Endoscopy in cranial and skull base surgery

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Introduction

- The advent of _neuroendoscopy_ has had a remarkable impact on the field of neurosurgery.
- It has been attended by a number of breakthroughs in optical physics, technology and instrumentation.
- Understanding the basic physics and instrumentation is essential for safe and successful work with these delicate instruments

History

- Walter Dandy, is considered the father of neuroendoscopy
- 1922, Dandy reported using a Kelley cystoscope to inspect the lateral ventricle. He coined the term *ventriculoscope*,
- Dandy was also the first to perform third ventriculostomy, but he used an open procedure to fenestrate the floor of the third ventricle.

W. Lau, C. Leow and A. Li, History of endoscopic and laparoscopic surgery. *World J Surg* **21** (1997), pp. 444–453.

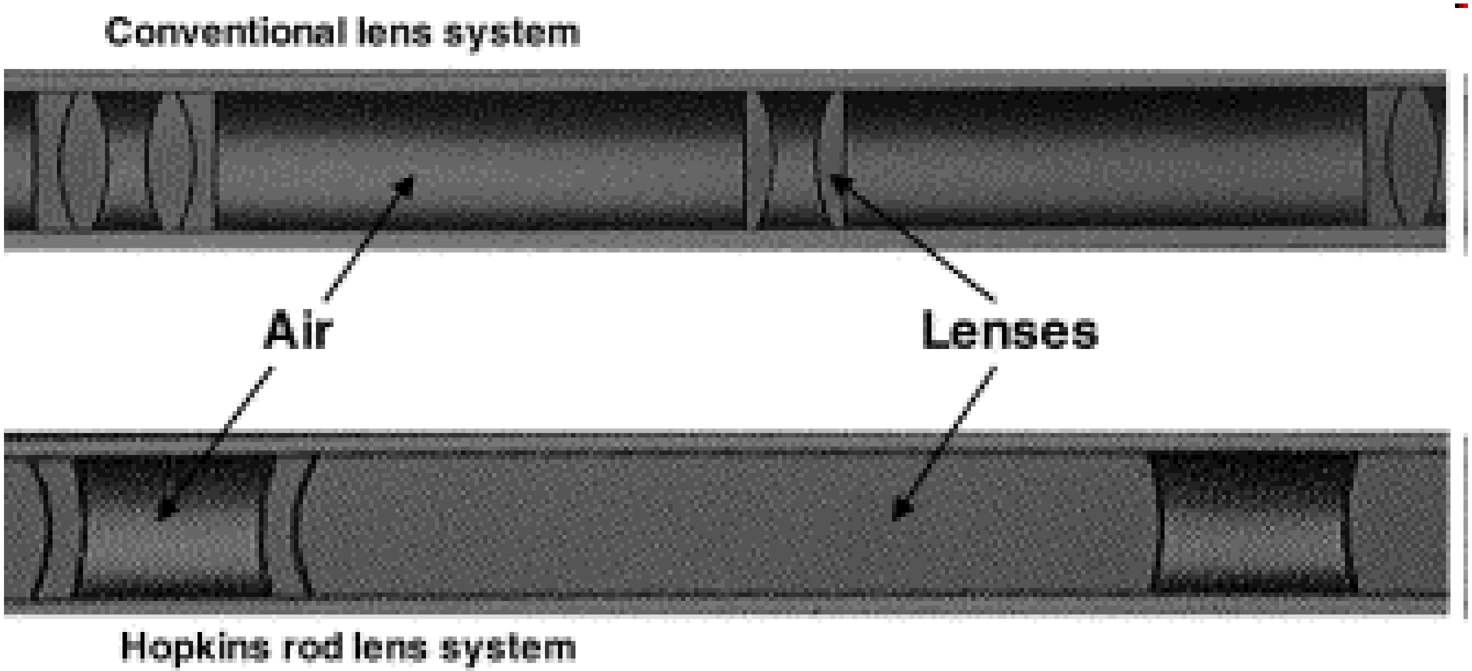
History of endoscopes

- Hopkins realized that the total amount of light transmitted through an endoscope is proportional to the refractive index of the material used

- He restructured the lens system to consist of long glass lenses interspersed with small lens-like air spaces

- These “rigid rod lens scopes,” with their increased light transmission ability, form the basis of most modern endoscopic systems

1960 – Hopkins developed the rod-lens scope which provided superior optics and improved illumination.



Optics

- Fiberoptic cables were invented in the sixties, a major breakthrough for endoscopic technology.
- This avoided the problem of tissue injury from heat and also delivered a more natural light.
- Fiberoptic cables are made of individually coated flexible fibers with an inner core of silica glass.
- Resolution of fiberoptic endoscopes is proportional to the number of fibers in the endoscope. More fibers provide an image with a much sharper resolution.

Light sources

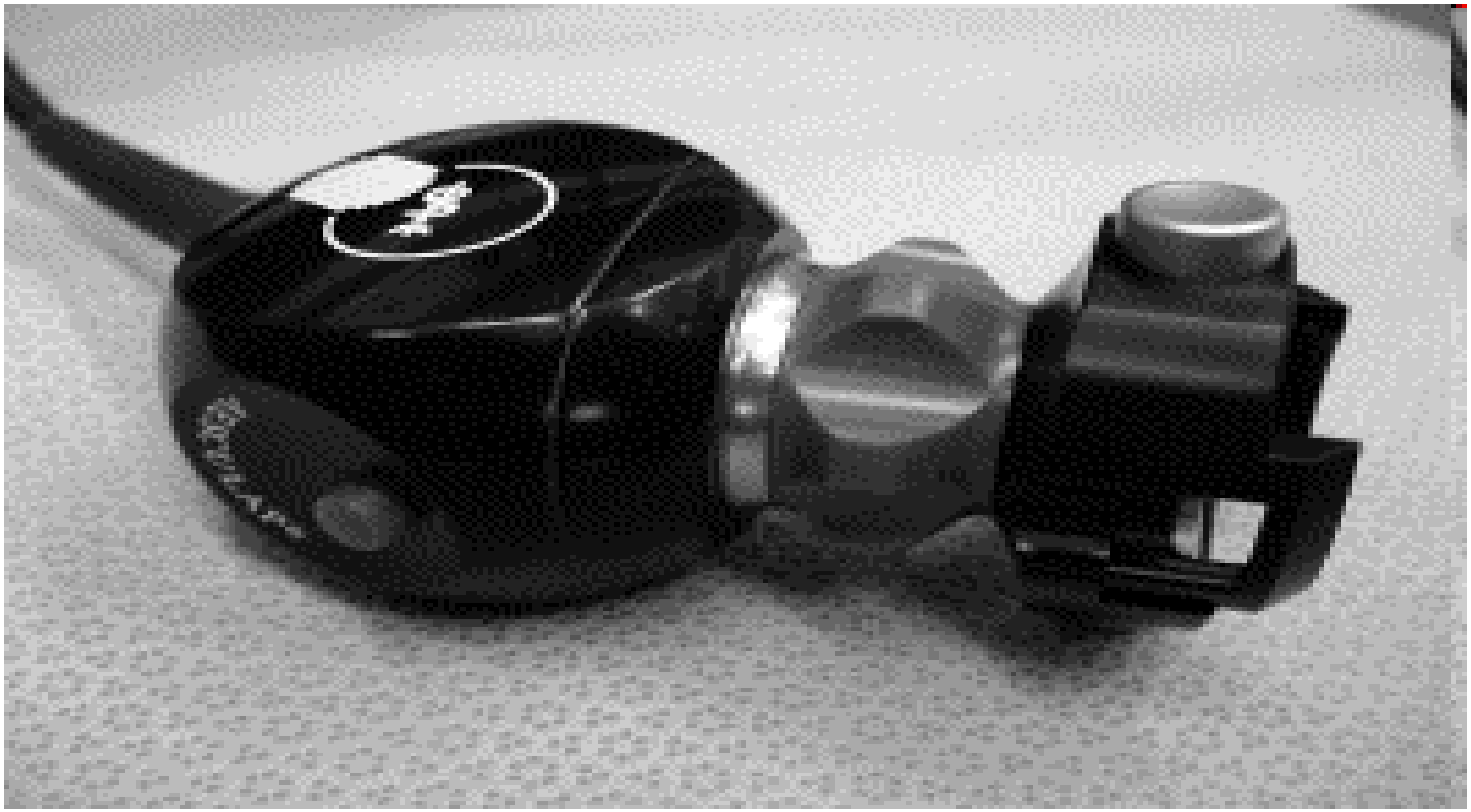
- High-intensity xenon light sources used.
- The light is transmitted through fiber bundles
- Light source of 300 and 500 W provides a superior picture quality.
- Light loss in a fiberoptic system is a significant issue.
  - 30% of light is lost at the lamp
  - Fiber mismatch accounts for another 20% loss, because of mismatch between the wider transmitting cable and the thinner scopes used in neurosurgery.
  - Addition losses from reflection in various surfaces.

J.F. Hulka and H. Reich, Light: optics and television. In: *Textbook of laparoscopy*, WB Saunders, Philadelphia (1994), pp. 9–21.

A. Nobles, The physics of neuroendoscopic systems and the instrumentation. In: D.F. Jimenez, Editor, *Intracranial endoscopic neurosurgery*, American Association of Neurological Surgeons, Park Ridge, IL (1998), pp. 1–12.

Cameras

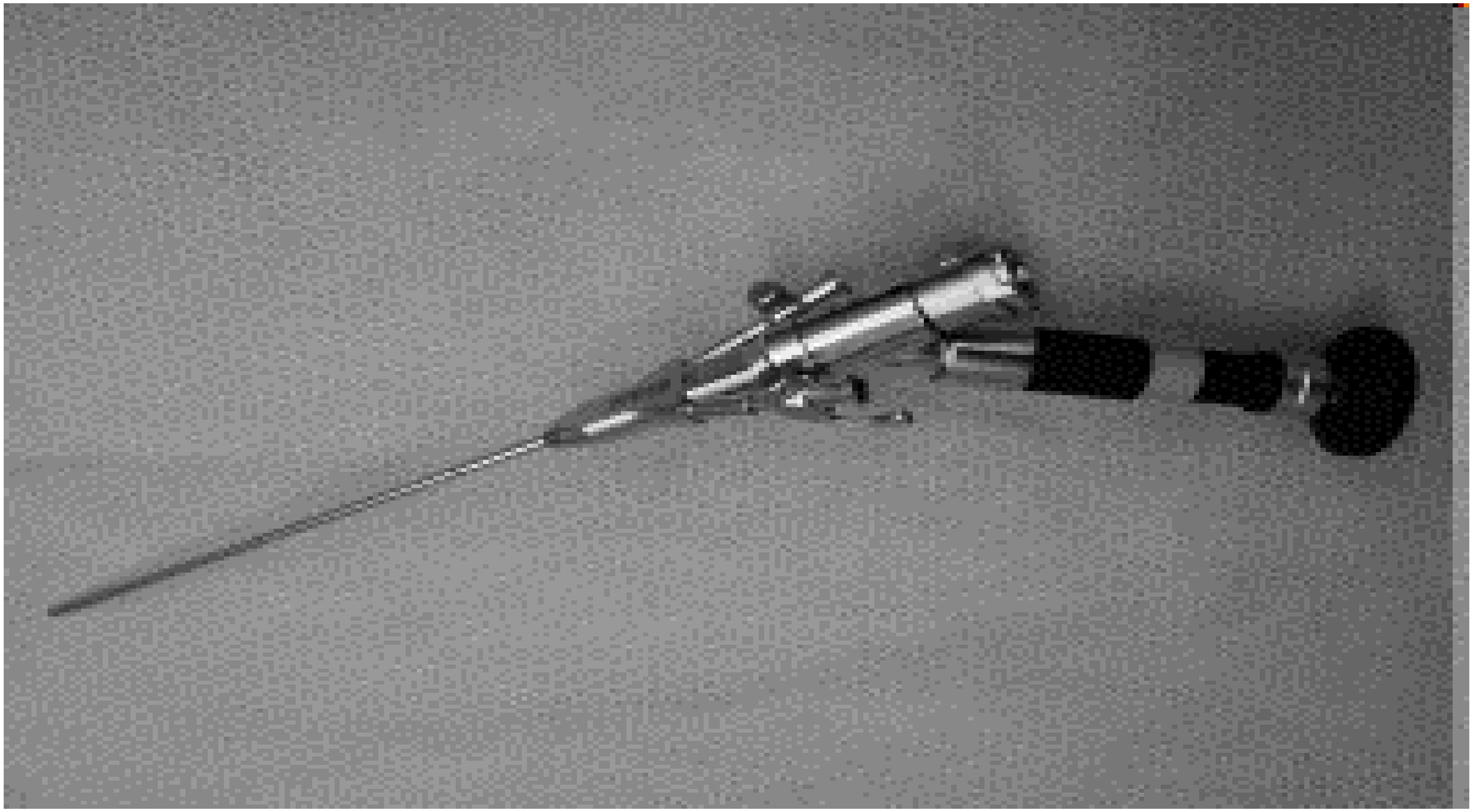
- In 1969, George Smith and Willard Boyle invented the first CCDs at Bell Laboratories
- "Charge-coupling" refers to the manner in which the electronic charges are stored and transmitted.
- Silicon chip capable of converting optical data into electrical current.
  - decrease in the size of the endoscope
  - improvement in the quality of the transmitted image
- Two kinds of CCDs :
  - the single-chip camera
  - three-chip camera.



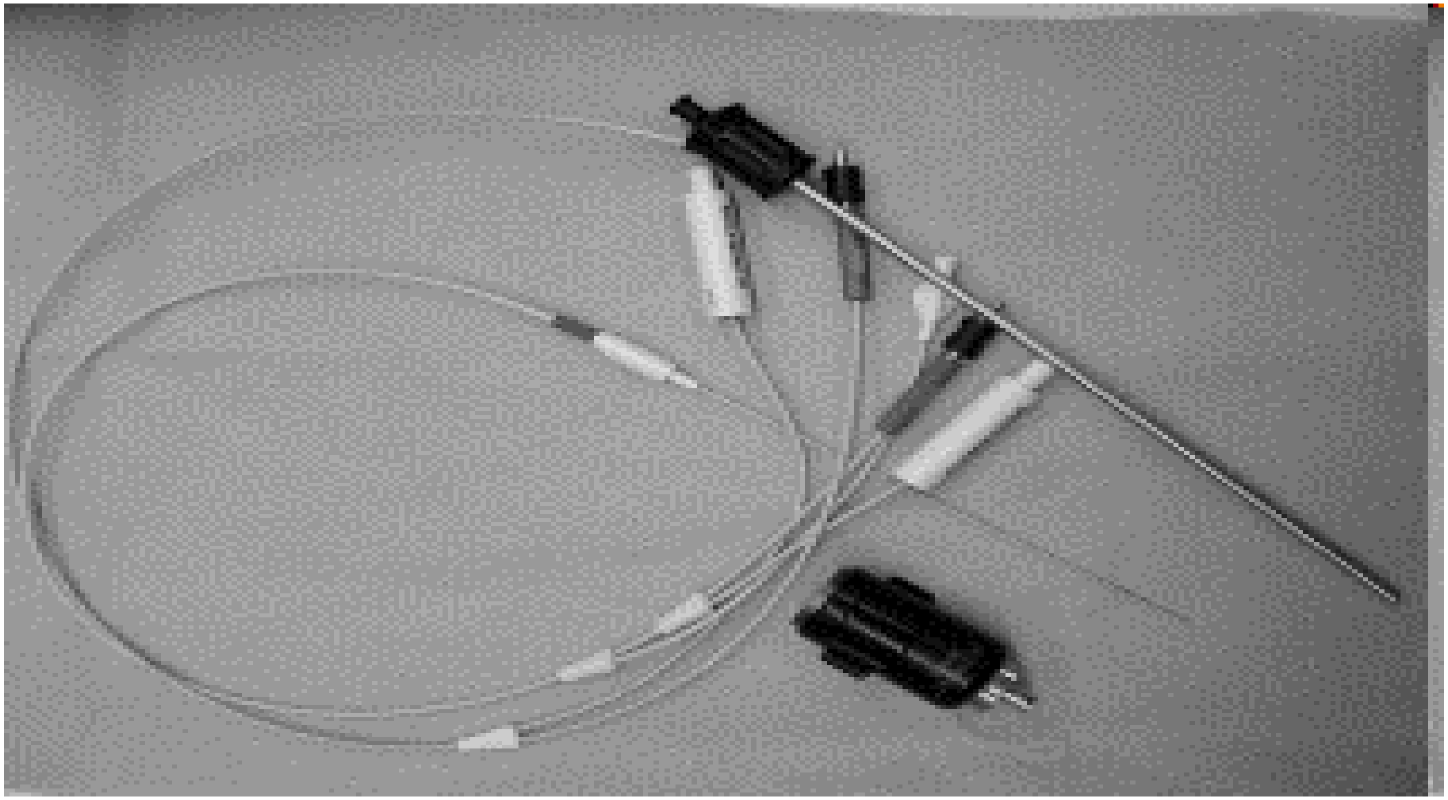
3-chip CCD camera (Aesculap, Center Valley, Pennsylvania).

Comparison of rigid and flexible scopes

	Rigid scopes Transmits images through a series of lenses	Flexible scopes Transmits images through arranged fibreoptic threads
Advantages	•Higher resolution •Wider view •Better light transmission	•Application to spine •Light weight •Steeribility
Disadvantages	•Less maneuverability •Not applicable to spine	•Narrow view •Pixel granules •Less true colour •Worse light •Smaller working channel



3.2 mm rigid endoscope (K. Storz, Tuttlingen, Germany).



Light-weight fiberoptic endoscope (Clarus, Minneapolis, MN).

Instrumentation

- Ports or working channels are available for instrumentation
- Instruments such as scissors, grasping and biopsy forceps, suction and irrigation catheters
- Irrigation with lactated ringers solution –
  - to clear the lens of debris,
  - clear the operative field of any blood,
  - to help prevent the collapse of the fluid-filled ventricular system and
  - to avoid thermal injury
- Endoscopic dissection can be performed with the use of a small fiberoptic laser- Nd:YAG, KTP or radiofrequency current

Applications

- Endoscope can be used as either the principal operative tool or an adjunct to conventional craniospinal procedures.

- Therapeutic and Diagnostic applications

- Diagnostic tool for anatomic surveillance

Applications

- Diagnostic :

  Neurooncology : Fukushima was the first to report the use of endoscope for biopsy procedures in intraventricular tumors

- Ventriculoscopy
- Endoscopic tumor biopsy
- Endoscope-assisted microsurgery

Applications

- Therapeutic
- Relief of hydrocephalus by ETV
- Endoscopic transphenoidal pituitary surgery
- Resection of colloid cysts and other intraventricular tumors
- Anterior skull base meningiomas
- Repair of CSF leak

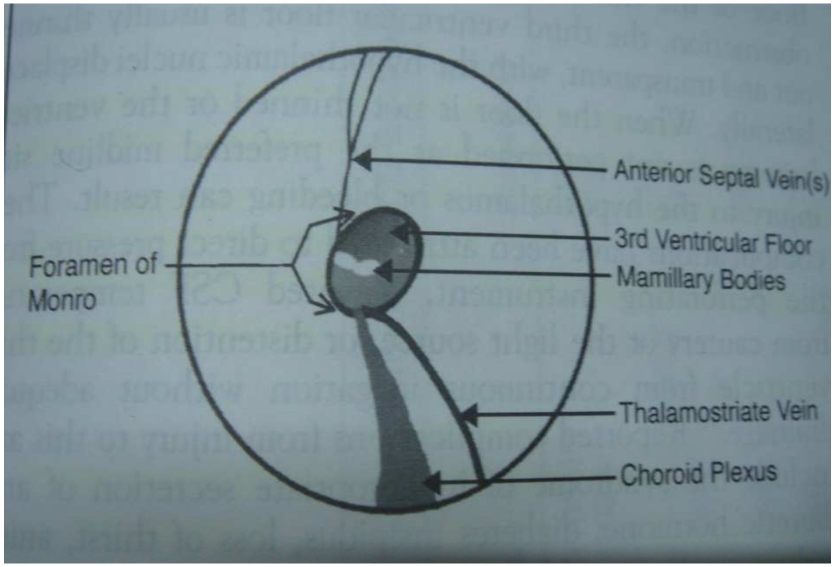
Ventriculoscopy

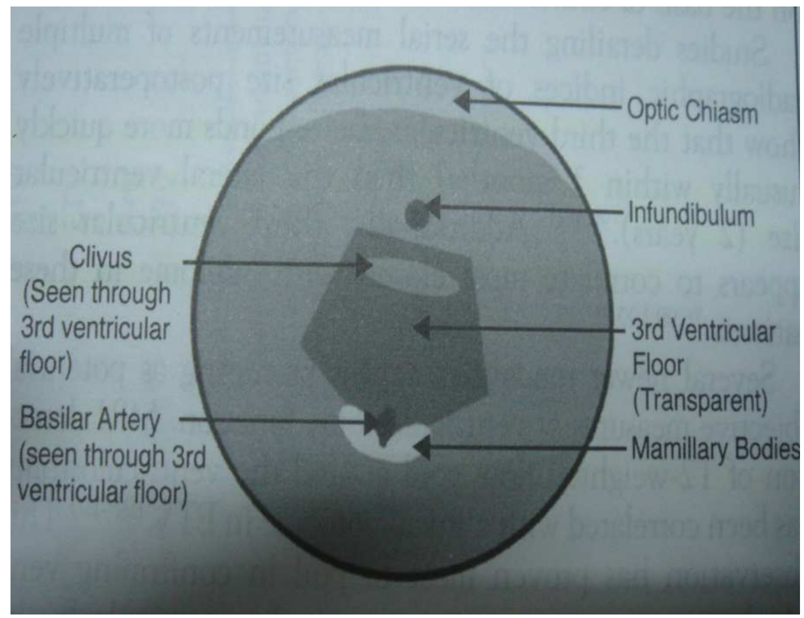
- Through a frontal or parietal burr hole, one can access the lateral ventricle, examine the surface, document any findings with color photography, and even biopsy suspicious areas.

- Definitive treatment of CSF obstruction can be achieved by either third ventriculostomy or tumor resection at the same sitting.

ETV Technique

- Right coronal burr hole
- Lateral ventricle cannulated and endoscope is directed through the foramen of monro into the third ventricle
- Foramen of Monro identified by the choroid plexus and septal and thalamostriate veins.


Anterior Septal Vein(s)
3rd Ventricular Floor
Foramen of Monro
Mamillary Bodies
Thalamostriate Vein
Choroid Plexus


Optic Chiasm
Infundibulum
Clivus (Seen through 3rd ventricular floor)
3rd Ventricular Floor (Transparent)
Basilar Artery (seen through 3rd ventricular floor)
Mamillary Bodies

ETV

- There are different techniques to perforate the floor of the third ventricle- thin neuroendoscope, bipolar or laser
- The third ventriculostomy can be made with the use of Fogarty's catheter
- Hemostasis done with bipolar cautery probes.

Outcome assessment

- Gradual decrease in the ventricular size
- Third ventricular size responds within 3 months and lateral ventricle in 2 years of the procedure
- MRI detection of T2 weighted flow void around the ventriculostomy
- Phase contrast MRI and doppler ultrasonography can quantify the CSF flow velocities

Success rates of ETV

- >75%
  - Acquired aqueductal stenosis
  - Tumor obstructing ventricular outflow
    - Tectal, pineal, thalamic and intraventricular
- 50-75%
  - Myelomeningocoele(previously shunted, older patients)
  - Congenital aqueductal stenosis
  - Cystic abnormalities obstructing CSF outflow
    - Arachnoid cysts, dandy walker malformation
  - Previously shunted patients with difficulties
    - Slit ventricle syndrome, recurrent or intractable shunt infections/malfunctions

Success rates of ETV

- Low success rates <50%
  - Myelomeningocoele (previously unshunted neonates)
  - Post hemorrhagic hydrocephalus
  - Post infectious hydrocephalus (excluding aqueductal stenosis of infectious origin)

Favourable features for ETV

- Clinical
  - Age > 6 months at diagnosis and ETV
  - No prior radiation
  - No history of hemorrhage / meningitis
- Radiographic
  - Obstructive pattern of HCP, aqueductal stenosis
  - Favourable third ventricular anatomy-width of foramen of monro >4 mm, thinned downward bulging floor
  - Absence of anomalous anatomy

ETV failure

Failure rate 10-40%

Maximum incidence of failure: first 1-2 months

No failure reported after 5 yrs.

- **Early : within 4 wks**
  - Non-absorption from arachnoid granulation despite good MRI flow
- **Delayed : after 4 wks**
  - Stoma closure gliosis / scarring (6-15%)
  - No MRI flow

Jones et al Min. Inv. Tech NS 1993
Siamin et al Childs Nervous System 2001
Cinalli et al Min. JNS 1999

Loculated hydrocephalus

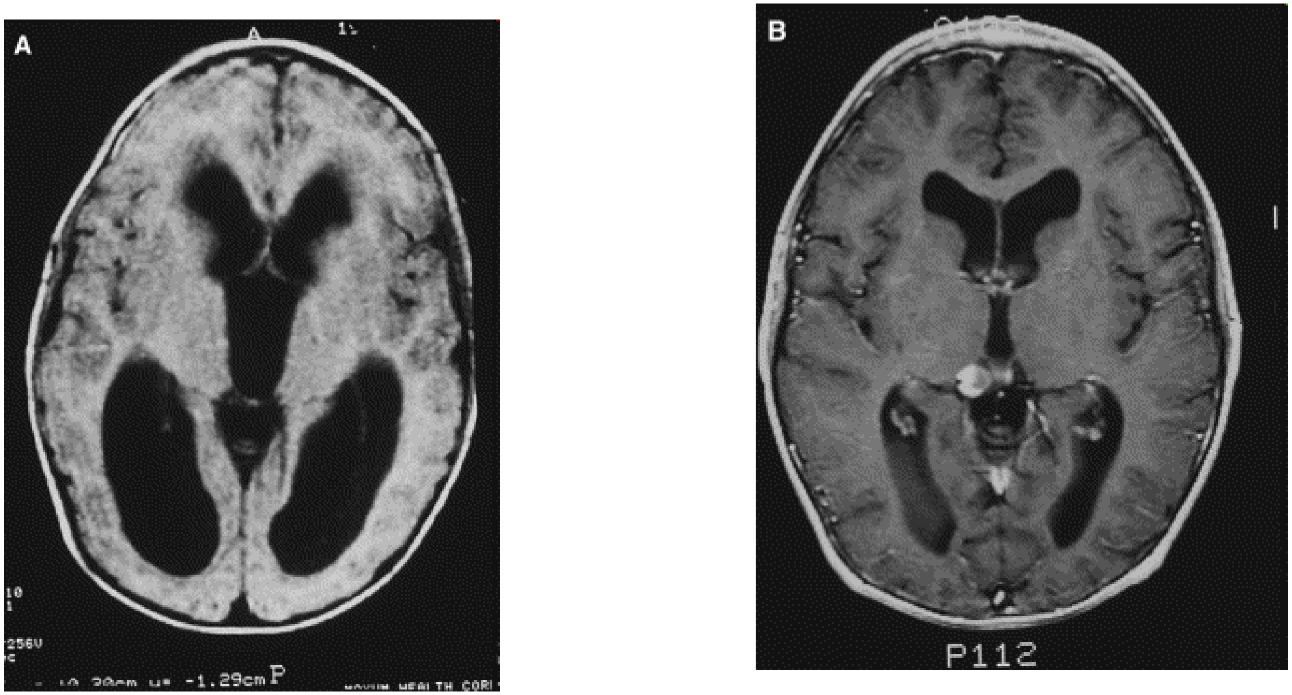
- Germinal matrix hemorrhage or infection cause trabeculation and encystment
- Endoscopic fenestration permit use of single shunt to drain multiple cavities or eliminating the need for a shunt
- Large fenestration made to prevent recurrent loculations

Complications

- Bleeding
- Raised intracranial pressure and CSF leak
- Injury to basilar artery, brain stem or cranial nerves
- Injury of the hypothalamus- SIADH, DI, loss of thirst amenorrhoea
- Chemical ventriculitis
- Memory dysfunction

Advantages of ETV

- Exploration of the third ventricle, taking biopsies if necessary.
- There is no risk of ongoing infection as can be seen with external drainage
- No risk of seeding as has been documented with ventriculoperitoneal shunting;
- No risk of upward herniation, which can potentially happen with any extracranial diversionary procedure.
- Finally, ETV may be the definitive treatment if the obstruction is caused by a tumor that does not require removal, such as a tectal plate tumor.



(*A*) The patient is an 11-year-old boy with profound hydrocephalus of unclear etiology. (*B*) After an endoscopic third ventriculostomy and resolution of the hydrocephalus, an occult pineal region tumor is now apparent.

Endoscopic shunt placement

- Goal is to place the ventricular catheter tip away from the choroid plexus.
- Small diameter endoscope as stylet within the ventricular catheter may allow more accurate catheter positioning within the ventricles.
- May decrease the chances of completely missing the ventricles.
- But does not improve the surgical outcome once the tip is within the ventricles.

Ventricular tumors

- Tumors can be biopsied, cystic tumors aspirated and certain tumors excised endoscopically
- Advantageous over conventional approaches in certain situations eg. Unresectable third ventricular tumor
- Large vascular tumors unsuitable for endoscopic resection

Endoscopic transphenoidal surgery

- Advantages of endoscopic surgery
  - Wide angled panoramic view
  - Direct visualizations of anatomical corners
  - Enhanced magnification
  - No anatomic disruption-no surgical incision, mucosal dissection
  - No nasal packing needed

Procedure

- Position – supine, head rotated to surgeon 20 deg
- Oropharynx packed with gauze roll
- Approaches- paraseptal, middle meatal or middle turbinectomy
- Endoscope inserted with inclined angle of 25 deg

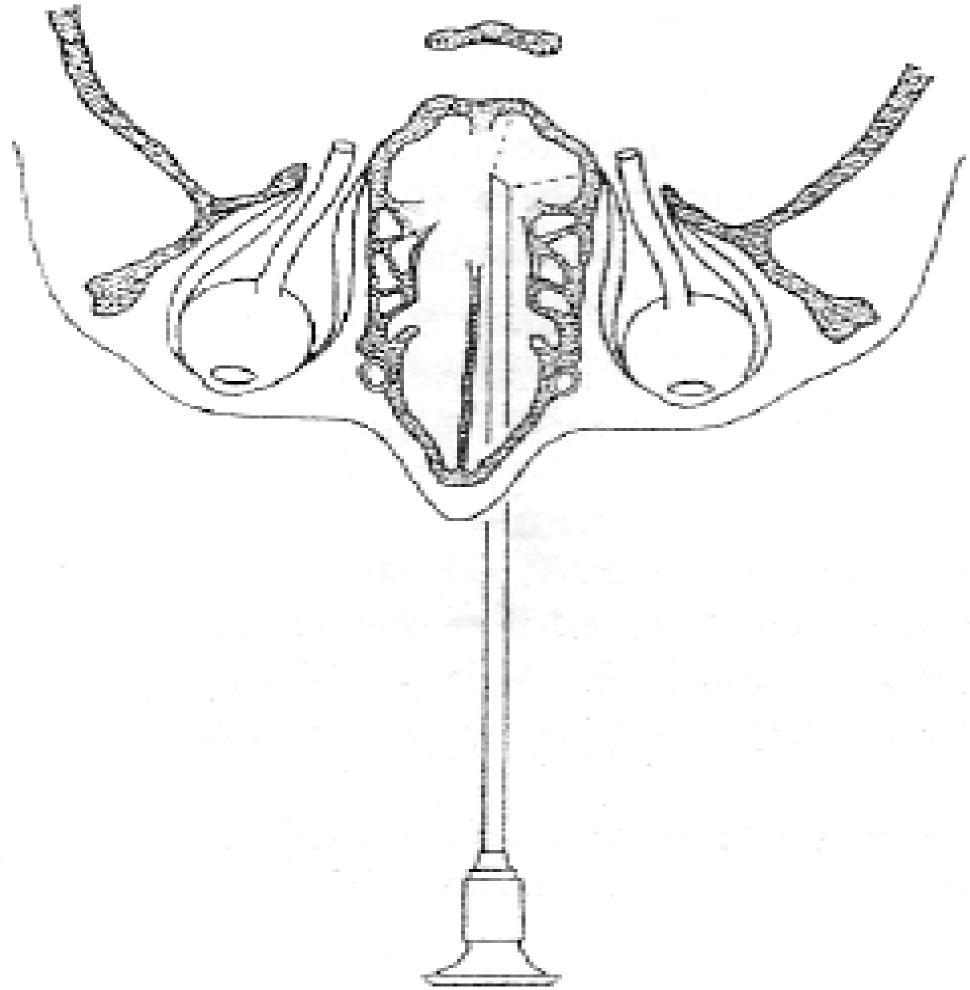
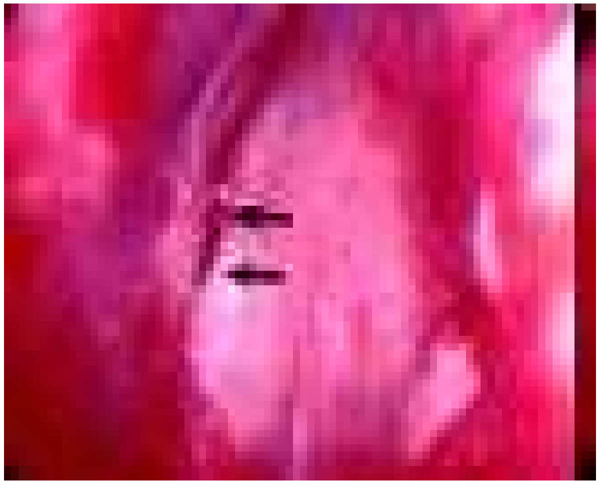
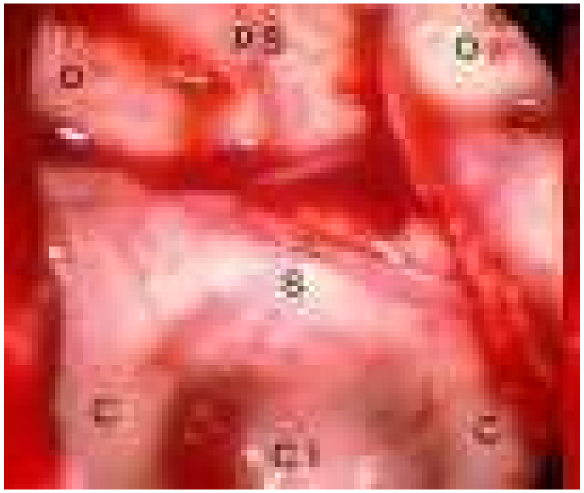


Figure 57.6 Schematic axial view of the nose and sphenoid sinus, demonstrating the ability of the angled (30°) telescope to see around corners to visualize all aspects of the sinus.

Procedure

- Mucosa at the rostrum of sphenoidal sinus is coagulated and divided vertically
- Posterolateral septal artery at the posteromedial corner of the inferior margin of the middle turbinate coagulated
- Anterior sphenoidotomy from inferior margin of middle turbinate to sphenoid sinus ostia
- Opening made in the sphenoid sinus mucosa





Intraoperative endoscopic images present a wide-angled panoramic view of the sphenoidal sinus demontrating the clival indentation (ci), ICA (c), sella (s), planum sphenoidale (ps), optic nerves (o).

Endoscopic TNTS

- Dura coagulated and opened
- Tumor curetted from inferior-lateral-superior poles
- Solid and fibrotic tumors exposed using a 30 deg scope or by further removal of bone at the tuberculum sella or planum sphenoidale
- Sellar packing with abdominal fat for large tumor cavity
- Anterior wall of sella reconstructed with autogeneous bone or titanium mesh

EEA

- Frameless stereotactic image guidance
- 3 pin fixation with neck in slight extension, turned to the right by 10-15 deg
- More extension for lesions anterior to cribriform plate and flexion to approach the upper cervical spine
- Nasal decongestant applied locally

Procedure

- Bilateral nasal (binarial) access to allow 2 surgeons and 4 hand technique
- Maximal removal of bone at the skull base create a wide surgical corridor
- Endoscope introduced at 12 o clock position and suction tip at 6 o clock position on the same side
- Dissecting instruments introduced through the left nasal cavity

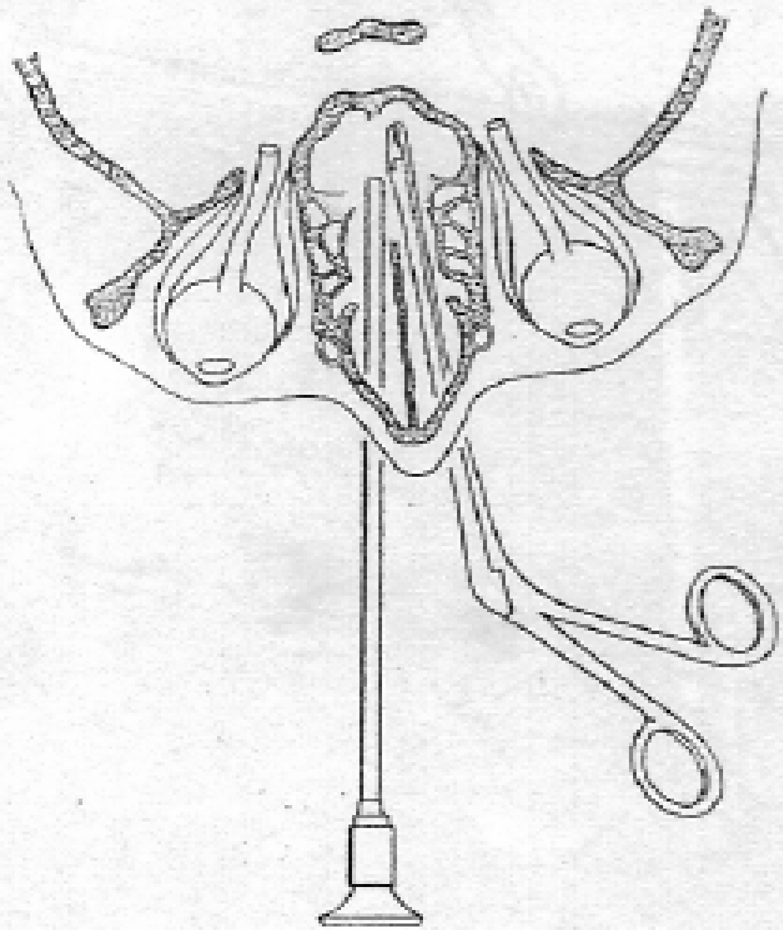


Figure 57.7 Schematic axial view of the nose and sphenoid sinus, demonstrating the use of instruments from either side of the nasal septum when opening the pituitary fossa.

Procedure

- Out fracturing of inferior turbinates and removal of one or both middle turbinates
- Wide bilateral sphenoidotomy extending laterally to level of medial pterygoid plates and lateral wall of sphenoid sinus, superiorly to planum sphenoidale and inferiorly to floor of the sphenoid sinus
- Resection of the Posterior edge of nasal septum facilitates bilateral instrumentation, lateral angulation and range of motion of instruments

Intradural endoneurosurgical dissection techniques

- Internal debulking followed by mobilization of tumor capsule
- Two suction debulking- small diameter suction tip in left hand to maintain gentle traction while a dissecting or debulking instruments in the right hand
- Ultrasonic aspirator used for firmer tumors
- Sharp extracapsular dissection

Hemostatic techniques

- Margins of the tumor is dissected circumferentially to cauterise the feeding arteries
- Bilateral ethmoidectomies and limited medial orbital decompressions allow endoscopic ligation of the anterior and posterior ethmoidal arteries
- Hypertrophied bone drilled and dura cauterized
- Diffuse venous bleed from mucosa or bone responds to warm saline 40 deg C

Pituitary and sellar surgery

- Intrasellar dissection
  - Dura opened in the center of sellar face
  - Opening extended obliquely at 5 and 8 o clock positions creating an inferior flap
  - Macroadenomas herniate through this inferior opening, resected
  - Dura opened superiorly
  - Dissection in each recess in inferior to superior direction

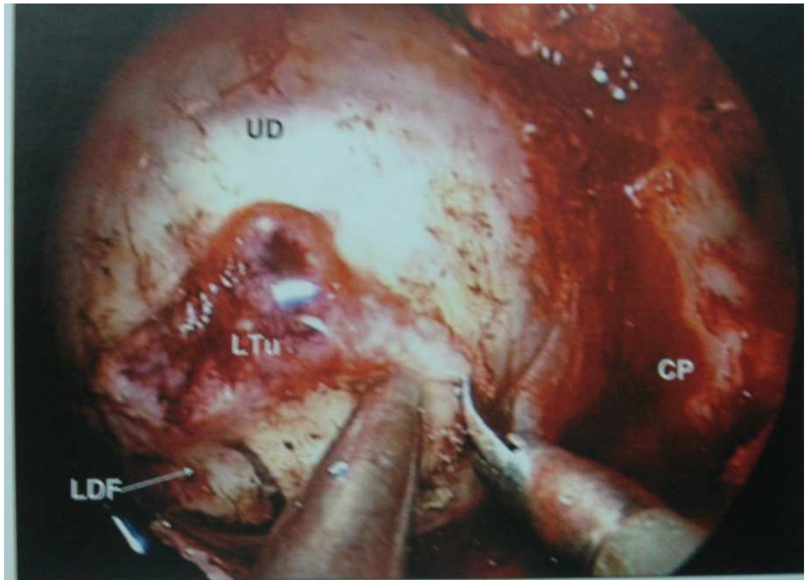


Fig. 10
Once the dura has been opened with the sickle knife, the endoscopic scissors are used to first open the lower based dural flap (**LDF**). This facilitates dissection of the lower aspect of the tumor (**LTu**) first. The upper portion of the dura (**UD**) is kept intact until the lower part of the adenoma is clearly removed. The durotomies are then extended to provide lateral and superior access. The carotid protuberance (**CP**) is shown as a landmark.

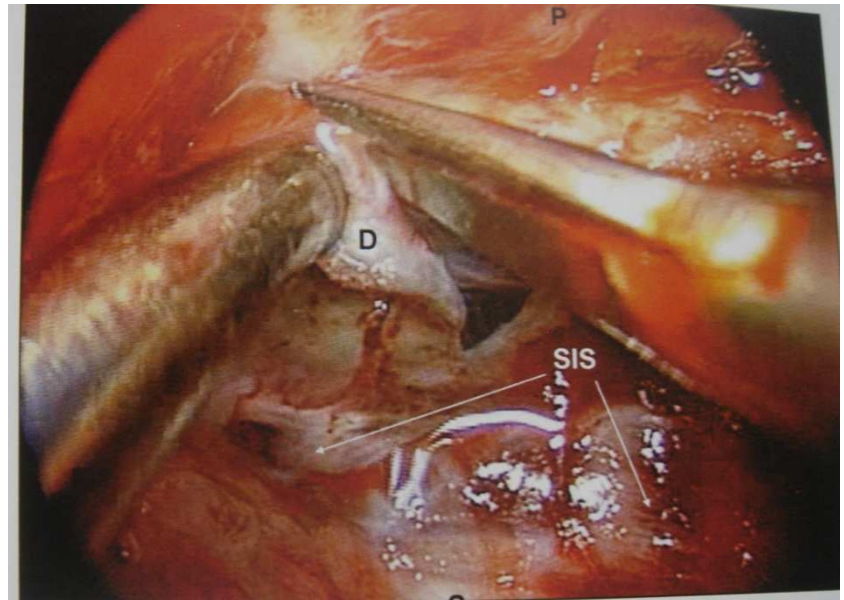


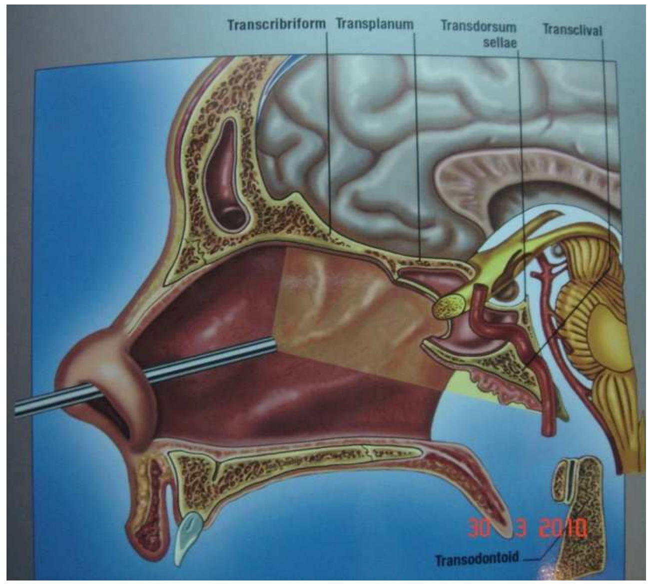
Fig. 18
The suprasellar dural opening (**D**) is completed with endoscopic scissors in a cruciate fashion. The superior intercavernous sinus (**SIS**) is demonstrated in between the sella turcica (**S**) and the planum sphenoidale (**P**).

Pituitary surgery

- Cavernous sinus extension
  - Opening of the cavenous sinus to access tumor within its medial segment
  - Area between the posterior clinoid carotid siphon is the ideal entry point
  - Tumor removed by two suction technique

Expanded approaches

- Transtuberculum/transplanum
- Transcribriform
- Posterior clinoid –trans/subsellar
- Transclival



Transplanum approach

- Wide bilateral posterior ethmoidectomies
- Planum drilled rostral to caudal
- Superior intercavernous sinus at the rostral part of sella cauterised and divided
- Optic strut and medial clinoids drilled

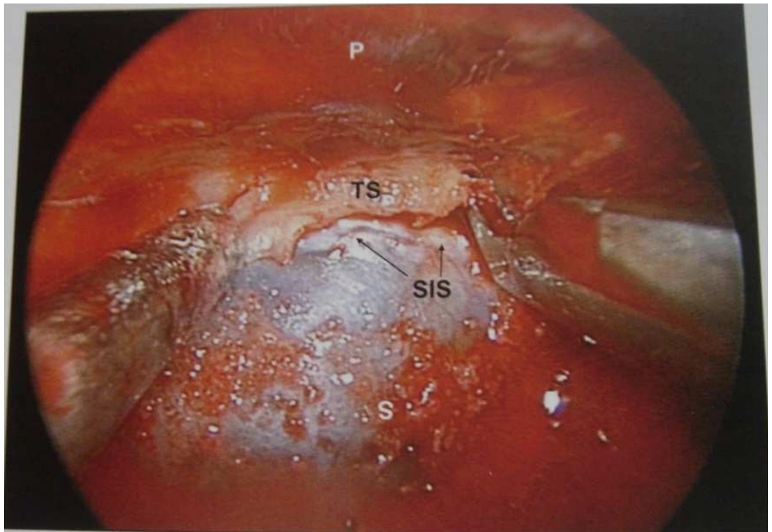


Fig. 15
Transplanum Approach. The thinned bone of the tuberculum strut (**TS**) is elevated and fractured with a blunt dissector or Kerrison rongeur exposing the superior intercavernous sinus (**SIS**) between the planum sphenoidale (**P**) and the sella turcica (**S**).

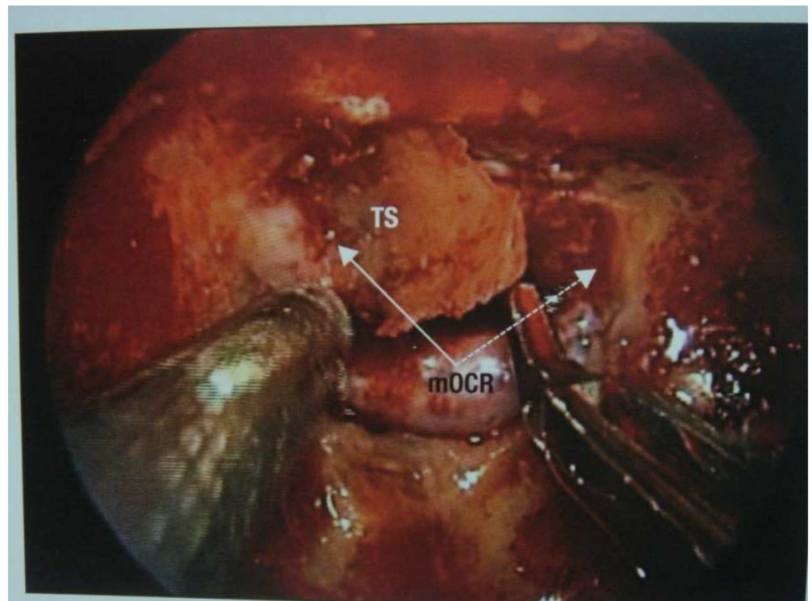


Fig. 16
The bony tubercular strut (**TS**) is thinned and then fractured inferiorly or removed with a 1 mm Kerrison rongeur. The medial optic-carotid recess (**mOCR**) is seen laterally.

Transplanum approach

- Paraclinoid carotid canals removed with a 1 mm kerrison rongeur
- B/L ICA and optic nerves exposed by extracapsular dissection of the tumor through the parachiasmatic cisterns
- Structures in parachiasmatic cistern- A com, recurrent artery of Heubner should be protected

Transcribriform approach

- Useful in olfactory groove meningiomas and esthesioneuroblastomas
- Middle turbinates and b/l complete ethmoidectomies
- Nasofrontal recess exposed anteriorly
- Frontal sinuses connected by creating defect in superior nasal septum
- Ethmoidal arteries cauterised and ligated.

Transcribriform approach

- Bone lateral to cribriform plates thinned and elevated from dura from frontal sinus to planum sphenoidale
- Dura opened on either side of falx
- Internal debulking exposing the free edge of the falx
- Coagulation of falx and feeders from the anterior falcine artery

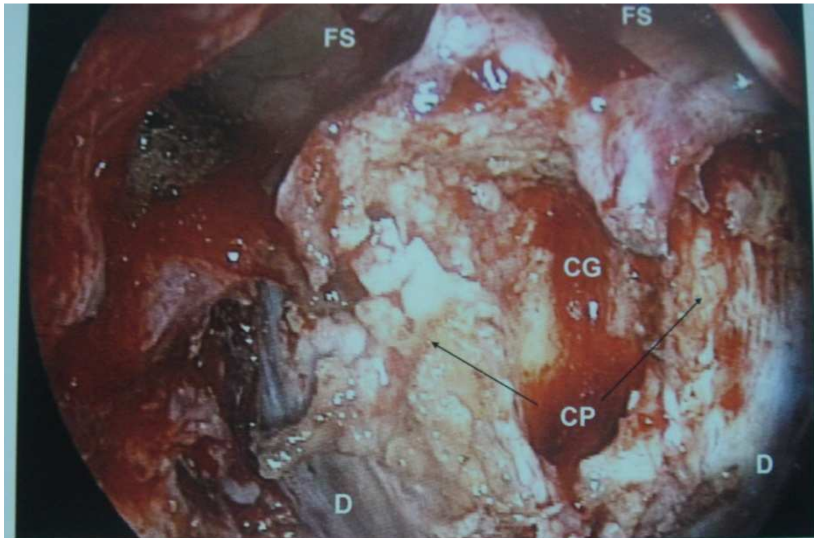


Fig. 21
Transcribriform approach. The floor of the frontal sinus (**FS**) is removed anterior to the crista galli (**CG**) demonstrating the anterior limit of resection. The area of the cribriform plate (**CP**) is demonstrated. The dura mater (**D**) of the anterior skull base is exposed bilaterally.

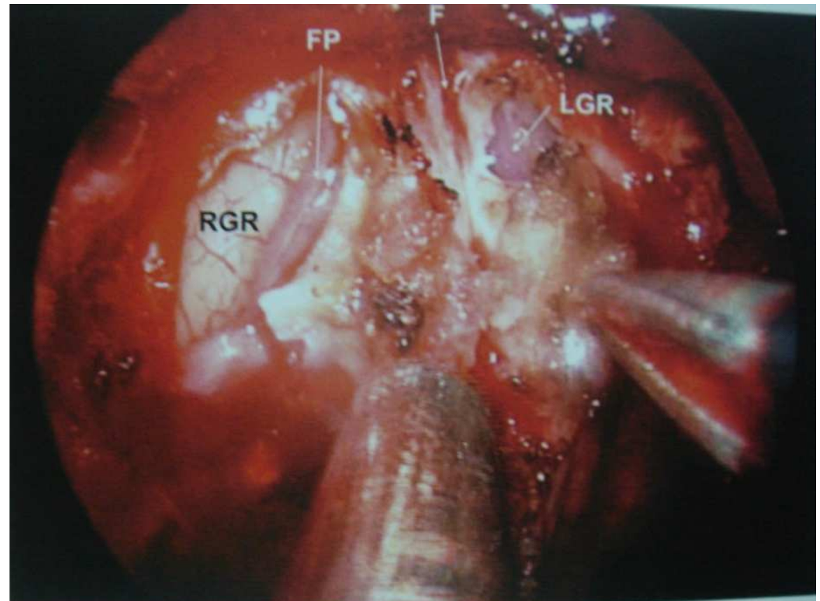


Fig. 25
The dura is opened on each side of the falx (**F**). The right gyrus rectus (**RGR**) is exposed and the right fronto-polar artery (**FP**) can be seen. The left gyrus rectus (**LGR**) is being exposed, still covered by arachnoid membrane and tumor.

Posterior clinoid approach

- Bone on the sellar face removed
- dura over the parachiasmatic cistern and pituitary opened
- Superior intercavernous sinus ligated
- Diaphragma is cut in midline to expose the stalk and gland retracted superiorly
- Dura over posterior clinoids dissected
- Posterior clinoids drilled
- Structures to be protected- ICA and abducens and oculomotor nerves

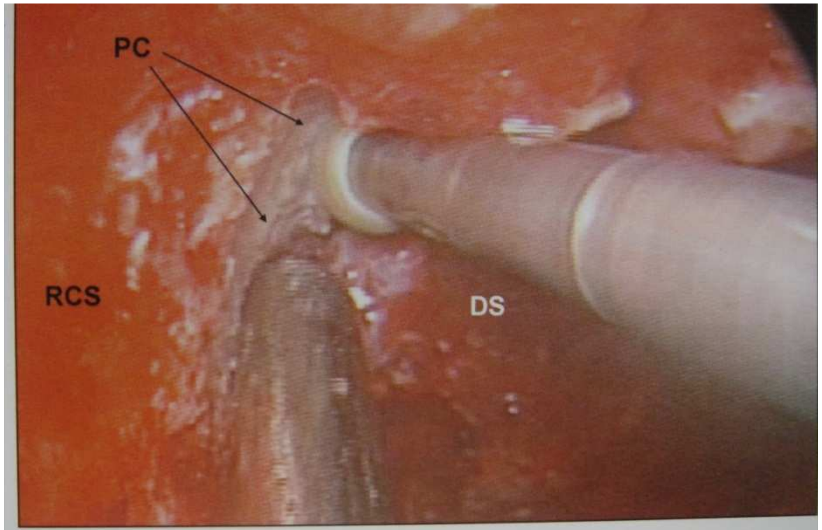


Fig. 33a
The posterior clinoid (**PC**) is thinned with a high speed drill in between the dorsum sellae (**DS**) and the medial wall of the cavernous sinus (**RCS**). The pituitary gland (**P**) is transposed superiorly.

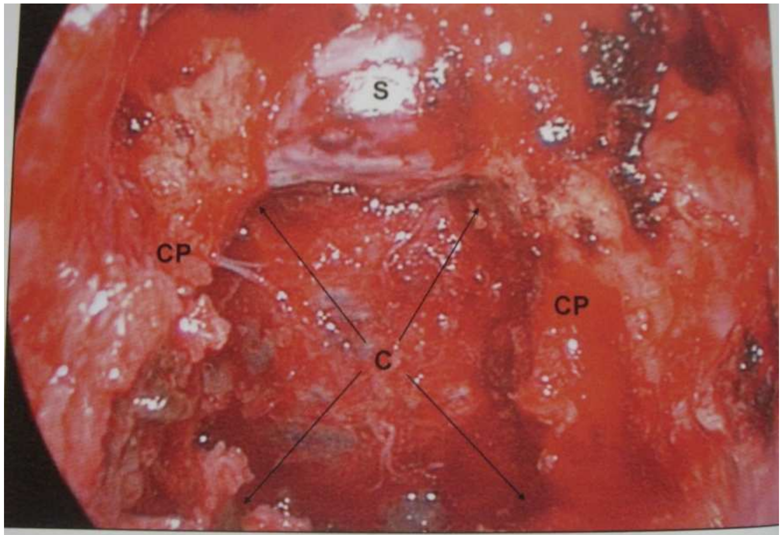
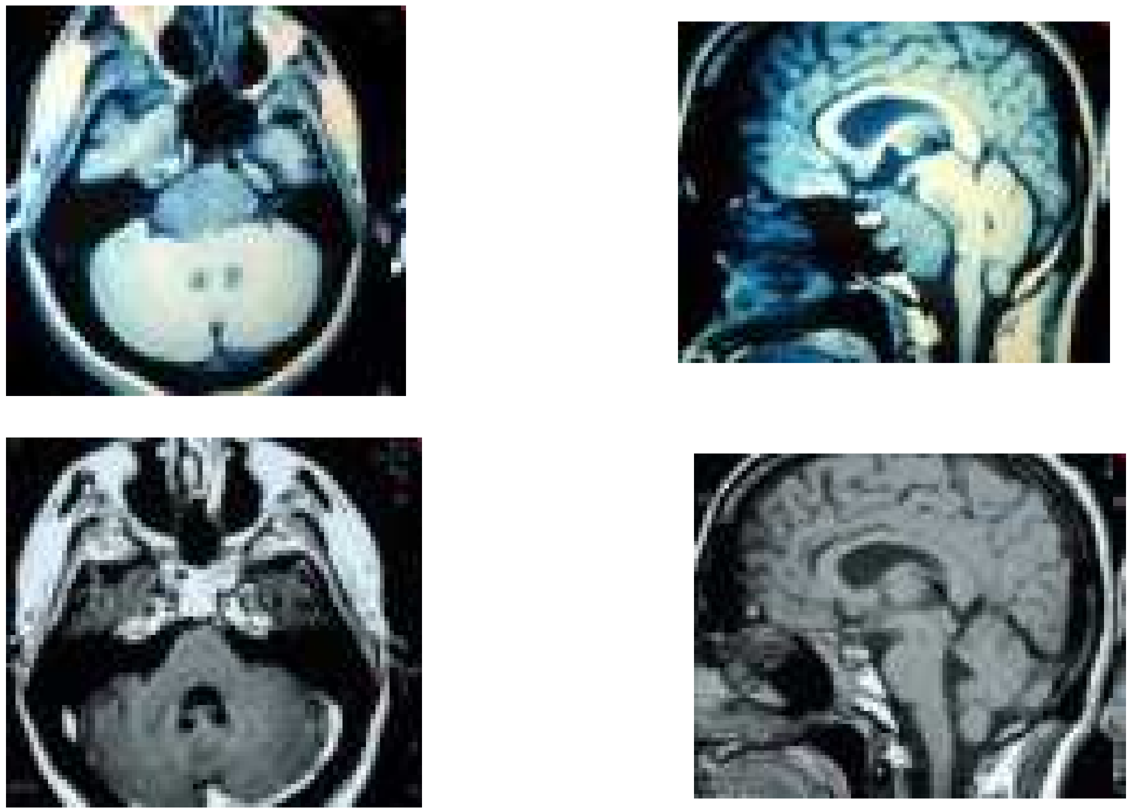


Fig. 35
Completed clival bone resection (**C**) is shown by the arrows bounded by the carotid canals laterally forming the paraclival carotid protuberances (**CP**). The sella (**S**) is shown superiorly.

Approach	Bone	Cistern	Brain	Cranial Nerve	Vessel	Common Pathologies
Transcribriform	Cribriform plate Crista galli	Interhemispheric fissure	Gyrus rectus Orbito-frontal Gyrus	Olfactory	A2, frontopolar, orbital frontal arteries	Olfactory groove meningiomas, Esthesioneuro-blastomas, Encephalocoeles, CSF leaks, Sinonasal tumors
Transplanum Transtubercular	Planum sphenoidale, Tuberculum planum, Optic strut, Medial clinoid	Suprasellar cistern, Pre-chiasmatic cistern	Gyrus rectus, Orbito-frontal Gyrus	Optic nerve, Optic chiasm	Anterior circle of Willis	Planum meningiomas, Suprasellar pituitary macroadenoma, Craniopharyngioma, Optic nerve gliomas
Posterior clinoid (trans/subsellar approaches)	Upper third of clivus, posterior clinoids, dorsum sella	Suprasellar cistern Anterior recess of III ventricle, Basilar cistern, Interpeduncular cistern	Uncus, Hypothalamus, Infundibulum, Mammilary body, Midbrain, Cerebral peduncles	II, III, VI	Basilar apex, P1, Pcom, P2, Perforators, SCA	Retrosellar craniopharyngioma, Pituitary macroadenomas, Petroclival meningiomas
Transclival	Middle and lower third of clivus, Petrous apex, Dorello's canal	Pre-pontine cistern Ponto-medullary cistern	Ventral pons, Upper medulla	V, VI, VII, VIII	Mid basilar, AICA, VBJ	Petroclival meningiomas, Chordomas, Chondrosarcomas, Sinonasal tumors



MR scans, axial (**A**) and sagittal views (**B**), show a large chordoma in the clivus and posterior cranial fossa preoperatively. The tumor was totally removed with an endoscope through a nostril. The patient's hospital stay was overnight. Postoperative MR scans, axial (**C**) and sagittal views (**D**), demonstrate complete removal of the tumor.

Expanded endonasal approach

- Contraindications
  - Pathology located distal or deep to critical neurovascular structures
  - When resection or reconstruction of major vessel is needed
  - When neoplasm involves superficial tissues

Endoscopic Craniopharyngioma Surgery

- For completely intrasellar craniopharyngiomas with no suprasellar extensions and no significant attachments to the optic chiasm-endoscopic transnasal approaches

- Craniopharyngiomas located in the suprasellar areas with adhesions to the optic chiasm are approached by placing an incision within the skin crease in the bridge of the nose and by performing a one centimeter keyhole midline frontal craniotomy.

- Advancing the endoscope along the floor of the anterior cranial fossa underneath the frontal lobe

- Under direct vision the tumor along with its adhesions to the chiasm is dissected and completely resected.

- Patients are discharged within twenty-four to forty-eight hours.

Colloid cysts

- Symptomatic obstruction of the foramina of monro
- Usually, the burr hole is placed behind the hairline and as far laterally (approximately 5–6 cm paramedian) as possible to allow straight access without damage to the caudate nucleus and fornix .
- Dissect the cyst wall, aspirate or resect completely
- Grasping forceps used to remove solid material from the cyst, capsule coagulated and shrunk with laser
- Ventricular system irrigated and ventricular drain for 48 hrs

Endoscopic Removal of Acoustic Neuromas

- Burr hole the size of a dime behind the mastoid.
- Thin, flexible and precise endoscopic instruments are inserted – slipping them between the brain and skull to the site of the tumor
- Rates of facial nerve paralysis, CSF leakage, hearing loss, neurologic injury such as strokes and cerebellar contusions have all decreased
- Any patient who is a candidate for an open approach such as either the translabyrinthine approach or the suboccipital approach can be a candidate for this minimally invasive endoscopic approach
- Patients to be discharged within 48 hours.

Endoscopic repair of CSF rhinorrhea

- Intrathecal fluroscein administration helps in localizing the defect.
- Fibrous tissue excised and Multilayered graft placement done
- Inlay collagen matrix graft placed in extra/subdural space
- Onlay acellular dermis graft over the bone

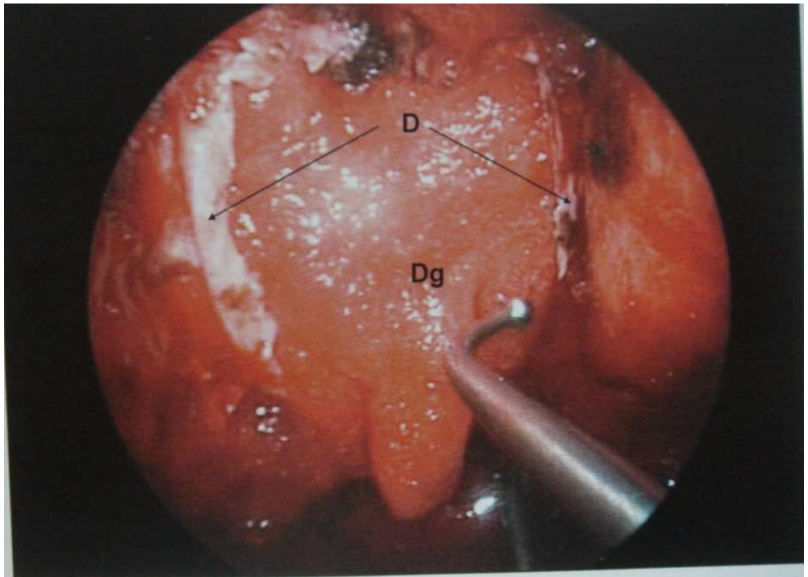


Fig. 46
An inlay Duragen graft (**Dg**) is placed between the brain and the dura (**D**).

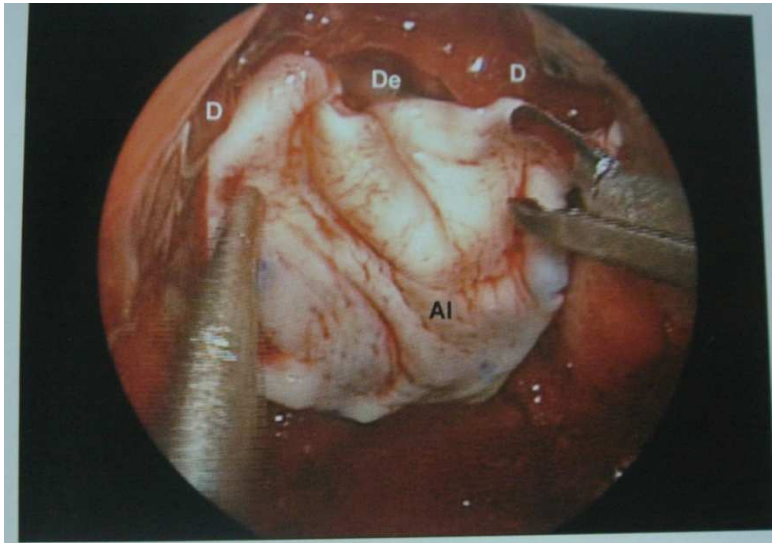


Fig. 47
An onlay Alloderm graft (**Al**) is placed extradurally and overlaps the bony defect (**De**). The dura mater of the edge of the defect is shown (**D**).

Endoscopic repair of CSF rhinorrhea

- Abdominal fat graft used as a bolster with fibrin sealant
- Nasal tampons / 12-24 Fr foley catheter inflated with 5-10 cc of water to compress the fat grafts for 4-7 days
- Suturing the onlay graft with U clips
- Vascularised mucoperiosteal flaps hasten healing

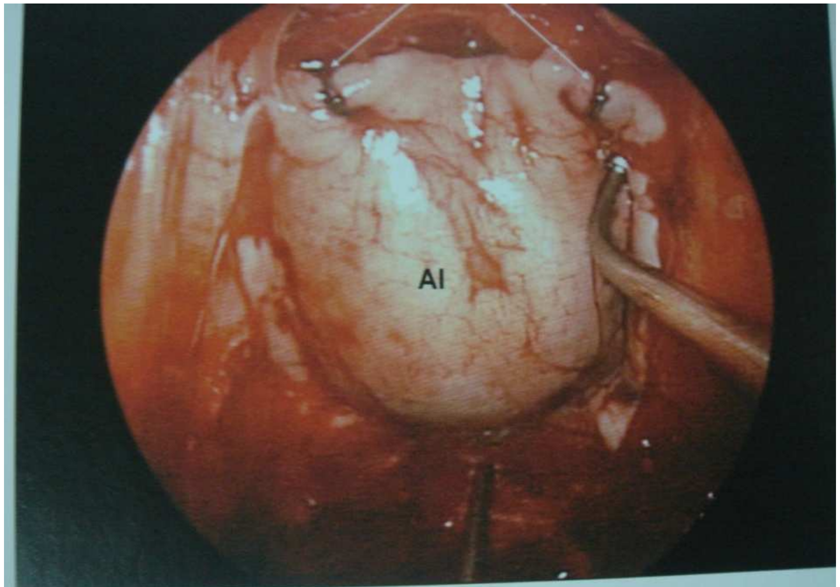


Fig. 50
The onlay Alloderm graft (**Al**) can be secured to the dural edge with sutures or nitinol U-clips (**UC**) to prevent graft migration.

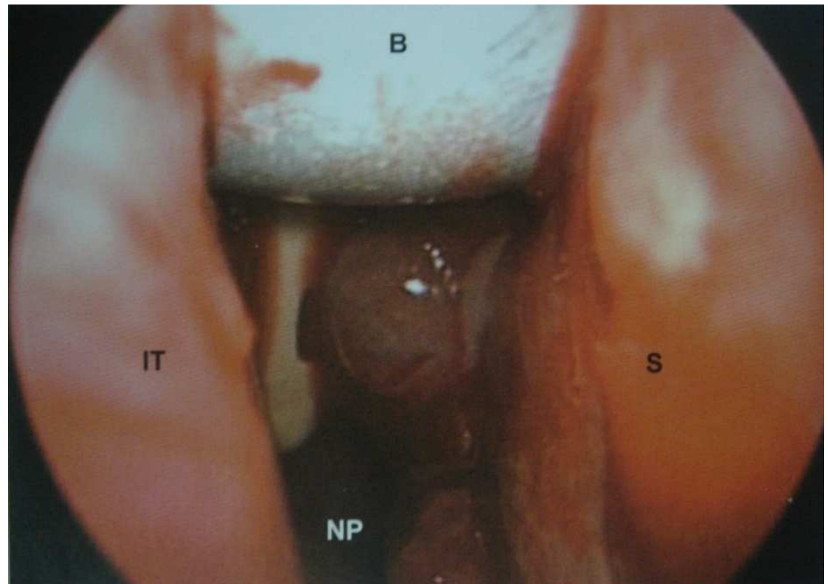


Fig. 49
A balloon catheter (**B**) is inflated intranasally to provide external support for the reconstruction during the early healing phase. The nasal septum (**S**), the nasopharynx (**NP**), and the inferior turbinate (**IT**) are shown.

Conclusion

- Versatile tool
- Useful in non-communicating loculated hydrocephalus, ventricular cysts and neoplasms
- Minimal injury to neural tissue but not free of risk
- Development of better instruments will extend future indications for neuroendoscopy

Thank you