

ORIGINAL ARTICLE

Computed Tomography Cisternography for the Management of Cerebrospinal Fluid Fistulae

¹Mukund D Rahalkar, ²Anand M Rahalkar, ³Vardhan S Joshi, ⁴Kailash V Sant, ⁵Kourabhi B Zade

ABSTRACT

Cerebrospinal fluid (CSF) fistula is an increasingly common condition these days with traumatic cause being commoner than either surgical or nonsurgical trauma. The patient usually presents either with rhinorrhea or less frequently otorrhea. Computed tomography (CT) cisternography is widely used in the diagnostic workup of such patients. It helps to localize the site of leak and to establish the underlying cause. The purpose of this article is to present an overview of CT cisternography findings in various types of CSF fistula, i.e., rhinorrhea, otorrhea, and otorhinorrhea and the management based on them. Magnetic resonance cisternography was not utilized as the CT provides bony detail much better, which is useful for the operating surgeon or endoscopist.

Keywords: Cerebrospinal fluid fistula, Cerebrospinal fluid leak, Computed tomography cisternography, Cribriform plate, Functional endoscopic sinus surgery for rhinorrhea, Management of cerebrospinal fluid fistulae.

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INTRODUCTION

A series of CT cisternographies (50 in number) is presented to depict causes and types of defects in the skull base and, particularly, to highlight the role of this procedure in managing the patient endoscopically or surgically. It is highly relevant because the current practice has limited the role of surgical treatment and increased the scope of endoscopic management. It also aims at correct diagnosis by studying the path of leak of contrast; in other words, it tells us how to diagnose or manage the images correctly. The fistulae are divided into occurring in anterior or middle and posterior fossa.

The CSF rhinorrhea associated with head trauma has been described as far back as the time of Galen. Dandy first described an intracranial repair of a CSF leak in 1926, and Dohlman in 1948 was the first to describe the extracranial repair. The technique of CT cisternography was first developed in 1970.¹

The CSF leak or fistula is defined as passage of CSF from the subarachnoid space through the osseous and dural defect into the skull base. Further, it drains into either nasal or ear cavity and labeled as CSF rhinorrhea, otorrhea, or otorhinorrhea.¹ Patients usually present with rhinorrhea, otorrhea, or with recurrent episodes of meningitis or headache. With introduction of endoscopic surgery [functional endoscopic sinus surgery (FESS)] by 2011 and its increasing use, the exclusive role of neurosurgery to close the fistulae has been challenged. Part I is our experience of 50 cisternographies and some inferences derived from them. Part II describes endoscopic or surgical approaches to treatment of CSF fistulae with illustrated images.

MATERIALS AND METHODS

Diagnosis of CSF Leak

There are different methods to confirm that the fluid is indeed CSF, like analysis of leaking fluid, magnetic resonance imaging (MRI) and fluorescein cisternography. However, in routine practice, the diagnosis is made based on the history and clinical signs/symptoms, and the patient is referred for CT cisternography for obvious advantages being cost and superiority in terms of showing bone details and defects. In confirming the fistula, there should be at least 50% increase in CT value, as compared with plain CT.

In patients with CSF leak, the imaging workup is required to confirm the diagnosis, evaluate the underlying cause, localize and characterize the defect site prior to surgery, exclude the other causes like meningocele, and guide the surgeon for the management.

Computed Tomography Cisternography

The CT cisternography has now become the standard method for evaluation of CSF leak.² Plain CT in coronal plane is first carried out to detect the site or sites of likely

^{1-3,5}Consultant Radiologist, ⁴Consultant Surgeon

^{1-3,5}Department of Radiology, Sahyadri Hospitals, Pune Maharashtra, India

⁴Department of ENT, Sahyadri Hospitals, Pune, Maharashtra India

Corresponding Author: Mukund D Rahalkar, 721/2B, Navi Peth, Pune 411030, Maharashtra, India, Phone: +919890311341 e-mail: mdrahalkar@hotmail.com

defects in cribriform plate, roofs of ethmoidal cells, or skull base. After the administration of nonionic contrast (8–10 mL of Omnipaque 180), the patient is kept in the prone Trendelenburg's position for about 20 minutes for opacification of basal cisterns followed by CT in prone position. It is important to ascertain that the cisterns and sulci are well filled in frontal regions; otherwise, the patient is kept in the head-low position for another 15 to 20 minutes and a CT is repeated.

Classification

The most widely accepted classification of CSF leak is by Ommaya et al,³ who divided the CSF leak into traumatic and atraumatic. A third category was added recently, which includes spontaneous CSF leak.⁴

- Traumatic—posthead injury or surgery
- Nontraumatic
 - High pressure, e.g., tumors, hydrocephalus, or benign intracranial hypertension⁵
 - Normal pressure leaks, e.g., congenital defects, tumors, arachnoid granulations, infection, empty sella, and idiopathic causes.
- Spontaneous—without history of head injury or congenital defects

RESULTS

A total number of 50 CT cisternographies were performed and are presented. There were eight cases in which no leak was seen including one in which there was a fracture of roof of attic and otorrhea. A leak was shown in delayed CT in three cases. A total of 45 cases including 42 cases with positive cisternography and 3 cases with delayed positive CT cisternography are divided according to the cranial fossa involved, e.g., anterior or middle and posterior. The breakdown of 45 cases according to site and cause of CSF leak is shown in Tables 1 and 2.

Table 1: Anterior skull base leaks

<i>Anterior skull base</i>	<i>Total number</i>
Sinus wall fractures—frontal sinus, orbit and ethmoid roof	11
<i>Defect in cribriform plate</i>	
1 Previous head injury: 4	14
2 Spontaneous: 10	
Congenital frontoethmoidal encephalomeningocele	2

Table 2: Middle and Posterior skull base leaks

<i>Middle and posterior skull base</i>	<i>Total number</i>
Sphenoid roof fractures	5
Erosion of floor of sella by a tumor	1
Congenital defect (persistent Sternberg' canal) including one with brain herniation	6
<i>Otorrhea</i>	
1 Fracture of tegmen tympani: 1	2
2 Postmastoidectomy: 1	
Leak along facial nerve through stylomastoid foramen with congenital extension of CSF sleeve along the entire VII nerve	1
Otorrhinorrhea following surgery for acoustic neuroma (2) and spontaneous 1	3

DISCUSSION

Part I

- We have seen leaks in the anterior skull base including roof of sphenoid sinus causing rhinorrhea (Figs 1 to 11). The defects can be traumatic or spontaneous, though spontaneous was greater in number in our series. It is normally expected that history of head injury would be very commonly seen in cases of rhinorrhea. In our experience, this was true for defects in roof of ethmoid sinus, which was seen in 10 out of 11 cases. In only one case, a leak was demonstrated with defect in ethmoid roof, which was spontaneous.

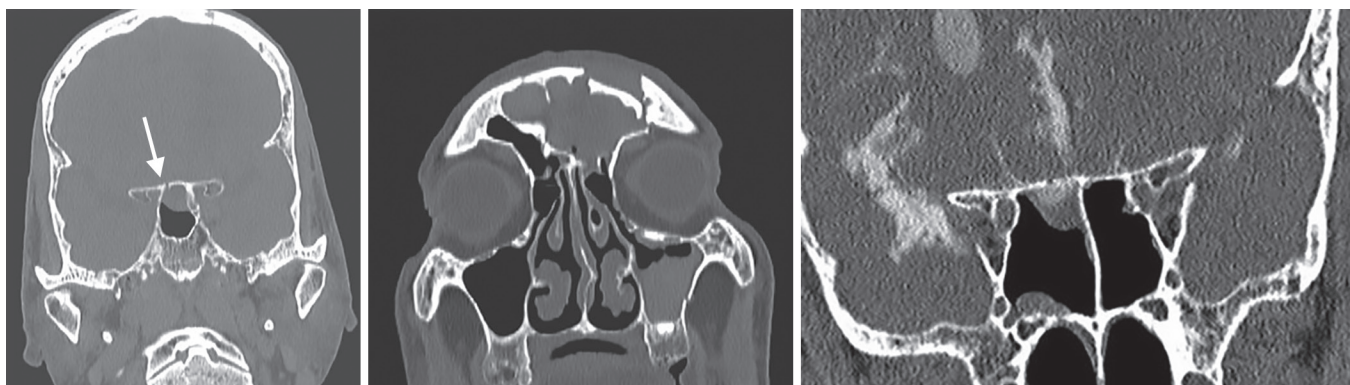


Fig. 1: A young 22-year-old male had head injury followed by rhinorrhea. Plain CT shows a defect (arrow) in the roof of right half of sphenoid sinus and a soft tissue density beneath. Cisternography showed leak from fracture of roof of sella on right, but did not show leak from other sites of defects. Treated by surgery

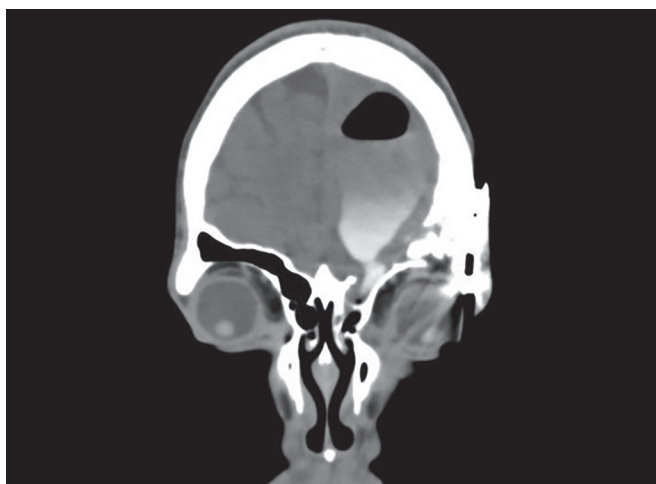


Fig. 2: This adult male with injury to head and left orbit developed rhinorrhea after 1 year. The CT showed an intracerebral CSF-filled cavity communicating with left ethmoid sinus, which was corrected surgically

It was a different scenario as far as the fractures and defects of cribriform plate were concerned. There were only four cases of rhinorrhea with a defect in cribriform plate of traumatic origin, but, in 10 cases, there was spontaneous rhinorrhea without history of head injury.

- Other causes of spontaneous rhinorrhea that we encountered were: congenital nasal encephalomeningocele (2 cases; Figs 7 and 8), persistent Sternberg's canal (6 cases; Figs 12 to 15), and infection in 1 case with no history of head injury in the past. There were 13 (nearly 25%) cases of spontaneous rhinorrhea out of 40 cases.

Presence of a persistent Sternberg's canal causing fistula and rhinorrhea was seen in six cases. This is rather a high incidence and it was due to awareness of this entity. Out of these cases, one was due to chronically raised intracranial pressure due to tuberculous meningitis (TBM) with hydrocephalus and the second presented with

recurrent meningitis. These led to progressive erosion or widening of Sternberg's canal. In one case, there was herniation of right temporal lobe through a wide Sternberg's canal into the sphenoid sinus causing rhinorrhea (Fig. 15). The remaining cases presented with rhinorrhea, and Sternberg's canal was discovered as a cause.

Sternberg's canal is located in the posterolateral wall of sphenoid sinus and inferolateral to maxillary nerve. It is a persistent lateral craniopharyngeal canal associated with spontaneous intrasphenoid leak due to formation of a meningocephalocele into the lateral recess of sphenoid sinus. We had one rare case of intrasphenoid temporal meningoencephalocele, which was investigated by CT as well as MRI. This is supposed to occur in approximately 1 in 35,000 cases.⁶ The aggravating factors are: Hyperpneumatization of paranasal sinuses, raised intracranial tension, infection, or obesity.

These defects were treated by an endoscopist using a special technique, which is called "endoscopic infra-temporal fossa approach to reach the defect of lateral pterygoid recess of sphenoid sinus."

- While looking for a leak, one has to see the images right up to anterior end of nasal cavity, where contrast may be seen as a line or blob. It is also important to keep in mind that there may be many defects, but leak may be seen from only one defect.

In 8 cases (17.5%), no leak of contrast was shown. Stone et al⁷ had also reported that 12 out of 42 studies were negative for leak. Various causes can be responsible, such as small size of defect, fibrosis, or sealing of the fistula, leak being intermittent, previous lumbar drainage of CSF as a part of treatment, long interval between the time when CT is advised by the surgeon and day when the patient turns up for CT, decreased CSF pressure, or inaccurate interpretation of study. However, based on the defect shown on

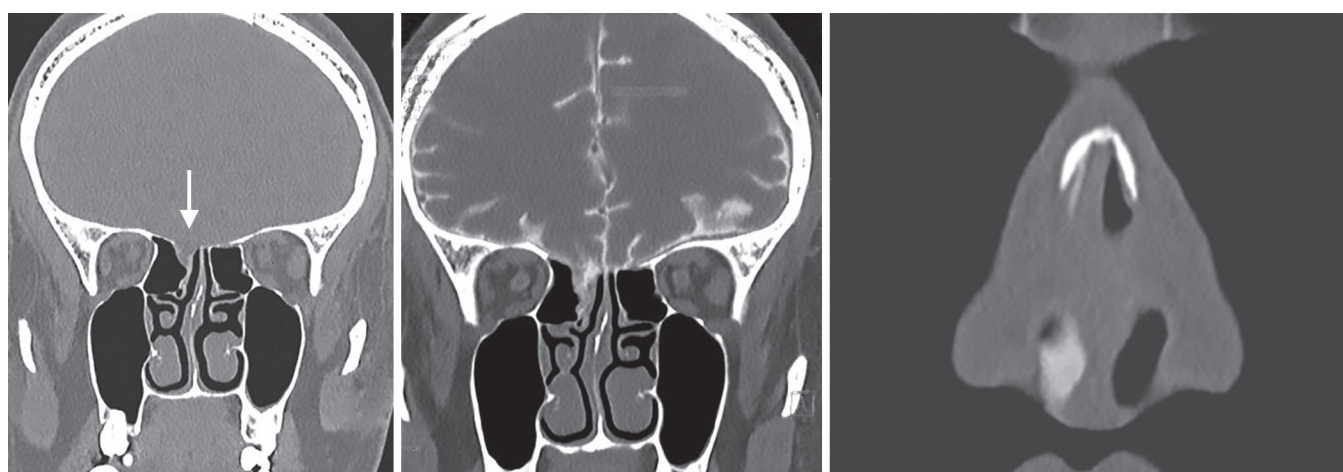


Fig. 3: This 31-year-old male had h/o head injury 5 months ago. Plain CT shows a defect in the roof of right ethmoid with a soft tissue density, highly suggestive of site of rhinorrhea (arrow). Leak of contrast from the same site and further pooling of contrast in the right anterior nasal cavity are well shown. Treated by endoscopy

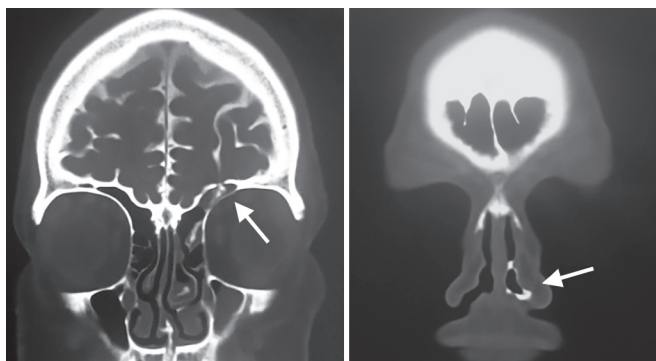


Fig. 4: Female, 34, with no h/o head injury developed rhinorrhea. The CT shows leak (arrows) of contrast through a tiny defect in the roof of supraorbital extension of left ethmoid. Treated by modified endoscopic Lothrop technique

the prior CT and a soft tissue density beneath it (as all our cases had shown), the surgery was carried out with positive results. There are many reports of plain CT alone being more sensitive than CT cisternography.¹ In three cases, leak did not occur at the time of CT scanning, but occurred later in the ward, which was proved on a repeat CT.

- There were two cases of otorrhea. One showed herniation of right cerebellum into external meatus after mastoidectomy, which did not show actual leak of

contrast (Fig. 16), as the bony defect itself was blocked by the herniating brain. It was treated by FESS.

- There was 1 case (2%) of leak through stylomastoid foramen (Fig. 17). Petrus and Lo⁸ had reported two cases of CSF fistula through dilated facial nerve canal. The geniculate ganglion fossa was enlarged and labyrinthine facial nerve canal was widened. Our case was exceptional in that the child was operated for rhinorrhea through a defect in the cribriform plate a few years in the past and later on presented with recurrent meningitis. The extension of CSF sleeve along the facial nerve in the dilated facial canal can be deficient and can cause rhinorrhea and recurrent meningitis.

Part II

Most CSF leaks resolve spontaneously with conservative management or by lumbar drain placements to decrease intracranial pressure and encourage healing. In our series, 15 cases were treated conservatively.

Intracranial or open repair (neurosurgical) is the traditional method to repair CSF leak. However, disadvantages include morbidity of craniotomy as well as anosmia associated with disruption of olfactory bulb and tracts.

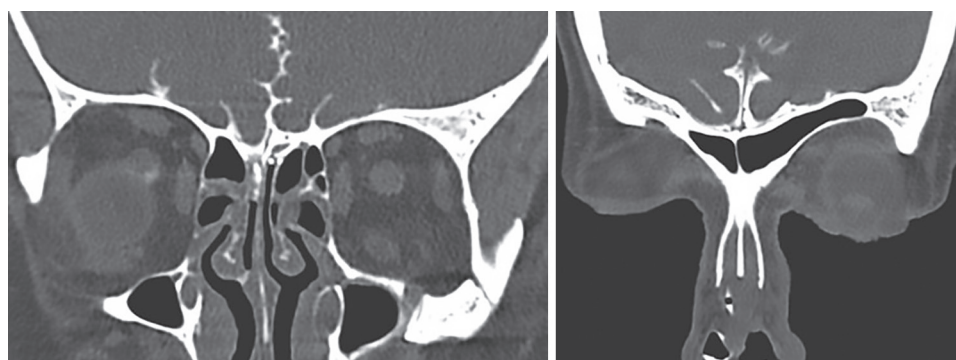


Fig. 5: This male, 26, had h/o head injury. The contrast is seen leaking from the defect in horizontal lamella on right and pooling in anterior nares. This was treated by FESS

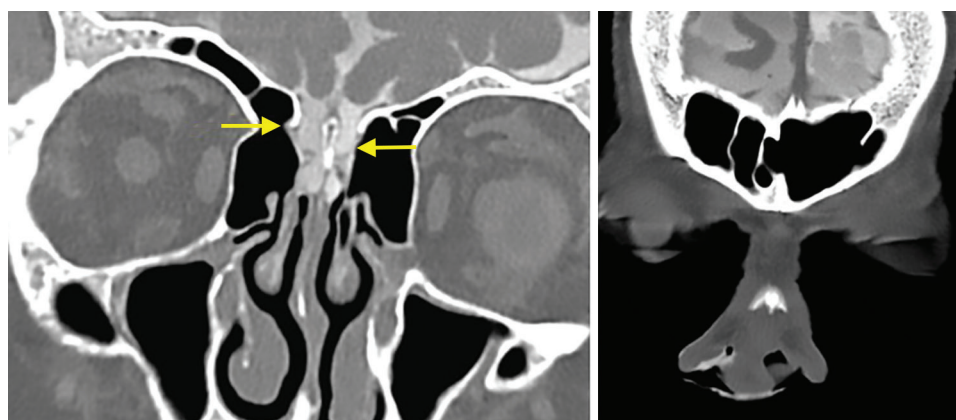
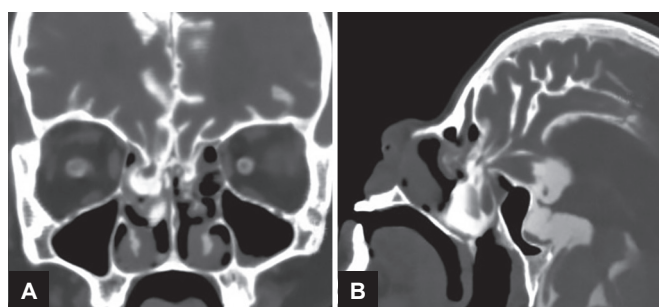


Fig. 6: An 83-year-old female with spontaneous rhinorrhea. No h/o head injury. There is leak from both horizontal lamellae (arrows) along the medial aspect of middle turbinates and then into nares. Treated by FESS



Figs 7A and B: (A) This young 24-year-old female suffered from recurrent meningitis. The CT cisternograms in coronal and sagittal planes show a well-defined large sac of contrast herniating into right nasal cavity due to a nasal encephalomeningocele; and (B) corresponding T2-weighted MRI confirming herniation of brain and meninges through a defect in a cribriform plate. She was treated by FESS

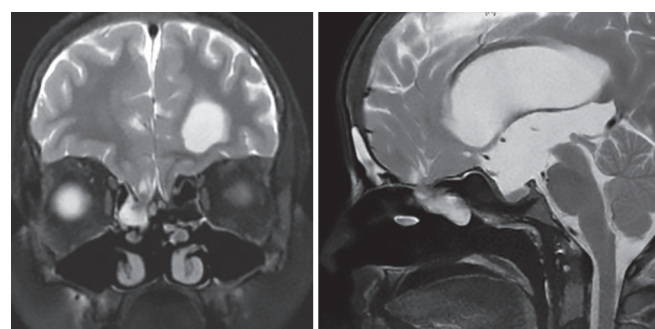


Fig. 8: This 30-year-old male also had a congenital encephalomeningocele through a large defect in cribriform plate. The CT shows all classical signs of a defect, soft tissue mass underneath, and a well-defined sac of contrast



Fig. 9: This young male, 24 years old, had rhinorrhea after head injury. Cisternogram shows a fracture in the roof of right half of sphenoid sinus with leak into Onodi cell. Treated by FESS

Endoscopic sinus surgery offers the transnasal approach to repair anterior and central skull base CSF leak. In experienced hands, this procedure offers higher success rates without morbidity of craniotomy. However, limitations with the extracranial technique include multiple skull base defects, deformed skull base, invasive skull base tumor, and high-pressure leaks.

At present, there seems to be a tacit understanding regarding who would treat the rhinorrhea, a neurosurgeon or an endoscopist. Here is a brief discussion on various operative techniques of duraplasty to repair the site of fistula.⁹ The criteria are:

- If the defect is anterior to anterior ethmoid artery (AEA) canal, i.e., involving roof or supraorbital extension of ethmoid sinus or frontal sinus, then neurosurgical approach is adopted (Figs 18 and 19).
- If the defects in anterior skull base are multiple, then again surgical approach is adopted, as in these cases FESS would be difficult and very time-consuming. Even if there is a leak from one defect, all defects are corrected by duraplasty.
- FESS is best under the following conditions:
 - The defect is posterior to AEA canal and involving anterior skull base up to the sphenoid walls, as the endoscope can reach the defect. It cannot be used more anterior to AEA canal because hemorrhage, if it occurs, cannot be stopped.
 - Size of defect, distance from AEA canal on plain CT, and if the leak is affecting horizontal or vertical lamella of cribriform plate are important. This information on a cisternogram is very useful so

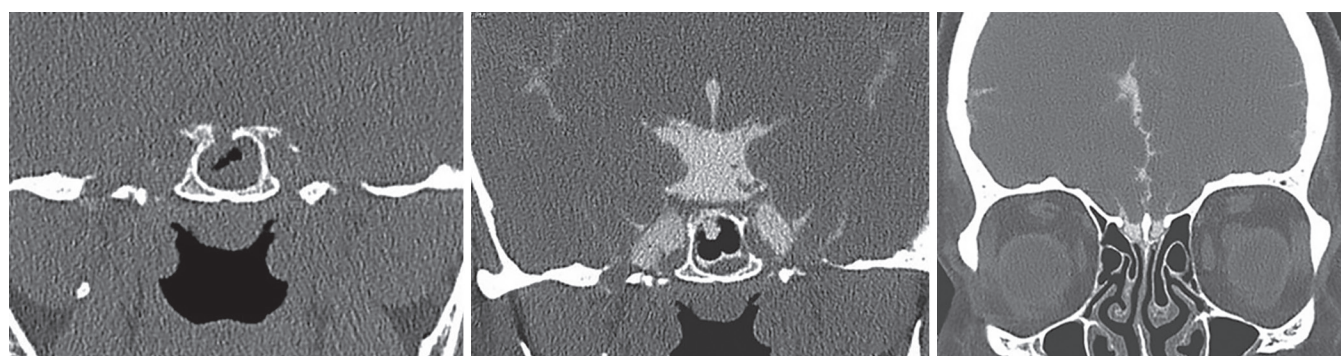


Fig. 10: An adult male, 34 years old, had h/o head injury followed by rhinorrhea. The CT showed a fracture of roof of sphenoid sinus on right with a leak into sphenoid sinus. More anteriorly, olfactory fossae look normal. Was treated by FESS

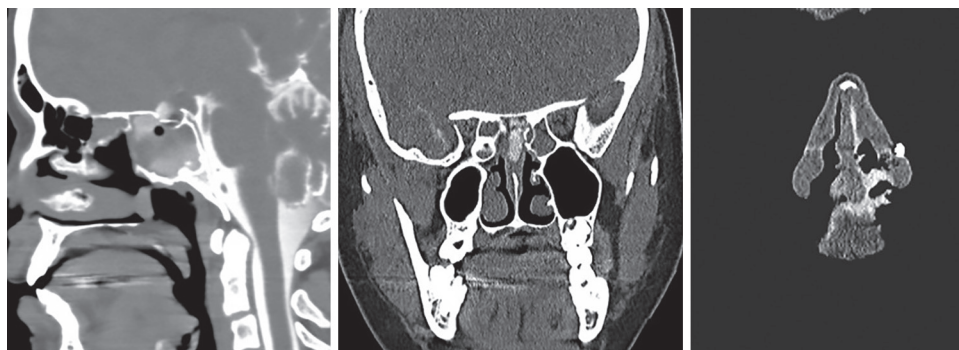


Fig. 11: A 33-year-old female had a pituitary tumor. Trans-sphenoid removal of the adenoma was carried out. Within a few months, she had rhinorrhea on left. A break in the floor of sella was seen on plain CT. The cisternogram showed free leak of contrast into sphenoid sinus, then into ethmoid sinus, and then into left nasal cavity. She was treated by FESS

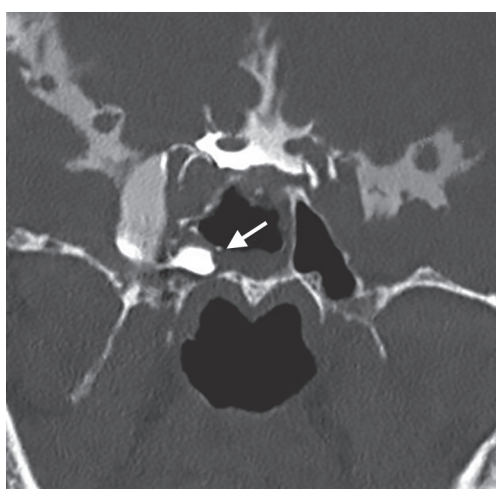


Fig. 12: In this adult male, 28 years old, there was h/o rec. meningitis, no h/o head injury. Cisternogram shows a meningocele into sphenoid sinus (arrow) through a Sternberg's canal. A little contrast entered into pterygoid fossa. Treated only intrasphenoid component by endoscopy

that the endoscopist can decide the advancement of the scope. If the defect is in the horizontal lamella at attachment of middle turbinate, the scope will be passed medial to middle turbinate with ease and straight up to the defect.

If the defect is shown involving lateral (vertical) lamella of cribriform plate (Figs 20 to 22), the scope will have to be advanced lateral to the turbinate, and to reach the defect anterior and posterior ethmoidectomy would have to be carried out to gain wide exposure to skull base.⁹

The advantages of duraplasty by FESS are:

- The FESS is supposed to be less traumatic than neurosurgery with less morbidity
- Better field visualization
- Magnified angled visualization

There are variations in the technique of duraplasty done by FESS like (1) underlay, (2) overlay, and (3) tobacco pouch method. The commonly used technique involves (1) identification of sac of meningoencephalocele and gliotic brain, which is excised, (2) bony defect being exposed, and (3) a big chunk of fat greater than the bony/dural defect interposed between brain and defect by "bath plug" technique. The threads are pulled outward to seal the defect. (4) Put glue (fibrin sealant) and gel foam over and under the surface of defect, and (5) put fascia lata or similar graft material to cover the defect.⁹

- For otorhinorrhea as a complication of excision of acoustic neuroma, a combined approach is taken by a neurosurgeon and ear, nose, and throat (ENT)

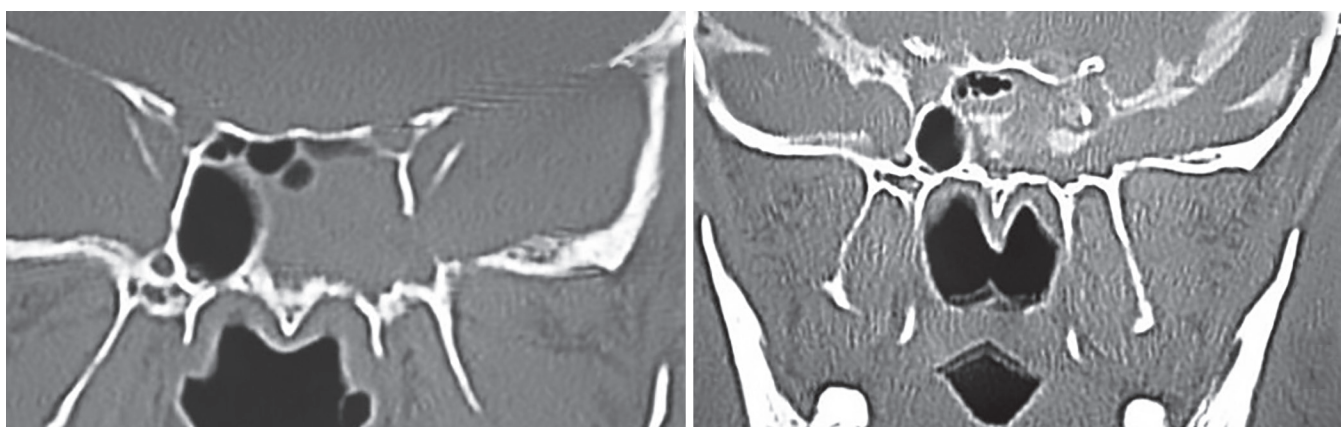


Fig. 13: This 51-year-old male had rhinorrhea without any h/o head injury. There is a leak through a widened Sternberg's canal on left. Endoscopic duraplasty done

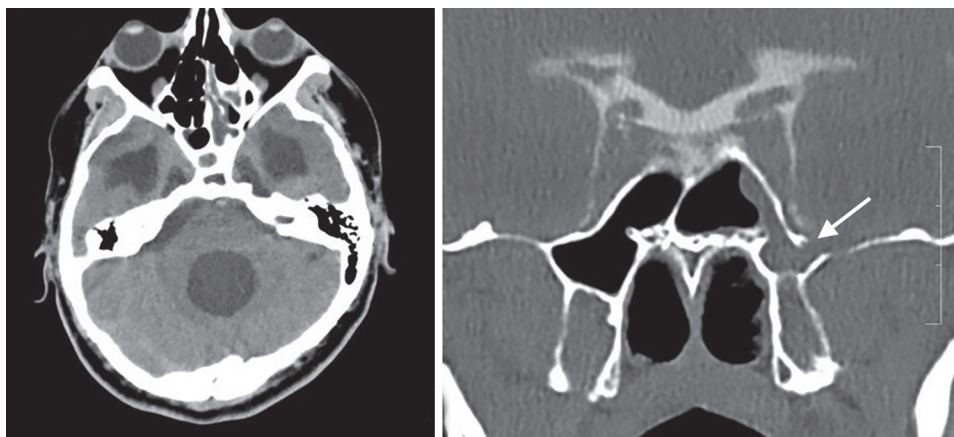


Fig. 14: A 32-year-old male who was being treated for TBM with hydrocephalus developed rhinorrhea. Plain CT revealed that he had a Sternberg's canal, which had perhaps slowly widened due to chronically raised intracranial pressure. Though cisternography failed to show the leak, he was treated by FESS and was also shunted for hydrocephalus. The image on left shows dilated ventricles and obliterated cisterns. The arrow in image on right points to Sternberg's canal

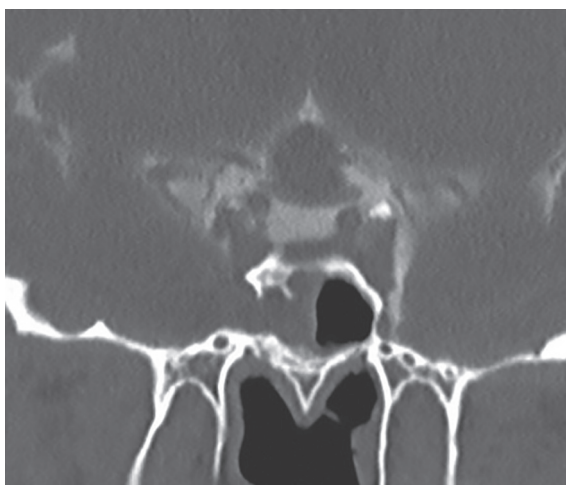


Fig. 15: This 34-year-old male had no h/o head injury. The CT and MRI showed herniation of right temporal lobe into sphenoid sinus. No leak shown. This was diagnosed as an intrasphenoid encephalomeningocele through widened Sternberg's canal. Treated by endoscopic duraplasty

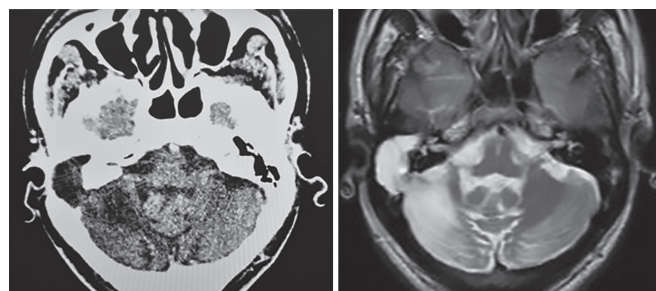


Fig. 16: This male, now 45 years old, had right mastoidectomy at the age of 32 years, now developed watery discharge from right ear. The CT and MRI confirmed herniation of CSF and gliotic right cerebellum into mastoid. This explained the otorrhea and he was treated by surgery. An otorrhea is a known late complication of mastoidectomy and the herniation of brain tissue is called as fungus cerebri

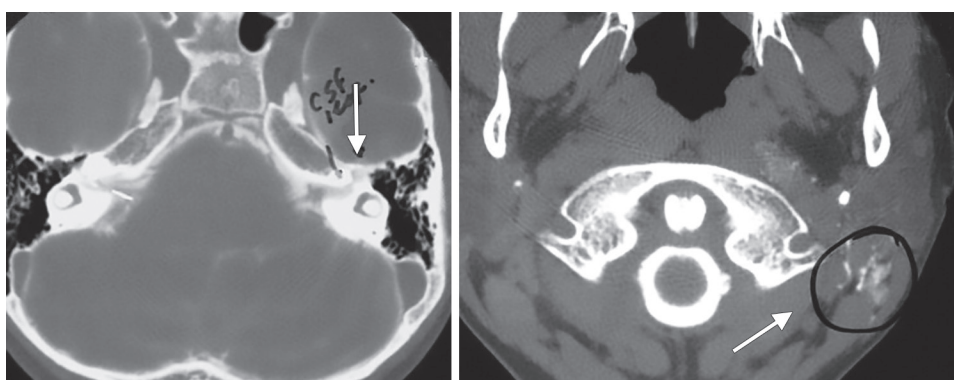


Fig. 17: This 15-year-old male had repeated attacks of meningitis and so was operated for CSF fistula into ethmoid fossa. He continued to have attacks of meningitis. The old CT was not available. Nuclear scan showed increased activity in the neck on left. New CT revealed widened geniculate fossa (arrow in image on left) and leak of contrast along the facial nerve canal into neck through stylomastoid foramen (arrow in image on right)

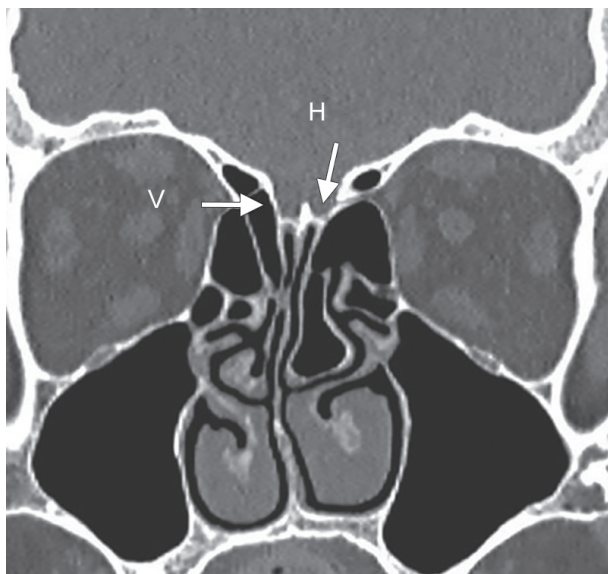


Fig. 18: The superior attachment of middle turbinate with ethmoid is at the junction of the horizontal and vertical lamella of cribriform plate, (arrows) as shown in the image

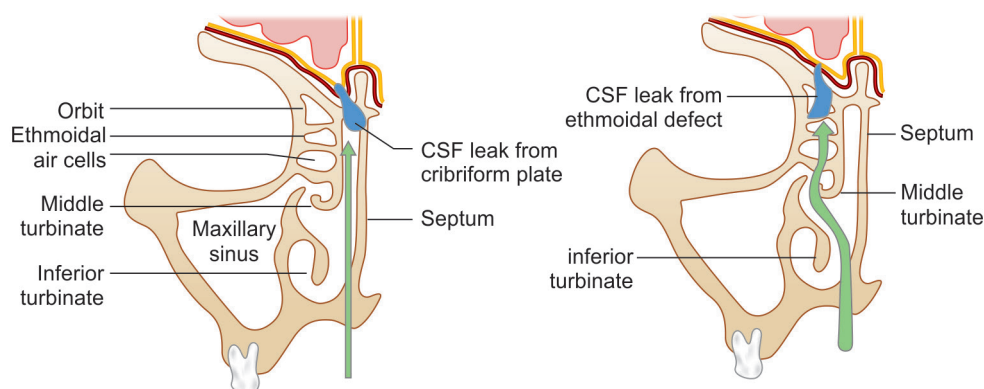


Fig. 19: Left: Defect in horizontal lamella and leak on medial aspect of middle turbinate. Appreciate passage of scope along the medial surface and straight access of endoscope to the defect. Right: Defect in vertical lamella and leak along lateral aspect of middle turbinate. This will require passage of the endoscope lateral to the middle turbinate and complete anterior and posterior ethmoidectomy to gain access to the defect (With permission from author, Rajesh Reddy Sonnareddy)

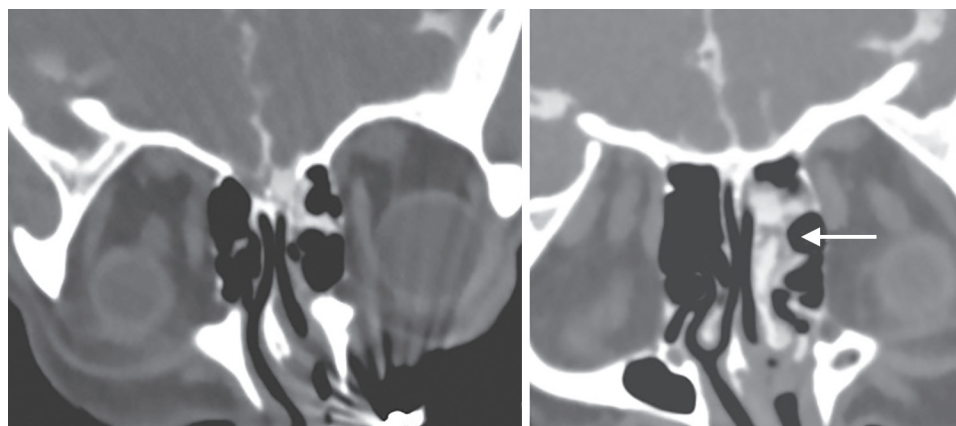


Fig. 20: A female, 44 years old, had h/o head injury and had developed rhinorrhea. Cisternograms show very clearly a defect over vertical lamella of middle turbinate on left and so leak over lateral surface of turbinate (arrow in image on right). Treated by FESS with passage of probe accordingly and sacrificing ethmoid cells

specialists (Figs 23 and 24). The goal is to cranialize the posterior fossa from pharynx and external meatus by subtotal petrosectomy), blind sac closure of external auditory canal, and Eustachian tube closure (ETC). The idea is to isolate the CSF oozing into the middle ear cavity or Eustachian tube or external meatus. We had a case of failure of ETC with recurrence of otorrhorrhea. This had to be corrected again by reclosure of Eustachian tube (Fig. 25).

In a case of otorrhorrhea (Figs 26 to 29), there was a leak from the defect in tegmen tympani into tympanic cavity, Eustachian tube, and then into nasopharynx. The defect was detected at surgery and appropriate duraplasty was carried out. This case incidentally illustrated perhaps the rarest finding of bilateral congenital absence of cribriform plates, which could have been due to continued pulsations of CSF or less likely due to congenital absence. These had remained intact and

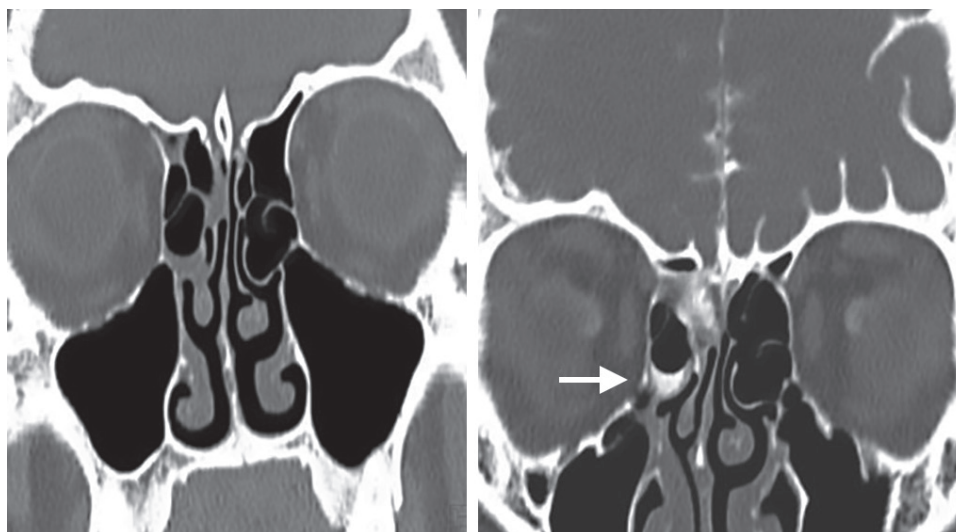


Fig. 21: In this adult, 33-year-old male, there was postinfective rhinorrhea. Cisternography images show CSF fistula through the vertical lamella and the contrast collecting in the ethmoid bulla on right side (arrow). Treated by FESS

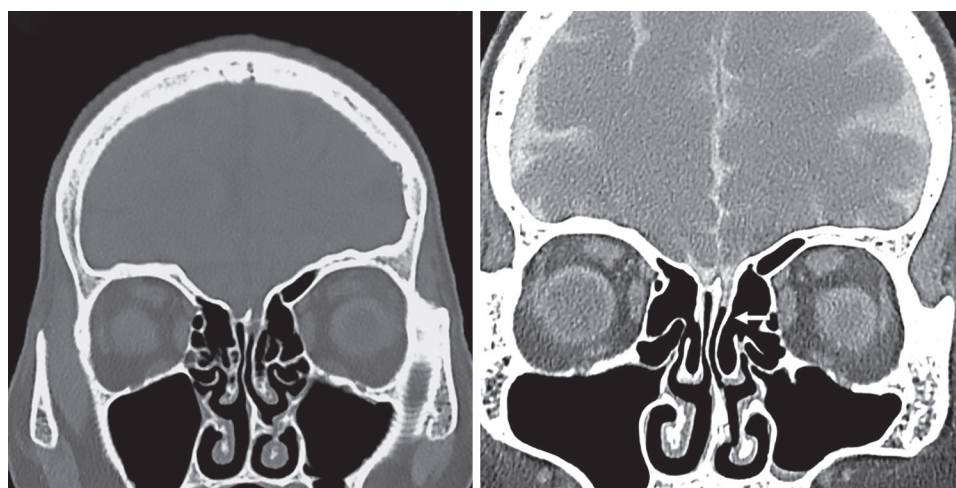


Fig. 22: A 62-year-old female with spontaneous CSF rhinorrhea showing defect in the horizontal lamella on left side and leak on medial side of middle turbinate (arrow). Treated by FESS

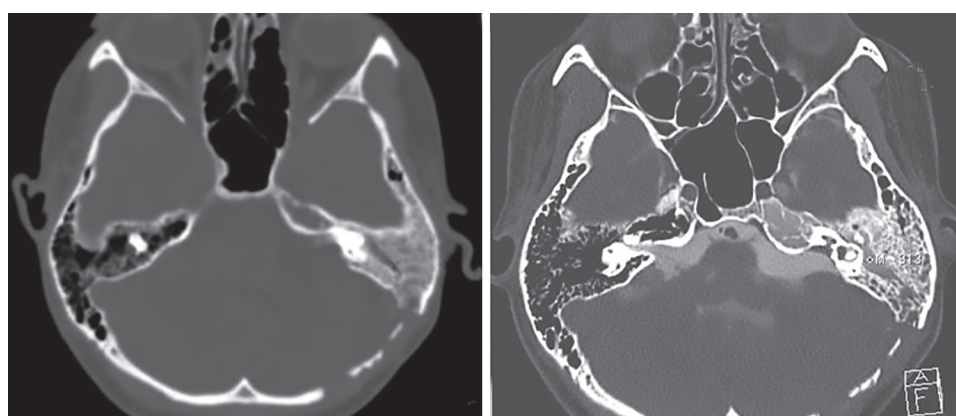


Fig. 23: This female, 26 years old, operated for acoustic neuroma, developed otorhinorrhea. Plain CT showed CT value of 88 in mastoid cells (image on left), while it increased to 313 (image on right) due to leak into mastoid cells. Treated surgically

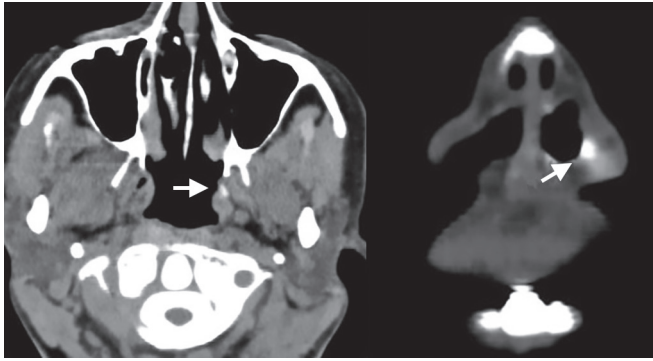


Fig. 24: Further contrast leaking into nasopharynx via Eustachian tube. Tiny blobs of contrast at the opening of Eustachian tube in the nasopharynx anterior to torus tubarius and in the anterior nasal cavity (marked by arrows) are found, thus confirming the path of leakage of CSF in otorhinorrhea. Treated surgically

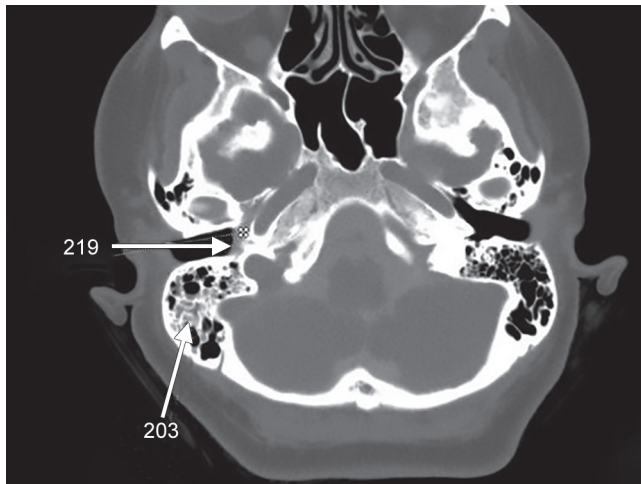


Fig. 26: This 35-year-old female consulted an ENT surgeon for heaviness in ear. The otoscopy showed a bulging drum. A fluid collection in middle ear was suspected and so was referred for plain CT followed by CT cisternography. The contrast entered into mastoid cells, tympanic cavity, and then into nasopharynx via Eustachian tube to establish otorhinorrhea. The arrows indicate CT values of more than 200 due to the leaked contrast



Fig. 25: A 40-year-old male, who was operated for acoustic neuroma, developed otorhinorrhea. He was surgically treated with subtotal petrosectomy and Eustachian tube closure, but again developed otorhinorrhea. The CT cisternogram shows a large postpetrosectomy defect filled with contrast (A), which leaked into and is seen in cartilaginous part of Eustachian tube and subsequently into nasal cavity marked by arrows in (B) and (C). This was due to failure of ETC and he had to be operated again for reclosure through external meatus

were not the site of leak. Such congenital absence of cribriform plates can be a component of a well-known Goldenhar syndrome.¹⁰ This case report mentions a nasotracheal tube entering into skull through a defective cribriform plate.

CONCLUSION

The CT cisternography is very useful in evaluation of patients with CSF fistula. With properly performed CT cisternography and careful evaluation of images, it can help to localize the site of CSF fistula and help in planning the treatment. We suggest that if there is no obvious leak under the defect, look for a blob or streak of contrast in the nasopharynx/anterior nasal cavity, which has been well

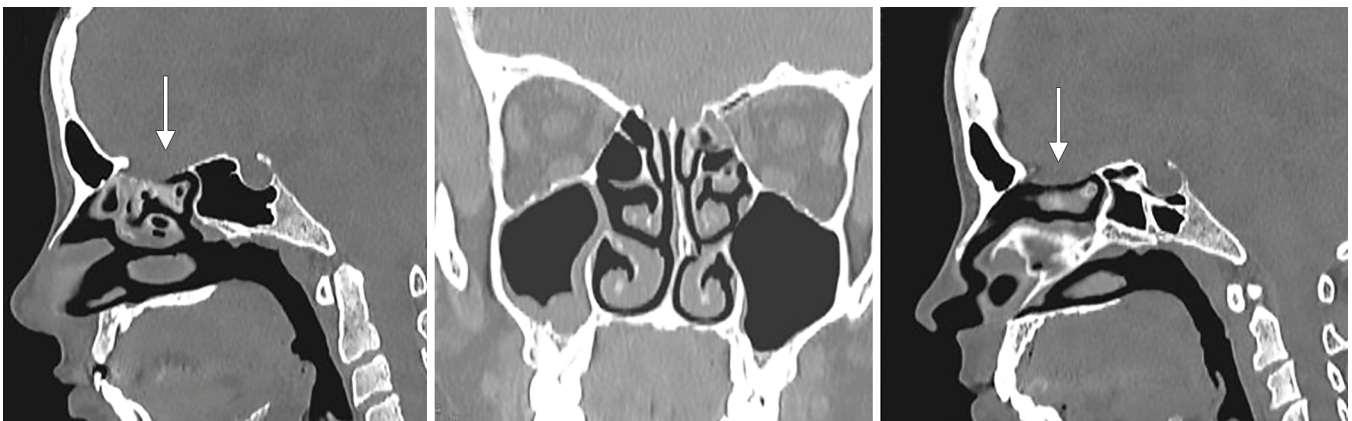


Fig. 27: Absent cribriform plates marked by arrows are incidentally noted

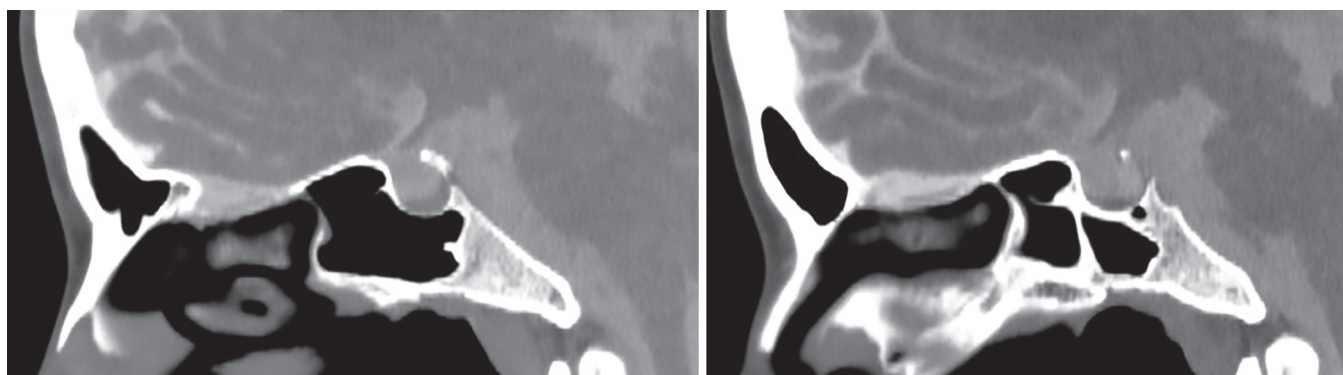


Fig. 28: The image reveals that there is no leak through the dural sheets on either side

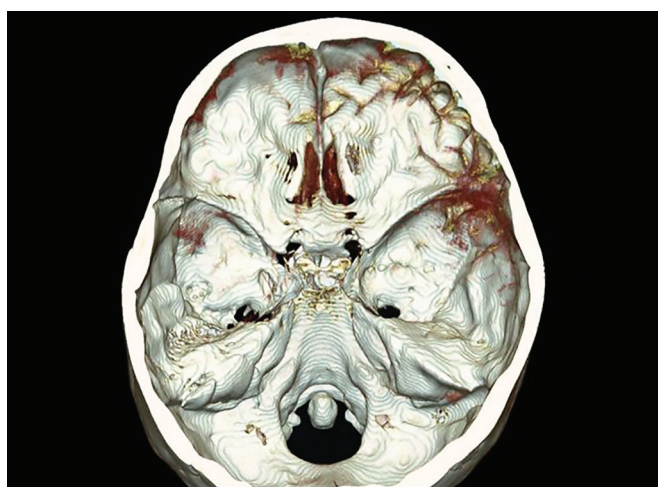


Fig. 29: A volume rendering technique image of anterior skull base showing large defects in the region of cribriform plates on both sides

demonstrated in our cases. Our experience of handling cases of negative cisternogram by repeating it within a few hours, correct interpretation of pattern of leak on medial or lateral aspect of middle turbinate, and value of findings of a defect in skull base associated with a soft tissue density beneath it on plain CT are sufficient for a neurosurgeon to operate for a repair of fistula.

The surgical or endoscopic approach of duraplasty can be dependent on findings on the CT cisternography, which has been amply demonstrated.

The study also shares our experience of rather a larger number of leaks through Sternberg's canal and two rare cases, one of CSF leak along the widened root sleeve of VII nerve resulting into leak through stylomastoid foramen in the neck and the other of congenitally absent cribriform plates on both sides.

We had an unusual case of recurrence of otorhinorrhea after subtotal petrosectomy and ETC, which was corrected again.

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