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Combined HRCT and MR Cisternography in the Evaluation of CSF Rhinorrhea

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Abstract

Background: Cerebrospinal fluid (CSF) rhinorrhea is a potentially devastating condition, that can lead to significant morbidity and mortality. So, accurate localization of the osseodural defect is important for effective surgical repair. The usual diagnostic technique is computed tomography (CT) cisternography. Because of its associated risks, alternative imaging approaches should be used. High-resolution CT (HRCT) is good in identifying the bony details, but CSF is poorly depicted. In contrast, magnetic resonance imaging (MRI) with 3D-CISS technique detect CSF track as a bright signal, but the detection of bony defect is poor. To overcome the defects of both techniques, we superimposed the images obtained from each modality with subsequent perfect surgical planning.

Aim of Study: To assess the diagnostic value of combined HRCT and MR cisternography in the evaluation of CSF rhinorrhea.

Results: Clinically all studied patients presented with CSF rhinorrhea. Of total 47 cases, the osseous defect was detected on HRCT in 44 cases with a sensitivity 94%. MR cisternography, delineated the flow of a CSF-like signal intensity that could be traced intracranially. Overlapping the CTs and MRIs correctly depicted the site of the CSF leak in 46/47 with a high sensitivity 97%, which was confirmed by the endoscopic sinus examination. The most common site of osseodural defect was at the ethmoid roof, followed by the frontal sinus and finally the sphenoid sinus. This is associated with meningocele in 33/46 (71.7%) and meningo-encephalocele in 10/46 (21.7%).

Conclusions: Combined HRCT and unenhanced MR cisternography is a non-invasive diagnostic technique and should be the favorite approach to delimit the site of CSF leakage prior to surgical repair.

Key Words: *CSF rhinorrhea – High-resolution CT – MRI cisternography.*

Ethics Approval and Consent to Participate: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (Institutional Review Board (IRB)" of Faculty of Medicine Alexandria University and with the Helsinki Declaration of 1964 and later versions. Committee's reference number is unavailable (NOT applicable). No consent was obtained from the patients since it was a retrospective study.

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Introduction

CSF rhinorrhea is described as the leak of cerebrospinal fluid (CSF) from the intracranial cavity through an osseous defect within the skull base into the paranasal sinuses or the nasal cavity. The patients may be presented with various symptoms including clear nasal discharge and headache **[1-3]**.

Many categorizations have been used for CSF rhinorrhea based mainly upon the etiology. However, the most accepted classifying process was described by Ommaya in 1960 dividing CSF leakage into traumatic or non-traumatic categories **[4]**. A third category of CSF leakage, representing a spontaneous type in patients with no history of any predisposing factor **[5,6]**. However, some authors are referring its etiology to chronic intracranial hypertension **[7]**.

List of Abbreviations:

CSF	: Cerebrospinal fluid.
HRCT	: High resolution computed tomography.
CT	: Computed Tomography.
MRI	: Magnetic resonance imaging.
FSE	: Fast spin-echo.
FLAIR	: Fluid attenuated inversion recovery.
3D	: Three-dimensional.
CTC	: CT cisternography.
MRC	: MR cisternography.
3D-CISS	: Three-dimensional constructive interference in steady state.
IIH	: Idiopathic intracranial hypertension.
SPSS	: Statistical Package for Social Science.

Post-traumatic CSF leaks represent about 90% of the diagnosed patients. The most usual traumatic sites include the anterior cranial fossa, with fractures through the frontal sinus or cribriform plate of the ethmoid bone. While, central skull base fractures include the sphenoid sinus. Iatrogenic CSF leakage is now considered the most prevalent type owing to the broad use of functional endoscopic sinus manipulation and complex skull base surgeries [8,9].

Non-traumatic CSF leaks may be seen in cases with skull-base tumors, infections or even congenital anomalies such as cribriform plate defect. This type can occur with normal or high intracranial pressure (ICP) conditions [10,11]. The skull base tumors or infections can erode the skull base and overlying dura with subsequent CSF leakage. Likewise, post-radiotherapy necrosis might also result in osseodural defect [12].

Lastly, spontaneous CSF leakage is considered a separate class occurring in patients with no apparent cause. Demographically, this type notably seen in obese middle-aged female. It can involve the skull base bone anywhere, mostly at the ethmoid roof, or at the sphenoid sinus [13-15].

Undiagnosed and unmanaged CSF leakage may lead to serious complications as meningitis and brain abscesses. Therefore, proper diagnosis with prompt identification of the defect site is essential for effective repair with avoiding life threatening complications [16].

Although the used imaging procedures have been recently improved, preoperative accurate identification of CSF leak is still a challenging dilemma for both neuroradiologists and neurosurgeons [17].

High-resolution computed tomography (HRCT) is good in obtaining perfect bony details but it is likely difficult in distinguishing paranasal sinus (PNS) secretions from leaked CSF, which is considered the major limitation. CT cisternography (CTC) can depict CSF fistula, but the ionizing radiation and intrathecal contrast administration are the major disadvantages of this technique [18,19].

Magnetic resonance imaging (MRI) with 3D-constructive interference in steady state (3D-CISS) giving unenhanced MR cisternography, replacing the invasive CT cisternography. It shows CSF as a bright signal with no intrathecal contrast injection. Moreover, MRI provides intracranial details in multiple planes, but has a deficient spatial resolution and lack of bony details [20-24].

Thus, CT and MRI act as complementary imaging procedures in accurately identifying the CSF leakage, and consequently effective surgical repair.

Patients and Methods

Study selection:

This prospective study was approved by the local ethics committee and written informed consent was waived. During a 2-year period from January 2018 till January 2020, we assess 47 patients with persistent or intermittent rhinorrhea, in private radiology center. All cases were subjected to a full clinical history with oto-rhinolaryngological examination to confirm the presence of CSF leak. Also, the suspected fluid was tested for β2-transferrin to confirm the presence of CSF leak, which was found to be positive in all cases.

High resolution CT examination:

HRCT was obtained on a 128-rows multidetector scanner; Aquilion 128, Toshiba Medial system with no IV contrast administration. All cases were examined in a supine position with the head first. Scanning were obtained from the level of skull vault to the mandible using the following parameters: 200mA; 120kVp; FOV 240, slice thickness 0.5mm with 0.3 interval. Total scan time about 3.6 seconds. A bone algorithm was used to enhance bone details. With MDCT, the images were first carried out in the axial plane, followed by reformatting the raw data into additional planes without a compromise in image resolution.

MRI examination:

The examination was done on a 1.5 Tesla MR scanner (Siemens, Magnetom Avanto, 32 channels) with a phased array head coil. It started with a routine brain sequence which included FSE T1WI in the axial and sagittal planes, FSE T2WI in the axial and coronal planes and FLAIR axial images.

MR cisternography (MRC) was obtained in the coronal and sagittal planes using a three-dimensional constructive interference in steady-state (3D-CISS) sequence. The needed parameters were 1200/263 (TR/TE), flip angle 70°, effective thickness 0.6mm, and field-of-view (FOV) 200 with an acquisition time of 10 min and 67s. The patient was in the supine position with no specific procedures like prone position, valsalva maneuver or contrast injection were applied.

Data extractions:

All findings were conveyed from the archive to a workstation (Vitrea 2.2 or Osrix), via internal network connections. Both HRCT and MRC images were assessed together in a different session by two expert radiologists with decision-making in consensus. The main references were the optic nerve, crista galli, and basal attachment of the middle turbinate. The CT image was used as the basic picture with the MRC superimposed on it. These compound pictures were analyzed and correlated with endoscopic sinus checkup.

On CT basis, the positive data included a visualized bone defect with adjacent extracranial fluid-like density. Then, the anatomical location of the defect and its severity were recorded.

The criteria for a CSF fistula on MRI with 3D-CISS were as follows: (i) A defect in the bone-dura interface and (ii) Hyperintense CSF track or bright CSF pouch protruding from the osseodural defect into the underlying paranasal sinuses with or without strands of soft tissue.

Statistical analysis:

The collected data were statistically analyzed using SPSS (Statistical Package for the Social Sciences, version 25.0). Parametric data were presented with mean and non-parametric data with median and range. Categorical data could be displayed in frequencies and percentages. The sensitivity and specificity of HRCT/MRC for CSF leak detection were determined. Then, correlation between the imaging findings & endoscopic data was done.

Results

In this cohort study, 47 patients with CSF rhinorrhea, including 31 females & 16 males (mean age, 37.7 years; range, 19-61 years) were analyzed. Clinically, our study included 33 active cases with persistent dripping and 14 inactive with sporadic dripping.

On HRCT, a bony defect was detected in 44 of 47 cases, with three cases couldn't be well identified. In these cases, CSF leak could be suggested by fluid-density opacification of the underlying sinuses. MRI with 3D-CISS technique, detected the flow of a CSF-like signal intensity that could be traced cranially with isointense soft tissue components or not. Overlapping CT and MRI images correctly delineated the site of the CSF leakage in 46 of 47 studied cases, which was confirmed by the endoscopic transnasal examination.

In this survey, the etiology of CSF leakage can be widely divided into three categories; post-traumatic (after road traffic accident or sport trauma), in 25 of 47 cases (53.2%), spontaneous in 15 (31.9%) with no noticeable cause and finally, iatrogenic (after sinonasal tumor resection or endoscopic sinus manipulation) in 7 (14.9%) (Fig. 1). Associated idiopathic intracranial hypertension (IIH) in spontaneous CSF rhinorrhea was detected (11/15 cases, 73.3%) with bilateral optic hydrops and empty sella (Fig. 2). In these cases, there was no evidence of cerebral venous thrombosis or hyperviscosity syndrome. No signs and symptoms of meningitis were detected in our study. HRCT imaging of the skull base and the paranasal sinuses is performed for all cases before MRC examination.

Our cases with an identified osseodural defect on combined HRCT/MRC (46/47) would be surveyed as follows: Thirty-seven cases (80.4%) had a single defect, six cases (13.1%) had two defects, and only three (6.5%) had multiple defects. Regarding the defect site, the ethmoid roof (32 cases, 69.6%), (with 21/35 cases at the cribriform plate and 11/35 cases at the fovea ethmoidalis) is the most affected bone, followed by the frontal sinus (10 cases, 21.7%) and then, the sphenoid sinus (4 cases, 8.7%). Three cases with multiple defects; two in the frontal/ethmoid area (Fig. 3) and one in the ethmoid/sphenoid area. Within our cases, 33 out of 46 cases (71.7%) had meningocele and 10 (21.7%) had meningo-encephalocele. The accompanying Table (1) summarizes the previous data.

Table (1): Survey of our studied cases with CSF rhinorrhea.

CSF Rhinorrhea (47 cases with positive β2-transferrin)	On Combined HRCT & MRC No. (%) of detected cases/46 cases
Osseodural defect	
Multiplicity:	
• Single	37 (80.4%)
• Two	6 (13.1%)
• Multiple	3 (6.5%)
Site:	
• Ethmoid bone	32 (69.6%)
• Frontal sinus	10 (21.7%)
• Sphenoid sinus	4 (8.7 %)
• Fovea ethmoidalis/ cribriform plate	6 (13.1%)
• Frontal/ethmoid	2 (4.3%)
• Ethmoid/sphenoid	1 (2.2%)
• Meningocele	33 (71.7%)
• Meningo-encephalocele	10 (21.7%)

The imaged 46 cases on HRCT/MRC with CSF leakage were confirmed by the endoscopic sinus examination with transnasal approach, with verifying the remaining case. By endoscopy, fenestration of the dura overlying the osseous defect with CSF dripping is a likely finding with arachnoid herniation in cases with meningocele / meningoencephalocele.

Of 47 patients with CSF rhinorrhea, 39 patients (83%) were repaired endoscopically by coagulation of the herniated arachnoid. Then, the defect was covered by a local mucoseptal flap. The remaining 8 patients (17%) were treated via surgical transcranial approach.

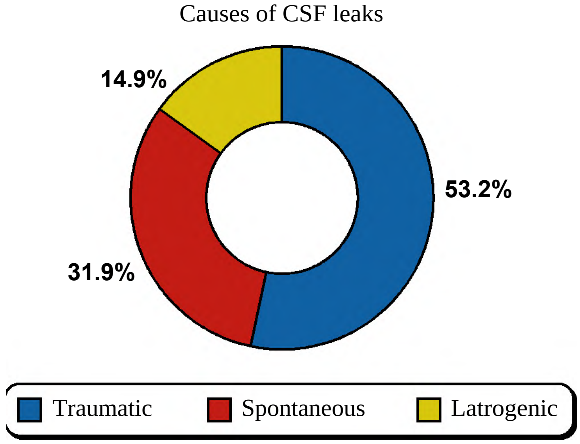
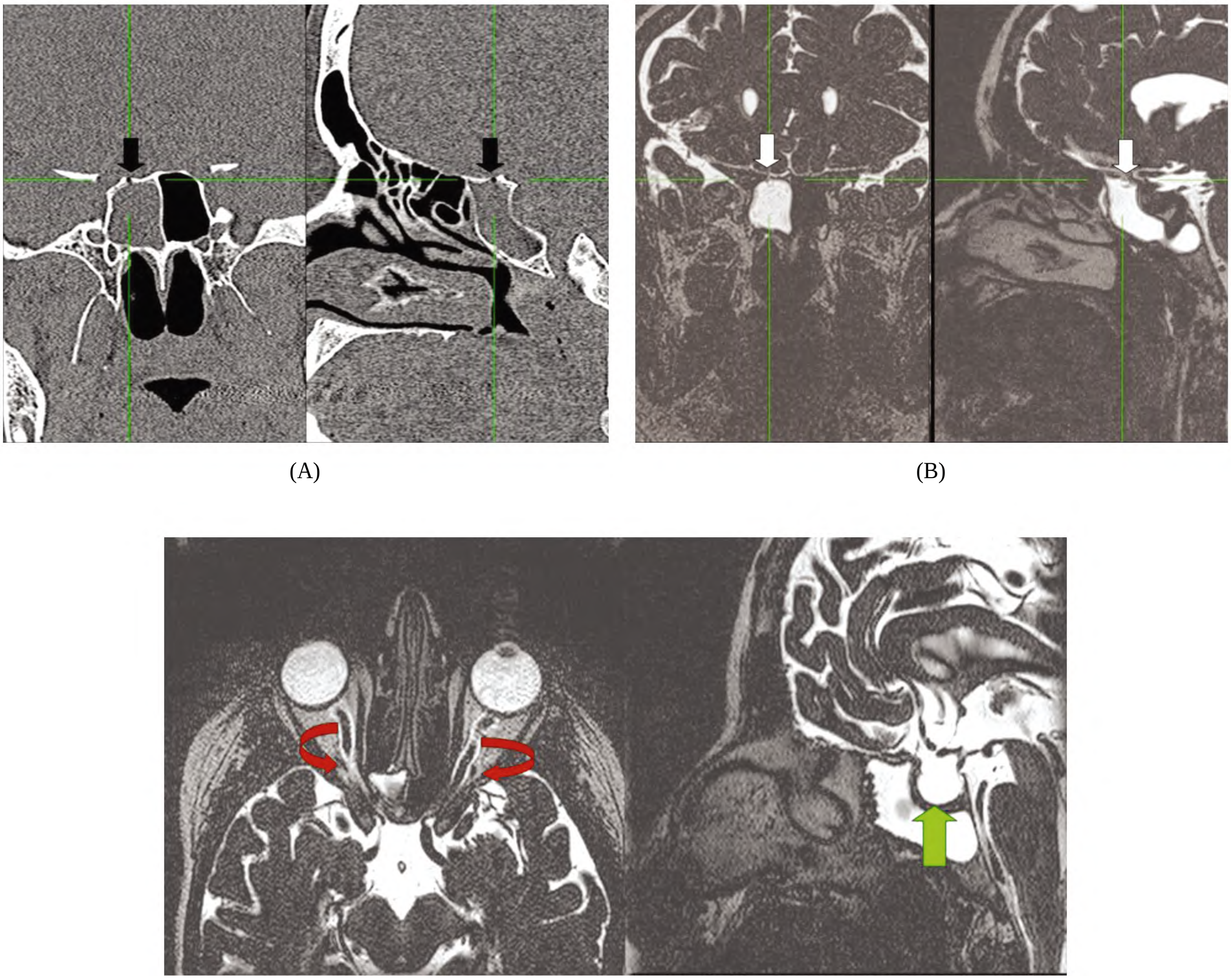


Fig. (1): Causes of CSF Rhinorreha among the studied patients.



(A) (B)

(C)

Fig. (2): A 56 years old female with spontaneous right-sided CSF rhinorrhea. Multiplanner MDCT with coronal and sagittal reconstruction shows tiny 1mm bony defect at the roof of the right sphenoid sinus (Black arrows) (A). 3D MR Cisternography shows the defect with a tiny meningocele (white arrows) and associated filling of the right sphenoid sinus by CSF signal (B). This is associated with idiopathic intra-cranial hypertension; manifested by bilateral optic hydrops (Red arrows) and ballooned empty sella (green arrows) (C).

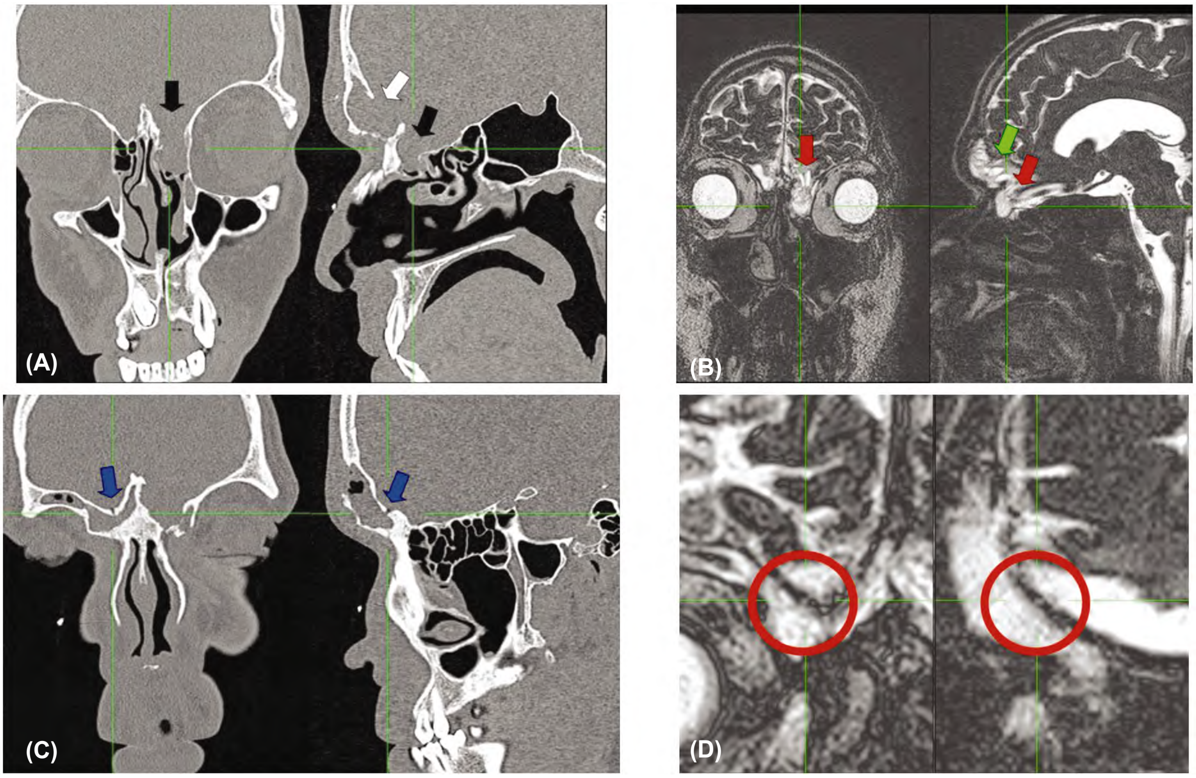


Fig. (3): A 21 years old male with posttraumatic bilateral CSF rhinorrhea. MDCT shows large bony defects at the posterior wall of the right frontal sinus (white arrow) and right ethmoidal roof (Black arrows) (A). 3D MR Cisternography demonstrates the defects with the associated frontal (white arrow) and ethmoidal (Black arrows) cephaloceles; both harboring gliotic frontal gyri (B). A tiny defect seen at the posterior wall right frontal sinus on CT (Blue arrows) (C) and MRI magnified views (Red circles) (D).

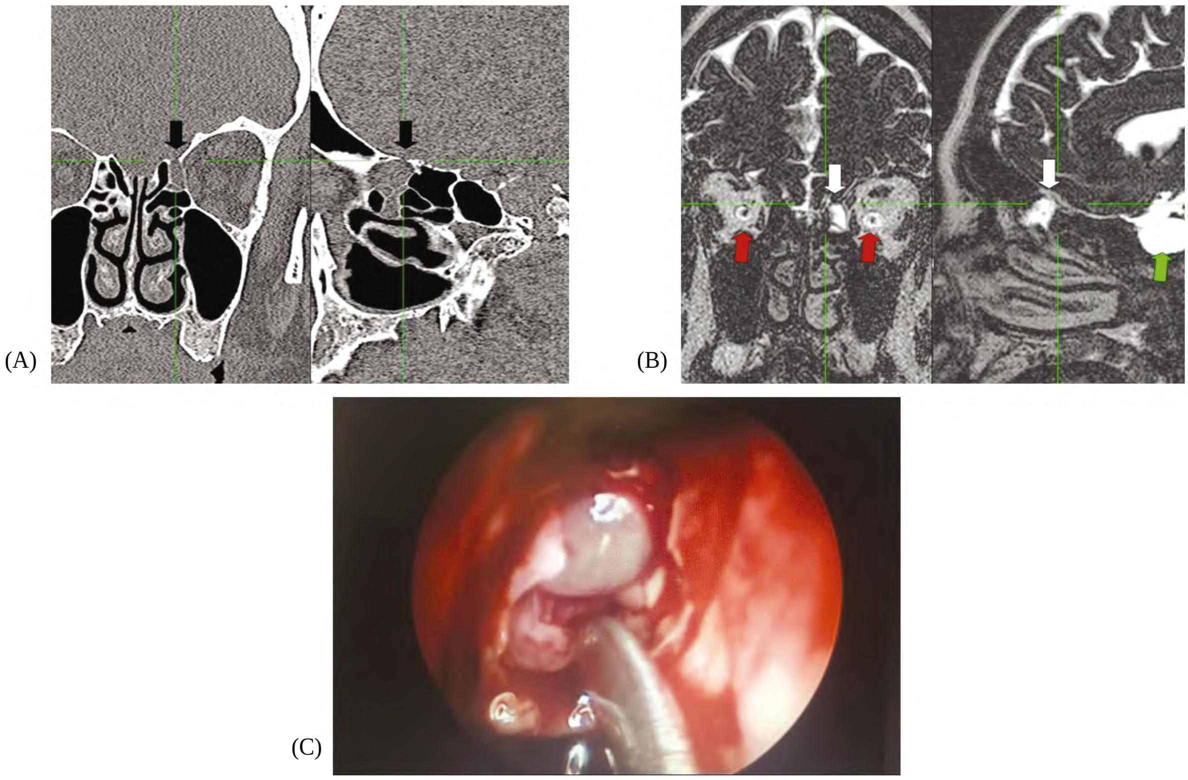
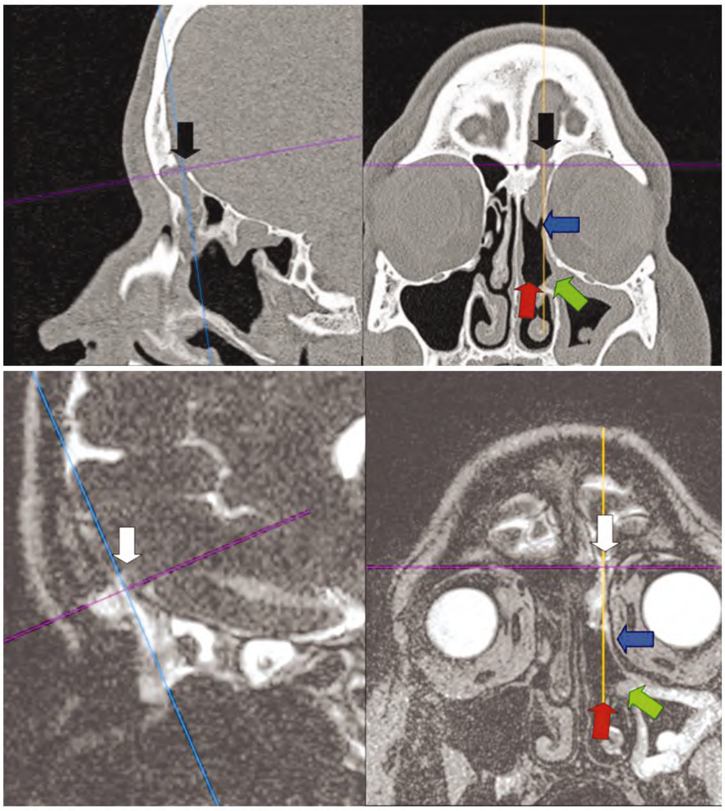


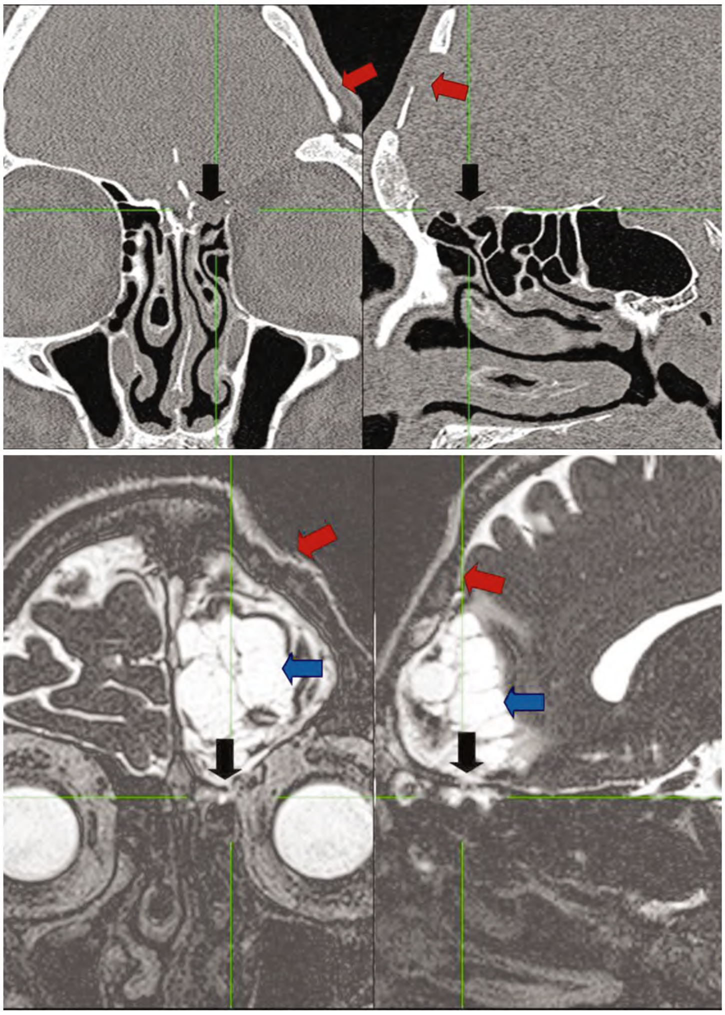
Fig. (4): A 54 years old female with left-sided spontaneous CSF rhinorrhea. MDCT shows a small bony defect at the left fovea ethmoidalis (Black arrows) (A). 3D MR Cisternography demonstrates small meningocele passing through the defect (white arrow) (B). Signs of IIH are noted, with bilateral optic hydrops (Red arrows) and ballooned empty sella (green arrow) (C). Endoscopic view shows the meningocele coming from the ethmoidal roof defect.



(A)

(B)

Fig. (5): A 36 years old female with post FESS left-sided CSF rhinorrhea. MDCT shows a bony defect at the posterior wall of the left frontal sinus (Black arrows) (A). 3D MR Cisternography shows the defect as well as the associated meningiocele passing through the defect (White arrow) (B). Post FESS changes are noted with left turbinectomies (Red arrow), maxillary antrostomy (Green arrow) and ethmoidectomy (Blue arrow) (B).



(A)

(B)

Fig (6): A 49 years old male with history of sinonasal tumor resection and complaining of left-sided CSF rhinorrhea. MDCT shows a bony defect at the left ethmoidal roof (Black arrows) (A). 3D MR Cisternography shows the defect with the associated meningiocele passing through the defect (Black arrows) (B). Left frontal craniotomy (Red arrow); coupled with underlying parenchymal encephalomalacic changes (Blue arrows).

Discussion

CSF rhinorrhea is a serious clinical entity in which a connection between the subarachnoid CSF space and the paranasal sinuses or the nasal cavity occurred with the risk of developing intracranial complications such as meningitis or abscess [25].

In a patient suffering from rhinorrhea, the perfect localization of a CSF fistula offers an easy surgical planning with a successful repair. Various laboratory and imaging approaches have been used for the preoperative detection of the osseodural defect with variable success rates in identifying CSF fistulas [26].

CSF rhinorrhea can have a number of etiological causes. In our study, post-traumatic cause is the most common, followed by spontaneous and iatrogenic types. Jayakumar et al., [27] showed the same finding with the post-traumatic CSF rhinorrhea account for nearly 80% of the cases. Also, Yilmazlar et al., [8] reported 90% of their cases with traumatic etiology.

The prime laboratory screening is the measurement of the β2-transferrin level in the collected fluid sample from the nose. It is a quick test with a sensitivity of 97% [28]. Its main limitation is that rhinorrhea must be active and it is not easy to collect the sample in cases of intermittent rhinorrhea [29].

Many imaging modalities have been used in order to detect the correct site of CSF leakage. High-resolution CT is considered the imaging modality of choice in localizing skull base defects, as it is possible to obtain very thin slices with a bone algorithm. In addition to, the examination takes a brief duration, allowing a perfect study in a supine position with reconstruction [30].

The CT findings in CSF leakage include a skull base bone defect with an air-fluid level or obliteration of the adjoining sinus. In this study, the site of presumed CSF defect was accurately localized by HRCT in 44 out of 47 cases with a sensitivity 94% and specificity 100%. This finding was consistent with Atta et al., [31], that observed the sensitivity of CT in bony defect detection is 95%.

In HRCT, false-positive findings were reported, especially in the entity of pre-existing paranasal sinus inflammation and in multiple osseous defects with opacified adjoining sinuses. In addition, CT may be inadequate in the differentiation of meningocele and/or meningo-encephalocele. In these instances, further evaluation by MRI is necessary. [14].

MR imaging offers a non-invasive technique in CSF leak evaluation. 3D-CISS "MR cisternography" technique, being heavily T2-weighted image with superior CSF-neuroparenchyma-bone discrepancy, is ideally suited to the accurate leak point evaluation than CT [18]. Also, it complements CT in demonstrating the extracranial extension of the CSF fistula, with good identification of the herniated content through the osseous defect that may be difficult to differentiate from inflammatory secretions or nasal tumors on CT, especially in cases with a very narrow defect [19].

The advantages of MRC includes thin slice examination in multiple orthogonal axes with some background suppression, thereby raising the screening accuracy within the entire area of interest. The primary disadvantages are its low spatial resolution compared with HRCTs and insufficient bony details [27].

Our literature reported that superimposing both techniques, HRCT scan and MR cisternography, are successful in the accurate localization of CSF fistula with no need for the previously used invasive techniques such as CT cisternography. Both are non-invasive, standardized, and readily available with a high sensitivity 97% and specificity 100%. This is in agreement with Mohamed et al., [3] who stated that a combined HRCT and 3D T2-weighted MRI allows proper evaluation of CSF leakage with a sensitivity 96%.

On combined HRCT/MRC, 46/47 patients with clinically CSF rhinorrhea were accurately diagnosed as 80.4% had a single osseodural defect with only 6.5% showed multiple bony defects. The ethmoid roof (Fig. 4) is the most common affected bone, notably the cribriform plate. The frontal sinus (Fig. 5) is less affected, followed by the sphenoid sinus. Differentiation of the herniated content was easy to done with 71.7% had meningocele and 21.7% had meningo-encephalocele. This is in accordance with the published literatures [32] that stated the ethmoid bone is likely vulnerable to CSF leak because of maldevelopments, specially the spontaneous type, with CSF dripping through the cribriform foramina.

The current study show almost perfect agreement between the superimposed CT/MR imaging (Fig. 6) and endoscopic transnasal examination with confirmatory diagnosis of our cases. This is quite similar to La Fatta et al., [33] that showed the imaging findings are accurate when compared with the endoscopic sinus interrogation.

Conclusions:

The present clinical study concluded that a combined HRCT/MRC was effective in localizing the precise CSF leak point in a patient with CSF rhinorrhea and should be the diagnostic approach of choice owing to the lack of contrast administration, non-invasiveness, high soft tissue resolution, in addition to, multiplanar image capacity. Thereby, the easy possibility to perform early and less invasive endoscopic surgical repair with minimizing the risk of ascending infection through the leak point.

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التصوير المقطعى عالى الدقة المدمج مع الرنين المغناطيسى للصهريج فى تقييم سيلان السائل الدماغى الشوكى من الأنف

سيلان السائل الدماغى الشو كى من الأنف هو حالة مدمرة يمكن أن تؤدى إلى أمراض ووفيات كبيرة. لذلك، فإن التحديد الدقيق للعيب العظمى مهم للإصلاح الجراحى الفعال. أسلوب التشخيص المعتاد هو التصوير المقطعى المحوسب للصهريج. لكن بسبب المخاطر المرتبطة به ، يجب استخدام طرق التصوير البديلة. يعد التصوير المقطعى عالى الدقة جيداً فى تحديد التفاصيل العظمية، لكن السائل الدماغى الشوكى يتم تصويره بشكل سيء. فى المقابل، يشكف التصوير بالرنين المغناطيسى للصهريج بتقنية ثلاثية الأبعاد أن مسار السائل الدماغى الشوكى كإشارة ساطعة، لكن إكتشاف العيب العظمى ضعيف. للتغلب على عيوب كلتا الطريقتين، قمنا بتركيب الصور التى تم الحصول عليها من كل طريقة مع التخطيط الجراحى المثالى اللاحق.

النتائج: جميع المرضى الخاضعين للدراسة سريرياً يعانون من سيلان الأنف فى السائل النخاعى. من إجمالى ٤٧ حالة تم الكشف عن الخلل العظمى بالتصوير المقطعى عالى الدقة فى ٤٤ حالة مع حساسية ٩٤٪. التصوير بالرنين المغناطيسى، يحدد تدفق السائل الدماغى النخاعى والتى يمكن تتبعها داخل الجمجمة. دمج التصوير المقطعى والتصوير بالرنين المغناطيسى يحدد بشكل صحيح موقع تسرب السائل الدماغى فى ٤٦ حالة من أصل ٤٧ حالة مع حساسية عالية ٩٧٪، وهو ما أكده فحص الجيوب الأنفية بالمنظار. كان الموقع الأكثر شيوعاً للعيب العظمى هو السقف الغربالى، يليه الجيوب الأنفية الأمامية وأخيراً الجيب الوتدى. يرتبط هذا بالقيلة السحائية فى ٣٣ حالة من أصل ٤٦ (٧١.٧٪) والقيلة الدماغية السحائية فى ١٠ حالة من أصل ٤٦ (٢١.٧٪).

الاستنتاجات: الدمج بين التصوير المقطعى عالى الدقة والرنين المغناطيسى للصهريج هو أسلوب تشخيص غير جراحى ويجب أن يكون النهج المفضل لتحديد موقع تسرب السائل النخاعى قبل الإصلاح الجراحى.