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DIAGNOSTIC ACCURACY OF PLAIN BRAIN COMPUTED TOMOGRAPHY WITH CONTRAST ENHANCED IN THE DIAGNOSIS OF MENINGITIS

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Abstract

Introduction: This study aims to evaluate the diagnostic accuracy of plain brain CT scans compared to contrast-enhanced CT scans for identifying meningitis. It focuses on determining the effectiveness of both imaging techniques in detecting the condition. The comparison will provide insights into which method is more reliable for diagnosing meningitis.

Objective: To find the diagnostic accuracy of plain brain computed tomography with contrast enhanced in the diagnosis of meningitis.

Materials and Methods: A cross-sectional study was carried out at Hamid Latif and Shalamar Hospital in Lahore, involving 42 participants selected through a suitable sampling method. Data analysis was performed using MEDCALC software. The inclusion criteria included patients with clinical suspicion of meningitis, symptom onset within the previous 72 hours, and symptoms such as fever, headache, neck stiffness, or altered mental state. The exclusion criteria comprised patients with symptoms lasting over 72 hours, those with open cranial malformations, patients.

Results: Among the 42 patients included in the study, the average age was 1.2 years. The findings indicated that contrast-enhanced CT provided greater diagnostic accuracy. Of the 42 patients, 32 were diagnosed with meningitis, while 10 did not have the condition. Analysis of CSF variables as a diagnostic classifier suggested limited capability in differentiating positive and negative infarction cases, good capability for identifying positive and negative cases of ventriculomegaly, and limited effectiveness in detecting midline shift, meningeal enhancement, and edema.

Keywords Meningitis, Computed tomography, Contrast Enhanced Computed Tomography

Introduction

Meningitis, which is caused by the inflammation of the meninges, subarachnoid space, and brain parenchyma, can result in critical outcomes that include the occurrence of seizures, elevated intracranial pressure, altered levels of consciousness, and stroke. The epidemiology of meningitis is region specific with low and middle-income countries suffering a higher burden than developed economies. The disease is usually initiated when the pathogen(s) manage(s) to cross into the central nervous system (CNS) through the bloodstream (hematogenous spread) or continuous extension with other infections, such as sinusitis or mastoiditis. This invasion results in inflammation and lysis of bacteria in the sub arachnoid space that triggers an immune response.

The causative bacterial organisms that are commonly associated with the disease, include *Streptococcus pneumoniae*, *Neisseria meningitidis*, *Haemophilus influenzae*, *Streptococcus agalactiae* (group B *Streptococcus*), *Escherichia coli*, and *Listeria monocytogenes*. Clinically, the patients can present with fever, headaches, neck stiffness, changes in behavior, generalised weakness, vomiting, vertigo, and photophobia, and in some cases purpuric rashes. Neurological manifestations can affect almost up to 50% of the survivors and can lead to hearing impairment, failure to thrive, and deficit in neurocognition. Other severe forms of disabilities like organ damage along with brain damage and deafness can also be present.

Diagnosis is the first step that must be performed in a very rapid and precise manner in order to offer an appropriate treatment. But meningitis can't be confirmed only on the basis of clinical symptoms, which are quite uncommon in other conditions as well. Therefore, it has been established that analysis of the cerebrospinal fluid (CSF), and particularly its culture, remains the measure of last resort for diagnosis. Various imaging techniques like CT and MRI are of complementary value in the assessment of meningitis itself and its secondary features. In CT scans, pial enhancement, hydrocephalus, and even cerebral edema are taken into the account, although it is generally accepted that MRI is more sensitive in the diagnosis of cerebral infection and its complications, hence, considered dominantly effective.

Meningeal enhancement on CE-MRI can be confidently stated to be superior to CT in terms of evaluating and diagnosing meningeal inflammation or other conditions that may pose a threat. In the assessment of a CT picture, either plain or enhanced CT images, it is still pertinent for the assessment of the abnormalities in the structures of the brain, which include the presence of edema and hydrocephalus. However, though services of plain CT scans are used to evaluate the possible cause of concern in the brain, contrast enhanced CT scan makes a more accurate evaluation concerning the possibilities of the presence of meningitis infection.

Even though it is important, it is not necessary to routinely perform CT scans on all patients with a diagnosis of meningitis made by CSF because it is expensive and patients are exposed to radiation risks. However, CT scans help demonstrate complications like cerebral abscess formation, hydrocephalus, and brain edema which are very important in the management of complicated states. Still, uncomplicated meningitis cases in some CTs including contrast CTs specialize in normal CT images even when contrast is used, thus the careful patient selection.

There is hope that the performance of CT imaging may improve in regards to diagnosis due to the development of technology which offers more accuracy, less risk, and better personalization of treatment strategies. Such development will enable a more accurate and timely diagnosis and treatment which will lead to better patient outcomes.

The refinement of the choice of diagnostic technique is assisted by comparative studies of plain brain CT and contrast-enhanced CT. On the one hand, it is important to highlight that plain CT is the first approach to determine whether significant intracranial abnormality is present and offers an anatomic frame while enhanced CT is applied to evaluate the presence of inflammation and its sequela if infection is still in a clinical picture of meningitis. People working in the position such as these studies can assist the practitioners in choosing suitable and effective imaging techniques in evaluation of meningitis, thus enhancing early management modes and patient care.

Two imaging methods, Brain plain CT and contrast-enhanced CT, are commonly used, but their diagnostic accuracy comparison remains essential. Plain CT is often used as the initial screening tool to rule out other intracranial conditions and establish a baseline assessment of brain structures. If meningitis remains a strong diagnostic consideration, contrast-enhanced CT is employed to provide a more detailed evaluation of inflammatory changes and the presence of complications. This study aims to compare the accuracy of both methods, aiding clinicians in choosing the best approach for the diagnosis of meningitis.

Materials and Methods:

The research was cross-sectional with study locations in Hamid Latif Hospital and Shalamar Hospital over a span of 4 months. In total, 42 study participants were incorporated in the study chosen via a convenient sampling technique. Inclusion factors involved the patients presenting themselves with a clinical suspicion of meningitis where the onset time of symptoms was not more than 3 days. So as to enhance validity and relevance in the participation, only those patients who had typical symptoms of meningeal involvement were eligible for recruitment. Exclusion factors were open cranial deformities, hypersensitivity to contrast mediums and pregnancy: all these variables may have impacted on the diagnosis, or provided extra risks. Siemens 64-Slice Multidetector CT Scanner was used in the study in imaging of the brain to enhance the diagnosis and assessment of meningitis.

Results

Forty-two patients met the inclusion criteria. Cerebrospinal fluid positivity test was taken as a classifying variable. Out of forty-two patients 32 patients (76.19%) tested positive for CSF test, and 10 patients (23.81%) tested negative for CSF. The study concluded that contrast-enhanced CT offers more diagnostic accuracy and enhanced sensitivity for detecting meningitis. Contrast-enhanced CT scans are better in diagnosis of meningitis as compared to brain plain CT.

Table 1: Descriptive statistics of Ventriculomegaly Evaluating CSF as classifier

ROC curve

Variable	Ventriculomegaly
Classification variable	CSF
Sample size	42
Positive group ^a	32 (76.19%)
Negative group ^b	10 (23.81%)

^a CSF = 1

^b CSF = 0

Disease prevalence (%)	unknown
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Area under the ROC curve (AUC)

Area under the ROC curve (AUC)	0.781
Standard Error ^a	0.0445
95% Confidence interval ^b	0.627 to 0.894
z statistic	6.313
Significance level P (Area=0.5)	<0.0001

^a DeLong et al., 1988

^b Binomial exact

Youden index

Youden index J	0.5625
Associated criterion	≤ 0
Sensitivity	56.25
Specificity	100.00

Criterion values and coordinates of the ROC curve [\[Hide\]](#)

Criterion	Sensitivity	95% CI	Specificity	95% CI	+LR	-LR
<0	0.00	0.0 - 10.9	100.00	69.2 - 100.0		1.00
≤0	56.25	37.7 - 73.6	100.00	69.2 - 100.0		0.44
≤1	100.00	89.1 - 100.0	0.00	0.0 - 30.8	1.00	

Table 1 assessed the CSF variable as a classifier of ventriculomegaly in a sample of 42 participants. ROC curve analysis indicated an AUC of 0.781 (SE: 0.0445, 95% CI: 0.627–0.894), well above 0.5 ($z = 6.313, P < 0.0001$). The optimal Youden index at a criterion of ≤ 0 was $J = 0.5625$, yielding 56.25% sensitivity and 100% specificity. For the specificity, it remained constantly at 100% while sensitivity varied, ensuring a clear discriminatory strength of the CSF variable.

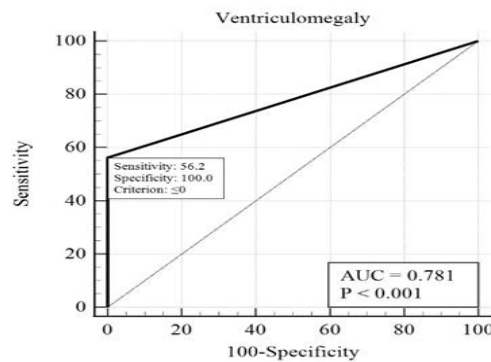


Table 2: Descriptive statistics of Midline Shift Evaluating CSF as classifier

ROC curve

Variable	Midline_shift Midline_shift
Classification variable	CSF
Sample size	42
Positive group ^a	32 (76.19%)
Negative group ^b	10 (23.81%)

^a CSF = 1

^b CSF = 0

Disease prevalence (%)	unknown
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Area under the ROC curve (AUC)

Area under the ROC curve (AUC)	0.563
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Standard Error ^a	0.0297
95% Confidence interval ^b	0.401 to 0.715
z statistic	2.104
Significance level P (Area=0.5)	0.0353

^a DeLong et al., 1988

^b Binomial exact

Youden index

Youden index J	0.1250
Associated criterion	>0
Sensitivity	12.50
Specificity	100.00

Criterion values and coordinates of the ROC curve [\[Hide\]](#)

Criterion	Sensitivity	95% CI	Specificity	95% CI	+LR	-LR
≥0	100.00	89.1 - 100.0	0.00	0.0 - 30.8	1.00	
>0	12.50	3.5 - 29.0	100.00	69.2 - 100.0		0.88
>1	0.00	0.0 - 10.9	100.00	69.2 - 100.0		1.00

Table 2 Classifies the CSF variable on the test sample of 42 subjects. The ROC curve revealed AUC = 0.563 (SE: 0.0297, 95% CI: 0.401–0.715); marginally >0.5; z = 2.104, P = 0.0353. At the optimum Youden index, J = 0.1250 with criterion >0 it yielded sensitivity 12.5% and specificity of 100%. Despite high specificity, the often low sensitivity suggests that the CSF variable is not very effective for the detection of midline shift.

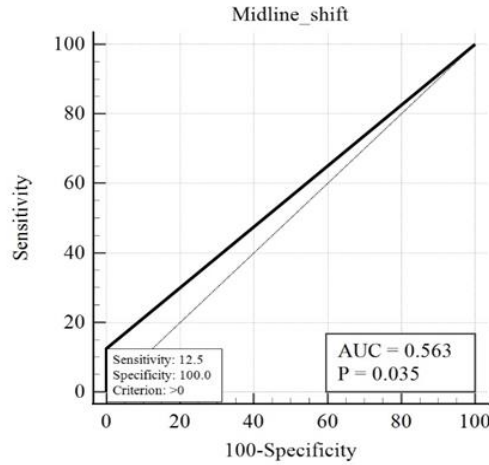


Table 3: Descriptive statistics of Meningeal Enhancement Evaluating CSF as classifier

ROC curve

Variable	Meningeal_Enhancement
Classification variable	CSF
Sample size	42
Positive group ^a	32 (76.19%)
Negative group ^b	10 (23.81%)

^a CSF = 1

^b CSF = 0

Disease prevalence (%)	unknown
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Area under the ROC curve (AUC)

Area under the ROC curve (AUC)	0.591
Standard Error ^a	0.0643
95% Confidence interval ^b	0.428 to 0.740
z statistic	1.410
Significance level P (Area=0.5)	0.1585

^a DeLong et al., 1988

^b Binomial exact

Youden index

Youden index J	0.1813
Associated criterion	>0
Sensitivity	28.12
Specificity	90.00

Criterion values and coordinates of the ROC curve [\[Hide\]](#)

Criterion	Sensitivity	95% CI	Specificity	95% CI	+LR	-LR
≥0	100.00	89.1 - 100.0	0.00	0.0 - 30.8	1.00	
>0	28.12	13.7 - 46.7	90.00	55.5 - 99.7	2.81	0.80
>1	0.00	0.0 - 10.9	100.00	69.2 - 100.0		1.00

Table 3 tests the CSF variable as a classifier for meningeal enhancement in 42 subjects. The ROC curve summary revealed an AUC of 0.591 (SE: 0.0643, 95% CI: 0.428–0.740), which was not significant at 0.5 ($z = 1.410$, $P = 0.1585$). The optimal Youden index ($J = 0.1813$) at a criterion of >0 gave 28.12% sensitivity and 90% specificity. While specificity was consistently high, the low sensitivity will indicate that the CSF variable has limited discriminative ability in detecting enhancement of the meninges.

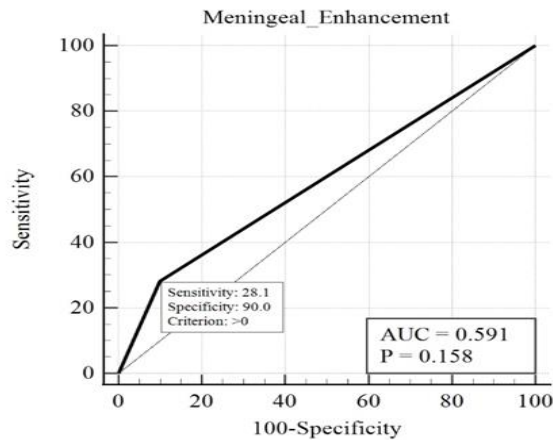


TABLE 4 : Descriptive statistics of Diagnostic Test

Diagnostic test

Data

	Disease Present	Disease Absent	
	32	10	42

	0	0	0
	32	10	

Results

Sensitivity	100.000%	89.112% to 100.000%
Specificity	0.000%	0.000% to 30.850%
AUC	0.500	0.342 to 0.658
Positive Likelihood Ratio	1.000	1.000 to 1.000
Negative Likelihood Ratio		
Disease prevalence	76.190%	60.550% to 87.948%
Positive Predictive Value	76.190%	76.190% to 76.190%
Negative Predictive Value		
Accuracy	76.190%	60.550% to 87.948%

Table 4 diagnosed brain parenchymal edema in a sample of 42 patients, 32 with the condition and 10 without. It had a 100% (95% CI: 89.1–100%) sensitivity but 0% (95% CI: 0–30.9%) specificity, with an AUC of 0.500 (95% CI: 0.342–0.658) and therefore no discriminative ability. The positive likelihood ratio was 1.0 and equal to the prevalence of the disease, that is 76.2% (95% CI: 60.6–87.9%). The test's positive predictive value and overall accuracy were also 76.2%. The negative predictive value and likelihood ratio were not reported due to the lack of true negatives.

Table 5: Descriptive statistics of Diagnostic Test

Data

	Disease Present	Disease Absent	
	32	1	33
	0	9	9
	32	10	

Results

Sensitivity	100.000%	89.112% to 100.000%
Specificity	90.000%	55.498% to 99.747%
AUC	0.950	0.835 to 0.993
Positive Likelihood Ratio	10.000	1.558 to 64.200
Negative Likelihood Ratio	0.000	
Disease prevalence	76.190%	60.550% to 87.948%
Positive Predictive Value	96.970%	83.290% to 99.516%

Negative Predictive Value	100.000%	66.373% to 100.000%
Accuracy	97.619%	87.434% to 99.940%

In Table 5, a diagnostic test is assessed in a sample of 42 patients (32 cases and 10 controls). The test shows great performance with a sensitivity of 100% (95% CI: 89.1–100%) and specificity 90% (95% CI: 55.5–99.7%). AUC was at 0.950 (95% CI: 0.835–0.993), showing great discriminative ability. Positive LR was at 10.0 (95% CI: 1.6–64.2), and Negative LR was 0.0. The test had a positive predictive value of 97.0% (95% CI: 83.3–99.5%) and a negative predictive value of 100% (95% CI: 66.4–100%). The overall accuracy was 97.6% (95% CI: 87.4–99.9%).

Discussion

Our study was designed to compare the diagnostic accuracy of plain brain computed tomography with contrast enhanced in the diagnosis of meningitis. Two imaging methods, Brain plain CT and contrast-enhanced CT, are commonly used, but their diagnostic accuracy comparison remains essential. Plain CT is often used as the initial screening tool to rule out other intracranial conditions and establish a baseline assessment of 4 brain structures. If meningitis remains a strong diagnostic consideration, contrast-enhanced CT is employed to provide a more detailed evaluation of inflammatory changes and the presence of complications. This study aims to compare the accuracy of both methods, aiding clinicians in choosing the best approach for the diagnosis of meningitis.

Table 1 shows the results of the ROC curve analysis for the CSF variable as a ventriculomegaly classifier with a sample size of 42 individuals. The AUC was 0.781 with a standard error of 0.0445 and a 95% confidence interval ranging from 0.627 to 0.894. With a criterion of ≤ 0 , the Youden index J was 0.5625, yielding a sensitivity of 56.25% and a specificity of 100%. Specificity remains high at 100% but sensitivity fluctuated according to the criteria, indicating that the CSF variable may distinguish between positive and negative cases of ventriculomegaly in this sample. McKenna et al in 2010 studies that Clinical features alone cannot determine whether meningitis is present and analysis of cerebrospinal fluid (CSF) is essential for diagnosis because many illnesses present with similar symptoms. The gold standard for the diagnosing meningitis is CSF culture. ([Kamr et al 2020](#))

Table 2 of our analysis shows a diagnostic test for a sample size of 42 individuals. It displays that 32 patients had the disease and 10 were normal. The test results showed a sensitivity of 100.000% (95% CI: 89.112% to 100.000%) and a specificity of 90.000% (95% CI: 55.498% to 99.747%). The area under the ROC curve (AUC) was 0.950 indicating excellent overall test performance. The positive likelihood ratio was 10.000, and the negative likelihood ratio was 0.000. The disease prevalence in this sample was 76.190%. The positive predictive value was 96.970% and the negative predictive value was 100.000%. The overall accuracy of the test was 97.619%. Table 4 of our research shows the CSF variable as a classifier for midline shift in a sample of 42 individuals, the ROC curve analysis revealed an area under the curve (AUC) of 0.563 with a standard error of 0.0297 and a 95% confidence interval from 0.401 to 0.715. The z statistic was 2.104, with a significance level (P-value) of 0.0353, indicating a slight deviation from an AUC of 0.5. The Youden index J was 0.1250 with an associated criterion of >0 , resulting

in a sensitivity of 12.50% and a specificity of 100%. The sensitivity remained low at 12.50%, while specificity was consistently high at 100%, suggesting the CSF variable has limited discriminative power for detecting midline shift in this sample. ([Hughes et al 2010](#))

Computed Tomography is a useful diagnostic tool for detecting intracranial complications of bacterial meningitis like hydrocephalus, cerebral abscess and cerebral edema. Table 6 of our study evaluate the CSF variable as a classifier for brain parenchymal edema in a sample of 42 individuals, the ROC curve analysis yielded an area under the curve (AUC) of 0.534 with a standard error of 0.0524 and a 95% confidence interval from 0.374 to 0.690. The z statistic was 0.656, and the P-value was 0.5117, indicating no significant difference from an AUC of 0.5. The Youden index J was 0.06875 with an associated criterion of ≤ 0 , resulting in a high sensitivity of 96.87% but a low specificity of 10.00%. While sensitivity was high, specificity remained consistently low, suggesting that the CSF variable has limited discriminative power for detecting brain parenchymal edema in this sample. Table 5 shows a diagnostic test for brain parenchymal edema with a sample size of 42 individuals, including 32 with the disease and 10 without, the results showed a sensitivity of 100.000% (95% CI: 89.112% to 100.000%) and a specificity of 0.000% (95% CI: 0.000% to 30.850%). The area under the ROC curve (AUC) was 0.500 (95% CI: 0.342 to 0.658), indicating no discriminative ability of the test. The positive likelihood ratio was 1.000 (95% CI: 1.000 to 1.000). The disease prevalence in this sample was 76.190% (95% CI: 60.550% to 87.948%). The positive predictive value was 76.190% (95% CI: 76.190% to 76.190%), and the overall accuracy of the test was 76.190% (95% CI: 60.550% to 87.948%). There were no reported values for the negative likelihood ratio and negative predictive value due to the lack of true negatives in the data. ([Manzoor Ahmed et. al 2023](#))

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Images



Figure 1 Shows Meningitis with few swollen gyri.



Figure 2 CT image shows meningitis with edematous gyri

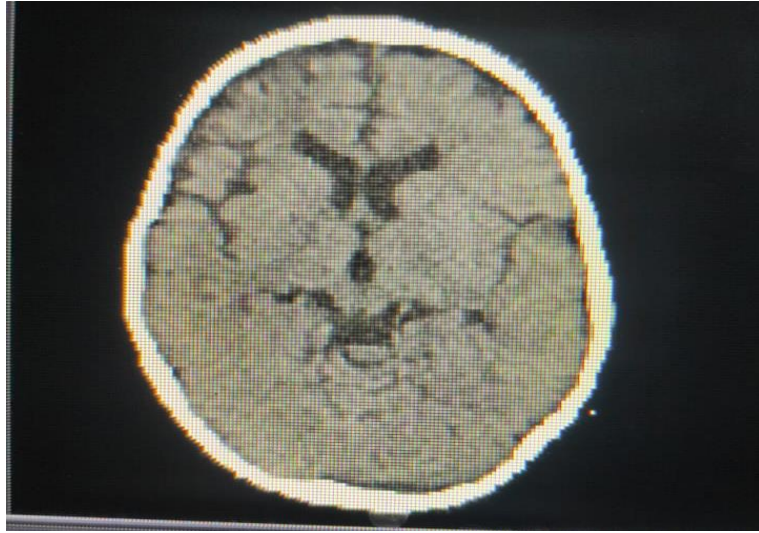


Figure 3 shows features suggestive of meningitis