewed above in this chapter with arthroscopic and percutaneous discectomies.

A 61-year-old female presented with progressively increasing low back pain. A lumbar MR (that did not include the sacrum) initially missed the large sacrococcygeal arachnoid cyst found on a pelvic MR. Outpatient endoscopic ablation was possible with Nd:YAG coagulation of the orifice. The patient had complete resolution of pain (Figs. 4, 5).

Endoscopic spinal surgical ablation of arteriovenous malformations and tumor biopsy or removal will surely come in the future.

Percutaneous Cervical Discectomy

Cervical laminectomy with its inherent risk of spinal cord injury was the classic operation until Cloward[69] and Robinson-Smith[70] developed the anterior approach to the cervical spine. The anterior approach allowed a direct method of dealing with herniated discs as well as osteophytes without the necessity of going around the spinal cord and therefore greatly decreased morbidity. Anterior microdiscectomy with or without fusion followed.

Percutaneous cervical discectomy was first performed by A. Capanna, on October 1, 1992, using a suction aspiration device, the Nucleotome® (Surgical Dynamics, Concord, Calif.). The S-Nucleotome® was developed, which is shorter and easier to manipulate. The approach used is similar to the technique used for stellate ganglion block. The trachea is moved with digital pressure medially and the carotid artery laterally. A small skin nick is made and then a guide wire placed under multiplanar fluoroscopy. An annular dilator goes over the wire and then an annulus cutter. The sheath is left in place, and the Nucleotome® placed in the disc space. Aspiration of the disc is accomplished by the suction-guillotine action of the Nucleotome® and manipulating the instrument (Fig. 6).

We have used this successfully on numerous patients. The principal advantages are: (1) immediate return to normal activities, (2) no need for fusion and therefore, no postoperative cervical collar, (3) outpatient procedure and (4) the spinal canal is not entered and therefore, scar tissue formation is eliminated.

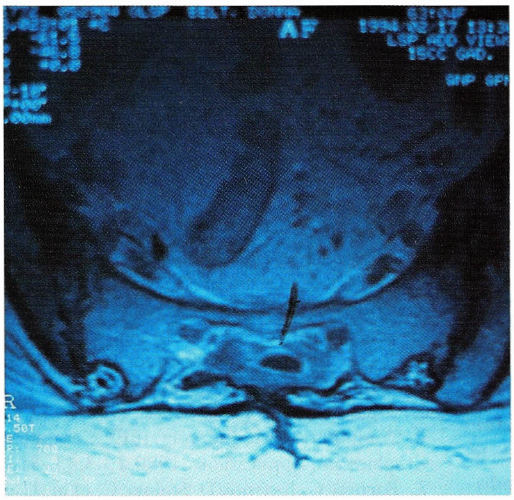

Figure 5. Postoperative MR (1½ years) after endoscopic ablation.

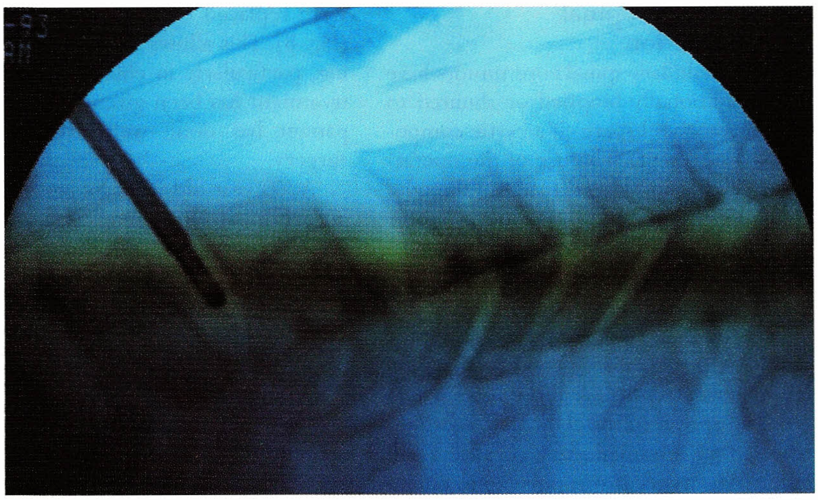

Figure 6. Intraoperative lateral cervical of percutaneous automated C5-6 discectomy with probe in disc space.

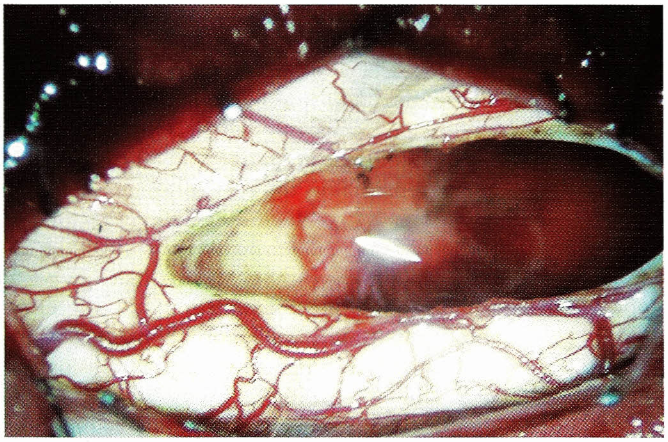

Figure 7. Cervical cord midline myelotomy with resection of intramedullary tumor.

Figure 8. Posterior spine reconstructed with laminae sutured in place.

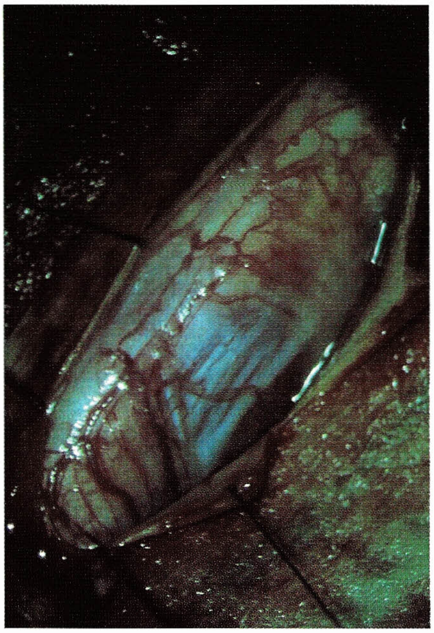

Figure 9. Cervical cord thinned over anterior tumor.

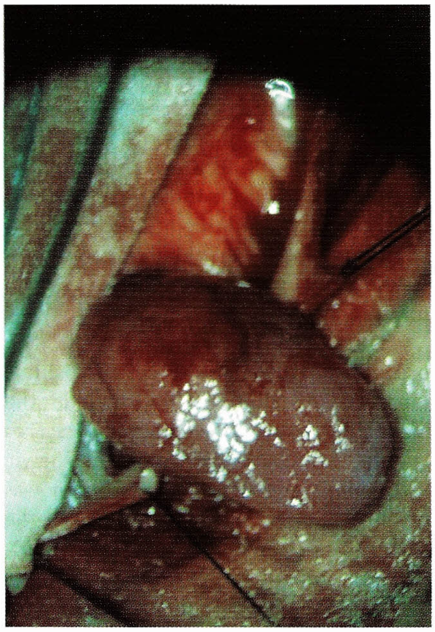

Figure 10. Meningioma delivered without difficulty with far lateral approach.

Intramedullary Spinal Tumor Resection and Spinal Reconstruction

Intramedullary spinal cord tumors have been traditionally biopsied or shunted to the subarachnoid space (if a cystic component was present). The use of the operating microscope, lasers (carbon dioxide, Nd:YAG, Argon), and ultrasonic aspirator have allowed us to be more aggressive in actually resecting the tumor tissue from within the spinal cord at all levels.[71]

A 51-year-old general surgeon had presented with paresthesias and pain of the left upper extremity for three years which now had spread to the right arm. Work up revealed an intramedullary cervical C5-6 lesion. At surgery it was possible to obtain a gross total resection of a malignant pilocytic astrocytoma (Fig. 7). The patient's posterior laminae and spinous processes were replaced to "reconstruct" the spine (Fig. 8). This allows for much better healing, particularly in children. No further treatment has been given to date, and the patient has done well five years after surgery.

A 60-year-old woman presented with quadriparesis. A far lateral cervical approach allowed total removal of her intradural-extramedullary meningioma (Figs. 9, 10). She made a complete recovery.

FUTURE IMPLICATIONS

The rapid progression of optics, illumination, and instrumentation promises to allow for further development of endoscopic neurosurgery. The use of various neuronavigational computer-assisted methods of surgery will surely progress. This all offers great hope that we will finally be able to realize "keyhole" neurosurgery intracranially.

There has been a rapid development of macrospinal instrumentation with rods, plates, screws and hooks, which have been useful developments in some situations. However, it clearly appears that the big gains in decreased mortality, morbidity and cost will come from minimally invasive neurosurgical techniques. Our hope is that, like the Internet handling the information explosion, miniaturization of neurosurgical technique will allow a great reduction in the trauma induced to nervous tissue surgically and new gains will be realized just as they were with the operating microscope, into the twenty-first century.

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