Evaluation of the role of high-resolution CT and MR cisternography in preoperative identification of skull base defect in cases of CSF rhinorrhea

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Abstract

Background: Preoperative identification of the site of CSF fistula and skull base defect accurately enhances the chance of successful surgical repair. High-resolution CT (HRCT) is highly effective in demonstration of the bony defect at the site of the leak. MR Cisternography can detect a CSF fistula by the bright signal of CSF on T2-weighted images.

Objectives: To determine the accuracy of combined HRCT and MR Cisternography in preoperative identification of skull base defect in patients with CSF rhinorrhea.

Methods: Ninety three patients were subjected to combined non-contrast HRCT of the nose and paranasal sinuses and MR Cisternography to identify the site of the leak.

Results: In all the patients, combined HRCT and MR Cisternography can detect skull base defects with a sensitivity of 96% and specificity of 90%.

Conclusion: HRCT combined with MR Cisternography are accurate and non-invasive methods for localization of the skull base defect.

Keywords: CSF Rhinorrhea, CT Cisternography, MR Cisternography, meningoceles, β transferrin

Introduction

Cerebrospinal fluid (CSF) leak or fistula describes the egress of CSF from the intracranial cavity through an osseous defect within the skull base. It implies a breach or disruption of the underlying dura mater and adherent pia-arachnoid mater, resulting in a communication between the intracranial cavity and either the nasal or middle ear cavity. The condition was first described as a pathologic entity in 1899 by Clair Thompson. Over the subsequent decades, the clinical importance of a CSF leak was recognized, demonstrating affected patients to be at risk of developing intra-cranial complications.

CSF leaks have been classified as to the aetiology and presentation by Ommaya in 1960 into two categories: traumatic and non-traumatic. A third category, spontaneous, which describes patients with no history of trauma or other predisposing aetiology.

Posttraumatic CSF leaks account for nearly 90% of all cases, with approximately 80% manifesting as rhinorrhea and 20% as otorrhea. CSF leaks second to skull base fracture complicate about 1%–3% of all closed head injuries. Also, included in this category the iatrogenic CSF leaks, which are caused frequently by otolaryngology or neurosurgical procedures. Nontraumatic CSF leaks can occur in both normal and elevated intracranial pressure states. This includes tumours, infection, or congenital lesions.

Finally, spontaneous, or primary, CSF fistula is considered a separate entity describing patients with no other discernible aetiology for their CSF leak. Demographically, these leaks most frequently occur in obese middle-aged women and co-exist with a small encephalocele.

Successful surgical repair of cerebrospinal fluid (CSF) leaks depends on accurate preoperative localization of the site of the defect. Several diagnostic techniques advocated for such localization can be notoriously difficult to perform. High-resolution computed tomography (HRCT) provides thin overlapping cuts in both the axial and coronal planes and enables good definition of bony structures. On plain CT scans, a CSF leak may appear as an opacification of a sinus, but this may be CSF, a mucosal reaction, a meningocele, or percolated CSF from a distal breach.

For many years CT cisternography has been considered to be the gold standard for detecting CSF leaks. Its detection rate ranges between 40 and 92%, and the leak must be active. This modality is therefore unsuitable for patients with intermittent leaks. Furthermore, it is contraindicated in patients with high intracranial pressure and in those with spinal disorders. Its acceptability is low and accurate results are highly operator dependent.
Magnetic resonance imaging (MRI) cisternography depends on heavily T2-weighted sequences with fat suppression. CSF appears as a bright signal without the need to inject contrast media intrathecally. Furthermore, MRI details the intracranial anatomy and pathology in multiple planes within a relatively short time. The main disadvantage of MRI is its poor spatial resolution and lack of bony details. Thus, CT and MRI seem to be complementary in the diagnosis of CSF leaks.

This study was therefore conducted to determine the reliability and accuracy of combining HRCT and MR Cisternography to identify the site of CSF leakage without the need for CT cisternography.

Material and Methods

Ninety-three patients were included in this study after approval by the Ethical Review Board (ERB) of Alexandria University, Egypt. The patients have been proven to have CSF rhinorrhea based upon the laboratory and radiological findings. All suspected fluid was collected from the patients and tested for beta2-transferrin and beta trace protein for verification of CSF leak, which was positive in all cases. Radiological investigation was performed in the form of HRCT and MR Cisternography to identify the site of the leak.

Imaging: The study included combined evaluation by HRCT and 3D T2 weighted MR Cisternography to identify the site of the leak.

High resolution CT (HRCT): Non contrast HRCT involves rapid, continuous volumetric acquisition of raw data by using Toshiba Aquilion 16 slices, thin collimation (16x1 mm), allowing for isotropic voxels, which leads to improved resolution for three-dimensional and multiplanar reformations. Thus, with HRCT, images can be acquired in only the axial plane, and then the raw data can be reformatted into additional planes without a compromise in image resolution.

MRI examination: MR Cisternography typically involves heavily T2-weighted fast spin echo sequences with fat suppression and subtraction of the adjacent background tissue signal to enhance conspicuity of the fistulous tract, or CSF column. The fast spin echo sequences have decreased susceptibility artefacts at the air-bone interface of the skull base, compared with conventional T2-weighted imaging. Overlapping heavily T2-weighted fast spin-echo sequences with fat suppression are then performed at (TR = 1200 msec) (TE= 263 msec) (Average 1.6) (Slice= 0.6 mm) (FOV = 20cm). The proponents of MR Cisternography state that the non-invasive and non-ionizing technique can localize the actual site of a fistulous tract, which may be particularly helpful in patients who have multiple potential fracture sites or osseous defects at CT. Statistical analysis was carried out using the Statistical Package for the Social Science computer software version 11 for windows (SPPSInc, Chicago, Illions, USA).

Results:

The study included 93 patients. Seventy-two patients were females and the remaining 21 patients were males. Their age range from 18 to 70 years (Table 1).

<table>
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<th>Age</th>
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Table 1: Age, Sex, Site and number of defects and aetiology of the CSF leak among the studied group.

According to the aetiology of CSF rhinorrhea, 60 cases had idiopathic CSF leak with a skull base defect (Figure 1, 2 A, B & C). Eighteen patients had a post-traumatic or post-operative aetiology. Nine patients of them showed a mening-encephalocele on MRI. Fourteen patients were confirmed clinically to have idiopathic intracranial hypertension (IIH) with bilateral optic hydrops (Figure 2 D). One patient was diagnosed with schwannoma of the trigeminal nerve, which eroded the posterolateral wall of the sphenoid sinus (Figure 3).
Figure 2: 42 years old female presented with left sided rhinorrhea. (A&B). HRCT revealed two skull base defects located at the lateral recess of the left sphenoid sinus and dorsum sellae. C. 3D T2 MR Cisternography revealed filling of the left sphenoid sinus by CSF intensity fluid continuous with the subarachnoid space through the described defect. D. Optic hydrops also noted “features of idiopathic intracranial hypertension”.

In the 93 patients, the site of the leak could be easily detected by the combined HRCT and MR Cisternography. The bony defect was easily visible on HRCT. But, in cases with multiple traumatic skull base defects, MRI helped to identify the leaking site by showing CSF signal intensity through the defect. Therefore, if the defect is visible on HRCT, MR Cisternography did not add to the diagnosis for localization of the defect.

Surgical repair of the skull base defect was carried on in all cases of the studied group except for 6 cases with benign increase of the intracranial tension they respond to medical treatment without the need for surgical intervention. During the operative procedure, the site of the CSF leak coincided with the preoperative radiological protocol.

The combined HRCT and 3D T2 weighted MR Cisternography images after statistical analysis had a sensitivity of 96% and specificity of 90% in detection of skull base defects. The positive predictive value was 90% and the negative predictive value was 96%.

Figure 3: A. Axial high resolution CT shows a bony defect in the posterior wall of the right sphenoid sinus. B. Axial T2W MRI shows a large space occupying hyperintense lesion occupying the left cerebellopontine angle and cavernous sinus (Trigeminal Schwannoma).

Figure 4: 18 year old male, presented with right sided CSF rhinorrhea.(A and B) HRCT revealed large ethmoidal roof defect with polypoid opacity filling the ethmoidal and nasal cavity. MRI (C &D) was performed to verify the nature of the opacity and revealed large meningoencephalocele with gliotic gyrus rectus.

Figure 5: The suggested radiological algorithm for cases presented with CSF rhinorrhea:

In our study the combined HRCT and 3D T2-weighted MR Cisternography detected bone defect in 96% of the cases. CT cisternography is only needed in equivocal cases. From our current study we suggest the following algorithm for localization of the site of the defect:

When the β2-transferrin test is positive and HRCT scan shows a single osseous defect, no other imaging is necessary to direct the repair. This is the most common scenario. If the β2-transferrin test is positive and the HRCT scan shows more than one osseous defect, an opacified sinus, or suspected cephaloceles or meningoceles; MRI should be obtained to determine site of leaking and nature of the pathology.

If MRI & HRCT are non-conclusive, further CT cisternography is performed.
Discussion

CSF rhinorrhea results from a communication between the subarachnoid space and the nasal cavity. Accurate localization of the site of the CSF fistula is challenging for neuro-radiologists as well as for surgeons. Precise identification of a CSF fistula helps in surgical planning and enhances the chances of a successful repair. Several laboratory and radiological methods have been used for the preoperative identification and localization of the defect. These methods have been associated with various rates of success.

Nowadays, HRCT is the best imaging study for localizing skull base defects and CSF leaks, as it is possible to obtain very thin slices (0.5 mm) with a bone algorithm. The examination is very short to the patients. It allows for a complete study in the axial, coronal, and sagittal planes in a supine position with reconstruction. In some cases, the coronal section has to be perpendicular to the hard palate to show the entire temporal bone and exclude a defect in the tegmen tympani or roof of the mastoid when CSF flow from the middle ear or the mastoid through the Eustachian tube could simulate rhinorrhea. Furthermore, CT data can provide intra-operative image guidance for the endoscopic surgical repair. The findings suggestive of a CSF leak include a skull base bone defect and an air-fluid level or opacification of the contiguous sinus. CT is helpful in evaluation of non-traumatic causes of CSF leak, such as an intracraniial or skull base tumour or meningocele and/or meningo-encephalocele, which may then require further evaluation with MR imaging. Occasionally, CT may be inadequate because of a small defect that can be missed through the partial volume effect, leading to both false-negative and false-positive findings. Inaccuracies can be minimized by using the thinnest sections possible but at the expense of a significantly higher radiation dose to the eye.

Detection of a small skull base defect on CT is not necessarily related to a connection between the nasal cavity and the intracranial compartment. In HRCT, the diagnostic criteria are not specific if pre-existing paranasal sinus inflammation has been reported or multiple osseous defects and adjacent opacified sinuses especially in the posttraumatic patient that may lead to false-positive diagnosis. In this instance, further imaging and evaluation may be necessary to localize the site of the leak and nature of the pathology with CT and MRI.

CT cisternography examination reserved for patients with multiple skull base fractures and/or defects, patients with negative CT scans, or those in whom the diagnosis is a question. This technique traditionally involves obtaining thin-section coronal and axial CT images in prone position through the region of interest (maxillofacial and temporal region) both before and after intrathecal contrast material. Approximately 3–10 mL of an iodinated nonionic low-osmolar contrast agent is administered by means of a lumbar puncture and the patient is placed in a Trendelenburg position to opacify the basal cisterns, followed by CT imaging. Maneuvers that provoke an active leak, such as sneezing or head hanging, are performed prior to the CT portion of cisternography. Post-contrast images are then compared with the pre-contrast images. A positive result involves the presence of a skull base defect and contrast opacification within the sinus or nasal cavity. If the sinus contents do not visually show an attenuation increase after cisternography, objective attenuation measurements is used in Hounsefield Units (HU) may be used. Increase in HU of 50% or greater after CT cisternography inside the nose or paranasal sinuses is considered a positive study for a CSF leak.

CT cisternography is only possible during active leak. It was considered the standard of reference for the diagnosis of CSF fistula. However, the technique is an invasive procedure, its acceptance by patients is low, adds to the expense and contains small morbidity rates, inherent risks of infection and lumbar CSF leak. The specificity and sensitivity of CT cisternography vary between 40 - 91%. In difficult cases, acquisition of CT images through the defect after intrathecal contrast administration may determine soft tissue continuity with the subarachnoid space. Contrast agents used are iohexol and iopamidol with low-osmolarity, which have a very low incidence of the major side effects (headache, meningeal irritation and seizures), compared with metrizamide which was routinely guidance for the endoscopic surgical repair. However, this procedure doubles the radiation exposure. Another non radiological invasive method is the intrathecal fluorescein, which is most commonly used as an adjunct to intraoperative localization of a skull based defect and the site of the leak.

MRI techniques offer non-invasive methods of imaging a CSF leak and are indicated to assess the possibility of an encephalocele or meningo-encephalocele through a bone defect that may be difficult to differentiate from obstructed secretions on CT. MRI with high resolution, 3-mm, axial, coronal, and sagittal in T1- and T2-weighted sequences is mandatory to formulate a differential diagnosis in cases with active CSF leak. It is always performed if there is an osseous defect and complete opacification of an adjacent sinus in the patient with a possible CSF leak, which is more sensitive than CT in detecting continuity between the nasal and cranial cavities. Demonstration of high signal intensity fluid extending from the subarachnoid space directly into adjacent paranasal sinuses or herniation of brain into a sinus through a bone defect, have been the principal diagnostic criteria. When there is a lesion with a very narrow neck, the examination is valuable in differentiating herniated brain from inflammatory nasal masses, nasal gliomas, or nasal dermal sinus cysts and to identify the contents of the herniated mass. MRI without contrast medium has been used by many authors for investigation of CSF fistulae.
Shetty et al, 1998, claimed an accuracy of 89%, but Hegarty et al, 1997, reported a relatively high (40%) false-positive rate. The presence of inflammatory soft tissue in the paranasal sinuses increases the rate of false-positive studies and false negatives were reported.

MR cisternography is a non-invasive technique demonstrating CSF-like signal in multiple planes without the disadvantage of ionizing radiation. Its accuracy in patients with active CSF rhinorrhea is 86%. The primary disadvantages of MRI are its poor spatial resolution compared with HRCTs and the absence of bony details.

In this study we combined both techniques of HRCT scans and MR Cisternography (3D T2-weighted MRI techniques). Both are standardized, non-invasive and readily available. Also, we believe that fat suppression increases the conspicuity of contrast medium leakage due to the saturation of medullary bone fat in the skull base increases the conspicuity of contrast medium leakage due to the saturation of medullary bone fat in the skull base.

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References