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Diagnostic Accuracy of Combined High-Resolution Computed Tomography and MR Cisternography in Evaluation of CSF Rhinorrhea Patients, Taking Surgical Findings As Gold Standard

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Author`s Contribution

[1,3]Substantial contributions to the conception or design of the work; or the acquisition, Critical review [2,6]Active participation in active methodology, [4]analysis, or interpretation of data for the work, [2,5]Drafting the work or revising it critically for important intellectual content

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ABSTRACT

Objective: To determine the diagnostic accuracy of combined high-resolution computed tomography and MR Cisternography in evaluation of CSF rhinorrhea patients, taking surgical findings as gold standard.

Methodology: The Observational Cross-sectional study was conducted at Benazir Bhutto and Holy Family Hospital, Rawalpindi from 1 June 2022 to 1 May 2023. All patients having CSF rhinorrhea (discharge of cerebrospinal fluid (CSF) from the nose) of >1-month duration was enrolled and underwent HRCT/MR cisternography subsequently followed by surgery and results of both modalities were compared.

Results: Out of a total of 156 patients enrolled, 136 (87.1%) were males and 20 (12.8%) females. The results of this study yielded a sensitivity of 93.3%, specificity of 61.9%, positive predictive value of 94% and a negative predictive value of 59%. The overall accuracy of combined HRCT/MR Cisternography for the diagnosis of CSF rhinorrhea was found to be 89.1% in comparison to surgery.

Conclusion: The use of Combined HRCT/MR cisternography for the diagnosis of CSF rhinorrhea is a feasible, safer and highly accurate modality for correctly identifying such cases and circumvents the limitations imposed by the use of any single modality in these patients.

Keywords: Cerebrospinal fluid (CSF) rhinorrhea, Imaging, HRCT, MRI

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Introduction

Cerebrospinal fluid (CSF) rhinorrhea ensues from a direct communication between the subarachnoid space and either the nasal cavity or the mucosa-lined space of the paranasal sinuses. This condition is precipitated by various factors, including osseous defects, disruption of the arachnoid and dura mater, and a CSF pressure gradient surpassing the healing tensile strength of the compromised tissue, resulting in the separation of dural fibers and subsequent leakage of CSF.[1, 2, 3] The ramifications of CSF fistulas are manifold, encompassing the facilitation of pathogenic dissemination leading to meningitis, as well as serving as a conduit for the development of pneumocephalus and secondary brain compression.[1,2,3]

Recognizing cerebrospinal fluid (CSF) leakage holds significance in the context of neurosurgery, potentially mitigating complications and enhancing surgical outcomes.[4] The efficacy of surgical interventions aimed at repairing CSF leaks crucially hinges upon precise preoperative localization of the site of the defect. Various diagnostic modalities proposed for such localization are often fraught with inherent challenges.[5, 6, 7] High-resolution computed tomography (HRCT) stands out as a promising tool, offering thin overlapping sections in both axial and coronal planes, thereby facilitating comprehensive delineation of osseous structures. Notably, conventional CT scans may present a CSF leak as sinus opacification; however, this imaging manifestation can be confounded by factors such as mucosal reactions, meningoceles, or percolated CSF resulting from distal breaches.[8,9]

Magnetic resonance imaging (MRI) cisternography relies on T2-weighted sequences with fat suppression for optimal visualization. Cerebrospinal fluid (CSF) manifests as a hyperintense signal, obviating the necessity for intrathecal contrast media administration. Additionally, MRI facilitates comprehensive delineation of intracranial anatomy and pathology across various planes, expediting diagnostic evaluation. However, MRI's limitations include suboptimal spatial resolution and inadequate depiction of bony structures.[11] Thus, CT and MRI seem to be complementary in the diagnosis of CSF leaks.[12] In a study, idiopathic CSF rhinorrhea was found to be 64.52% and the combined HRCT and MR Cisternography images had a sensitivity of 96% and specificity of 90% in detection of skull base defects in CSF rhinorrhea patients.[13]

This study aimed to integrate two imaging modalities, namely High-Resolution Computed Tomography (HRCT) scans and Magnetic Resonance Cisternography (3D T2-weighted MRI techniques), both of which are standardized, non-invasive, and readily accessible. Additionally, it was assumed that employing fat suppression would enhance the detection of contrast medium leakage by mitigating interference from medullary bone fat saturation in the skull base and nasal cavity, thereby minimizing potential confusion with leakage. Intraoperatively, alignment between the site of cerebrospinal fluid (CSF) leak and the preoperative radiological protocol was observed during repair of the skull base defect, underscoring the reliability of these imaging modalities for localizing the site of the leak within our academic milieu.

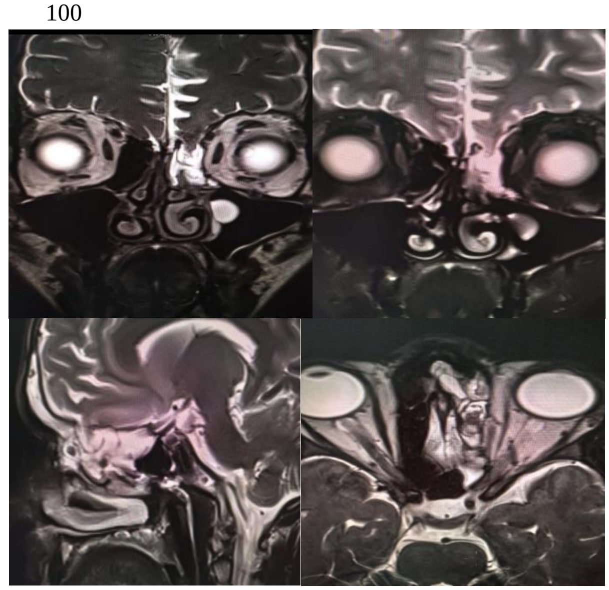
Methodology

This was a cross sectional validation study conducted in Department of Medical Imaging RMC and Allied Hospitals, Rawalpindi, in collaboration with Surgical department of the same hospital from 1 June 2022 to 1 May 2023**.** Sample size of 156 cases has been calculated with 95% confidence level, prevalence of idiopathic CSF rhinorrhoea as 64.52%[7], 4% desired precision for sensitivity of 96.0% and 8% desired precision for specificity of 90.0% of combined high-resolution computed tomography and MR Cisternography in evaluation of CSF rhinorrhoea patients.[7] Non-probability Consecutive sampling technique was used. All patients 25-70 years of either gender having CSF rhinorrhea (all patients with discharge of cerebrospinal fluid (CSF) from the nose) of >1-month duration was included. Patients with skull base congenital defects and Rathke's cleft cyst (assessed on medical record), meningoceles or meningoencephaloceles (assessed on clinical examination) and h/o of previous surgery and radiotherapy for pituitary adenoma (assessed on medical record) were excluded.

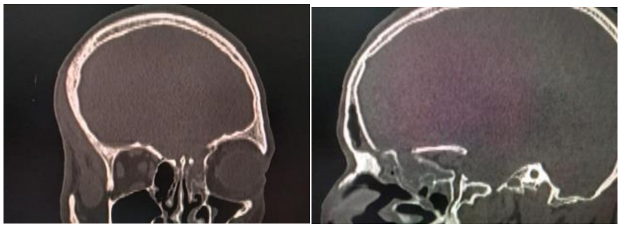
Following approval from the ethical committee of Rawalpindi Medical College and Allied Hospitals, 156 patients meeting the inclusion criteria were recruited for the study. Informed consent was obtained from all participants, and the procedures were thoroughly explained to each individual. The non-contrast high-resolution computed tomography (HRCT) technique entailed swift and continuous volumetric data acquisition utilizing the Toshiba Aquilion 16-slice scanner with thin collimation (16x1 mm), thereby enabling isotropic voxel formation. This approach enhances resolution for three-dimensional reconstructions and multiplanar reformations. Subsequently, strongly T2-weighted rapid spin echo sequences were used for MR sternography, together with fat suppression and background tissue signal reduction to improve the visibility of the fistulous tract, or CSF column. When compared to traditional T2-weighted imaging, the fast spin echo sequences reduced susceptibility artifacts at the air-bone contact of the skull base. Then, at (TR = 1200 msec) (TE = 263 msec) (Average 1.6) (Slice = 0.6mm) (FOV = 20cm), overlapped strongly T2-weighted rapid spin-echo sequences with fat suppression were carried out.

The HRCT and MR Cisternography findings were interpreted by one consultant radiologist and presence or absence of skull base defect noted. All the patients underwent surgery in the concerned ward and presence or absence of skull base defect was noted. HRCT and MR Cisternography findings were compared with surgical findings. This all data (age, gender, duration of CSF rhinorrhea, skull base defect on HRCT and MR Cisternography and surgery) was recorded on a specially designed proforma. Collected data was analysed through computer software SPSS 22.0. 2×2 contingency table was used to calculate the sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of combined high-resolution computed tomography and MR Cisternography in evaluation of CSF rhinorrhoea patients, taking surgical findings as gold standard. The formulas that were used for calculation are as follows:

1. Sensitivity = $\frac{TruePositive}{TruePositives+FalseNegatives}$ x 100
2. Specificity = $\frac{TrueNegative}{TrueNegatives+FalsePositives}$ x 100
3. Positive Predictive Value = $\frac{TruePositive}{TruePositives+FalsePositives}$ x 100
4. Negative Predictive Value = $\frac{TrueNegative}{FalseNegatives+TrueNegatives}$ x 100
5. Accuracy = $\frac{TruePositives+TrueNegatives}{TruePositives+TrueNegatives+FalsePositives+FalseNegatives}$ x 100



Coronal, axial and sagittal MR images showing defect in left skull base with fluid Opacification of left ethmoid air cells



CT bone window demonstrating the bone defect in a left cribriform plate defect, near the fovea ethmoidal is with fluid Opacification of the left sided ethmoid sinus.

Results

A total 156 patients of either gender with age between 25-70 years who had CSF rhinorrhea (discharge of cerebrospinal fluid (CSF) from the nose) of >1-month duration were enrolled in the study. Patients with history of skull base congenital defects and Rathke's cleft cyst, patients with meningoceles or meningoencephaloceles patients with h/o of previous surgery and radiotherapy for pituitary adenoma were excluded from the study. Informed consent was taken from each patient. Results of HRCT and MR cisternography were compared with per-operative findings. 136 (87.1%) patients were males with the mean age of 38.6 years ± 8.2 SD and 20 (12.8%) were females with mean age of 37.1 years ± 8.7 SD. Cumulative mean age was 38.0 years ± 8.4 SD. There were 110 (70.5%) of patients who were between age 18-40 years and 46 (29.5%) were greater than 40 years of age.

HRCT/MR Cisternography revealed that among the subjects assessed, 101 patients (64.7%) tested positive on HRCT, while 126 patients (80.7%) tested positive on MR Cisternography. Conversely, 301 patients (9.23%) were identified as negative according to the operational parameters outlined in Table III. Surgical examination subsequently identified 135 patients (86.5%) as positive and 21 patients (13.4%) as negative, adhering to the criteria delineated within our operational framework.

Analysis of these findings involved the construction of 2 x 2 contingency tables, which facilitated the enumeration of subjects meeting various criteria: those positively identified through combined HRCT/MR cisternography and confirmed as such during surgery (true positives); those testing positive via HRCT/MR Cisternography but demonstrating negativity during surgery (false positives); those testing negative via HRCT/MR Cisternography but found to be positive during surgery (false negatives); and those testing negative via HRCT/MR Cisternography and confirmed as such during surgery (true negatives). This tabular representation afforded a comprehensive overview of true and false positives, as well as true and false negatives.

Table I: HRCT/MR Cisternography frequency and percent results.

	N	%
POSITIVE	126	80.7
NEGATIVE	30	19.23
TOTAL	156	100.0

Our study findings indicated that within the overall study cohort, 80.7% (n=126) were true positives, 0.08% (n=13) were true negatives, 0.05% (n=9) were false positives, and 0.05% (n=9) were false negatives.

Table II: Frequency and percent in Surgical operation results.

	N	%
POSITIVE	135	86.5
NEGATIVE	21	13.4
TOTAL	156	100.0

Table III: Cross-tabulation of HRCT/MR Cisternography and surgical results.

HRCT/MR Cisternography	**Surgical Findings**		
	POSITIVE	**NEGATIVE**	**Total**
Positive	126 True Positives	8 False Positives	134
Negative	9 False Negatives	13 True Negatives	22
Total	135	21	156

Sensitivity (using equation 1): 93.3%,
Specificity (using equation 2): 61.9%
Positive Predictive Value (using equation 3): 94%
Negative Predictive Value (using equation 4): 59%
Over all Accuracy (using equation 5): 89.1%

Discussion

CSF rhinorrhea is defined as flow of CSF in to the nasal cavity and nasal sinuses from brain via defect in cribriform plate and a tear in underlying dura. This can be secondary to fracture / trauma. CSF rhinorrhea is a potentially life threatening condition and has excellent survival outcomes if it is managed appropriately. The accurate diagnosis by radiologists describing the exact point of defect in bony skull plays the key role in successful surgery and repair of the defect hence facilitating successful surgical outcome.

Hence the accurate preoperative localization of the presence and site of leakage in order not to miss any such leakages and prevent unnecessary surgical complications is mandatory.

The diagnostic method known as computed tomography (CT) cisternography is traditional. Different options have been proposed, nevertheless, because of the hazards associated with radiation exposure and patient rejection. Fluid detection is not as good with 1- to 2-mm thick coronal HRCTs using a bone algorithm (HRCT), but bony details are well-preserved.

In contrast, T2-weighted magnetic resonance imaging (MRI) shows CSF as a bright signal, but its use is limited by a poor spatial resolution to localize exact location in relation to bony landmarks.[14,15] To overcome these shortcomings, we aimed to superimpose the images obtained from both modalities and used the result to plan surgical explorations where indicated.

The results of this study yielded a sensitivity of 93.3%, specificity of 61.9%, positive predictive value of 94% and a negative predictive value of 59%. The overall accuracy of combined HRCT/MR Cisternography for the diagnosis of CSF rhinorrhea was found to be 89.1% in comparison to surgery.

One such study previously published in literature yielded a comparative sensitivity of 89.74% but the actual site of leakage was incorrectly identified in two (10%) patients.[16] Other values were not computed. Another similarly aimed study found the sensitivity of HRCT and Contrast enhanced MR as 88% and 100% respectively.[17,18,19] Individual values for each modality were not calculated in our study, as it aimed to delineate the advantage of combination of two modalities over the use of any single one for diagnosis of CSF rhinorrhea.

HRCT scan of the skull base and MRI complement each other in evaluation of CSF rhinorrhea as HRCT is the modality of choice for depicting the bone defects; whereas evaluation of the soft tissues is best analyzed by MRI. [20]

Also these two are non invasive and are generally present under single roof in radiology departments so these two combined with each other can be safely used as primary method of diagnosis for early and exact diagnosis of the CSF rhinorrhea in order to get correct surgical planning.[21,22] These modalities can also be used to asses post operative outcomes and to follow the patients which are managed conservatively by neurosurgeons.

Conclusion

The use of Combined HRCT/MR cisternography for the diagnosis of CSF rhinorrhea is a feasible, safer and highly accurate modality for correctly identifying such cases and circumvents the limitations imposed by the use of any single modality in these patients. Its use may thus be inculcated into clinical practice thereby eliminating unnecessary invasive.

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