Original Article

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Paediatrics Section

Epidemiology of Lumbar Puncture and the Validity of Meningeal Signs in Predicting Meningitis in Children: A Cross-sectional Study

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ABSTRACT

Introduction: Predictive models have been developed to estimate the likelihood of bacterial meningitis in patients with clinical features suggestive of Central Nervous System (CNS) involvement. Early diagnosis and prompt treatment of bacterial meningitis in children are crucial due to the severity and rapid progression of the disease. However, making a definitive diagnosis in the early stages can be challenging, as clinical symptoms are often non specific and may overlap with other conditions. Lumbar Puncture (LP) is a crucial diagnostic and therapeutic procedure in paediatric medicine to diagnose various neurological diseases, particularly meningitis, by analysing Cerebrospinal Fluid (CSF).

Aim: To analyse the epidemiological trends of LP performed in children and to evaluate the accuracy of meningeal signs in predicting the presence of meningitis in paediatric patients.

Materials and Methods: This was a cross-sectional study conducted in the Department of Paediatrics at Amala Institute of Medical Sciences, Thrissur, Kerala, South India, from August 2018 to July 2019. The records of paediatric patients (aged 1 month to 12 years) who underwent LP during the one year from August 2018 to July 2019 at the centre were collected. A checklist was prepared for all the patients, where demographic data, clinical presentations, findings of CSF, and blood analysis were recorded. The data obtained were analysed using Statistical Package for Social Sciences (SPSS) version 23.0.

Results: Out of 3,125 paediatric admissions during the study period, LP was performed in 125 (4%). The most common indication for LP was fever with seizure in 53 (42.4%), followed by fever and vomiting in 44 (35.2%). There was a statistically significant association between both CSF protein and CSF sugar and a diagnosis of meningitis. Among children presenting with fever and seizure in the age group of one month to two years, 19 (52.8%) had meningitis. The incidence of pyogenic meningitis was 26 (20.8%). Organisms were isolated in 2 (1.6%) of cases. Among the meningeal signs, the Johny Vincent sign and neck stiffness showed better sensitivity, while Kernig's sign was the most specific.

Conclusion: The present study concludes that, in paediatrics, LP remains an essential procedure for differentiating patients with meningitis from those without meningitis when they present with the same symptoms, especially in children less than two years of age. In older children, clinical variables such as meningeal signs and seizures at admission had lower sensitivity and Positive Predictive Value (PPV), which again highlights the need for performing an LP.

Keywords: Cerebrospinal fluid, Fever, Kernig's sign, Seizure

INTRODUCTION

The CSF plays a critical role in brain function, where alterations in its composition, flow, and pressure can be associated with various neurological disorders [1]. LP is a critical diagnostic and therapeutic procedure in paediatric medicine, providing valuable insights into the CSF that bathes the brain and spinal cord [2]. Analysis of the CSF obtained can help identify the presence of infection, subarachnoid haemorrhage, autoimmune diseases of the CNS, and neoplastic meningeal diseases [3].

Although the technique is the same as in adults, difficulties arise in small infants due to the short subarachnoid space and the thin, soft ligaments. In these cases, the usual snap is not produced when the needle passes through the ligament, which may lead to entry into the venous plexus on the vertebrae and cause a traumatic tap [4]. Contraindications for LP include raised intracranial pressure that can lead to transtentorial or cerebellar tonsil herniation, suspected intracranial space-occupying lesions, skin infections at the site of LP, coagulopathy, severe thrombocytopenia, bleeding diathesis, or anticoagulant therapy [5-7]. Various complications can arise following LP [3,8]. Even cortical vein thrombosis and reversible cerebral vasoconstriction syndrome have been reported as very rare complications of low CSF pressure states that can follow LP [8,9].

A child with meningeal signs is suspected of having bacterial meningitis. Kernig's sign, Brudzinski's sign, neck stiffness, and the Johny Vincent sign are the bedside diagnostic signs mainly used to evaluate a patient's risk for meningitis [1,7]. Not many studies are available to date to assess their diagnostic accuracy, although these clinical signs have been used as indicators of meningeal inflammation for almost a century now [10,11].

The objective of present study was to analyse the epidemiological trends of LP performed in children and to evaluate the accuracy of meningeal signs in predicting the presence of meningitis in paediatric patients. To the best of authors knowledge, present study is the first of its kind from the Indian subcontinent.

MATERIALS AND METHODS

This was a cross-sectional study conducted in the Department of Paediatrics at Amala Institute of Medical Sciences, Thrissur, Kerala, South India, from August 2018 to July 2019. All procedures performed in present study involving human participants were conducted in accordance with the ethical standards of the Institutional and/or National Research Committee (Ethical clearance number: 25/IEC/19/AIMS-23). All patients who underwent LP and belonged to the age group of one month to 12 years during the study period were enrolled in the study.

Inclusion and Exclusion criteria: All patients within the age group of one month to 12 years who underwent LP during the study period were included in the study. Patients with incomplete medical records and those who were discharged against medical advice were excluded from the study.

Study Procedure

The present study gathered patient data from medical records obtained through the Medical Records Department and completed a detailed proforma. This included demographic information, clinical features such as the presence or absence of meningeal signs, LP results, any complications following the procedure, and the final diagnosis.

STATISTICAL ANALYSIS

The collected data were compiled in a Microsoft Excel spreadsheet and analysed using the Statistical Package for Social Sciences (SPSS) (IBM Corporation, version 23.0, Chicago, USA). Descriptive statistics were used to describe categorical variables (frequency and percentages) and continuous variables (mean and Standard Deviation (SD) or median and range, depending on the normality of the data). Sensitivity and specificity analyses were performed to assess the accuracy and reliability of meningeal signs in predicting meningitis. A p-value of <0.05 was considered statistically significant.

RESULTS

Out of 3,125 paediatric admissions during the study period, LP was performed in 125 (4%) of cases, all of which satisfied the study criteria. The median age of the study population was 11.0 months (range: 30 days to 12 years); 87 patients (69.6%) were aged one month to two years. Among the participants, 77 (61.6%) were females and 48 (38.4%) were males. Development was normal in 120 patients (96%), while delayed development was noted in only 5 patients (4%). The most common indication for LP was fever with seizure, which occurred in 53 (42.4%) of cases, followed by fever and vomiting in 44 (35.2%) [Table/Fig-1]. Out of 53 patients presenting with fever and seizures, 16 (30.1%) were diagnosed with meningitis, showing a low sensitivity of 5%, a high specificity of 78%, and an overall accuracy of 49%. Among the 45 children aged one month to two years who presented with fever and seizures, 11 (24.4%) were diagnosed with meningitis.

Parameters	Total patients (n=125)	Non meningitis (n=89)	Meningitis (n=36)	p-value
Age (months), median (range)	11.0 (1.0-144.0)		-	-
Age-wise distribution				
1 month to <2 years	87 (69.6)	68 (76.4)	19 (52.8)	0.002
2 years to 12 years	38 (30.4)	21 (23.6)	17 (47.2)	
Gender				
Male	77 (61.6)	51 (57.3)	26 (72.2)	0.120
Female	48 (38.4)	38 (42.7)	10 (27.8)	
Symptoms				
Fever and seizures	53 (42.4)	37 (41.6)	16 (44.4)	0.082
Fever and vomiting	44 (35.2)	27 (30.3)	17 (47.2)	0.074
Headache	15 (12.0)	4 (4.5)	11 (30.6)	-
Lethargy	15 (12.0)	8 (9.0)	7 (19.4)	-
Poor feeding	14 (11.2)	8 (9.0)	6 (16.7)	-
Excessive cry	14 (11.2)	11 (12.4)	3 (8.3)	-
Fever alone	14 (11.2)	11 (12.4)	3 (8.3)	-
Altered sensorium	11 (8.8)	10 (11.2)	1 (2.8)	-
Fever, vomiting and headache	10 (8.0)	1 (1.1)	9 (25.0)	-
Seizure alone	3 (2.4)		-	-
Vomiting alone	1 (0.8)		-	-
Pulse rate (bpm), median (range)	120.0 (62.0-209.0)		-	-
SBP (mmHg), median (range)	90.0 (71.0-180.0)		-	-
DBP (mmHg), median (range)	57.0 (33.0-140.0)		-	-
Respiratory rate breaths per min, median (range)	32.0 (16.0-88.0)		-	-
Developmental history				
Normal	120 (96.0)	85 (95.5)	35 (97.2)	0.657
Abnormal	5 (4.0)	4 (4.5)	1 (2.8)	
Immunisation status				
Fully immunised	113 (90.4)	81 (91.0)	32 (88.9)	0.715
Partially immunised	12 (9.6)	8 (9.0)	4 (11.1)	
Sensorium				
Normal	107 (85.6)	76 (85.4)	31 (86.1)	0.918
Altered	18 (14.4)	13 (14.6)	5 (13.9)	
Meningeal signs*	(n=38)	(n=21)	(n=17)	
Neck stiffness	17 (44.7)	7 (33.3)	10 (58.8)	
Kernig's sign	8 (21.1)	3 (14.3)	5 (29.4)	-
Brudzinski's sign	5 (13.2)	3 (14.3)	2 (11.7)	
Johny Vincent sign	2 (5.3)	-	2 (11.7)	

[Table/Fig-1]: Demographic characteristics.
*Meningeal signs are illustrated in patients belonging to age group of 2 to 12 years (n=38); Data shown as n (%); Unless otherwise specified; DBP: Diastolic blood pressure; SBP: Systolic blood pressure

Among the 125 children in whom LP was performed, CSF protein was found to be high in 9 (7.2%) patients, of whom 5 (55.5%) were diagnosed with meningitis. In contrast, among the 116 patients (92.8%) with normal CSF protein, only 31 (26.7%) were diagnosed with meningitis (p-value=0.01). CSF sugar was found to be normal in 117 children (93.61%), out of which 28 (23.9%) were finally diagnosed with meningitis. All children with low CSF sugar (n=8) were diagnosed with meningitis (p<0.0001) [Table/Fig-2].

Parameters	Total (%) (n=125)	Diagnosed meningitis (%) (n=36)	p-value
CSF protein			
Normal	116 (92.8)	31 (26.7)	0.01
High (>40)	9 (7.2)	5 (55.56)	
CSF glucose			
Normal	117 (93.61)	28 (23.9)	<0.0001
Low	8 (6.4)	8 (100.0)	

[Table/Fig-2]: Cerebrospinal Fluid (CSF) protein and glucose.

Neutrophils were detected in 34 (27.2%) samples, and lymphocytes were found in 83 (66.4%) samples, among which meningitis was diagnosed in 14 (41.1%) patients with neutrophils and 17 patients (20.5%) with lymphocytes, respectively (p<0.001 and p-value=0.002, respectively). CSF culture was positive in 2 (1.6%). The organisms isolated were *Haemophilus influenzae* type B (n=1) and non typhoidal Salmonella (*S. Enteritidis*, n=1). A neurosonogram was performed in 14 patients (under one year of age), of which 6 (42.9%) reports suggested meningitis.

Out of the 125 patients who underwent LP, 36 (28.8%) were diagnosed with meningitis, among which 26 (72.2%) had pyogenic meningitis, 3 (8.3%) had meningoencephalitis, and 7 (19.4%) had aseptic meningitis [Table/Fig-3]. Of the 15 children admitted with atypical febrile seizures, 3 (20%) were diagnosed with meningitis. Except for 5 (4%) chidren who complained of

low backache, no significant postprocedural complications were observed.

Diagnosis	Frequency (n)	Percentage (%)
Febrile seizure	38	30.4
Pyogenic meningitis	26	20.8
Aseptic meningitis	7	5.6
Meningoencephalitis	3	2.4
Seizure disorder	2	1.6
Other	49	39.2

[Table/Fig-3]: Final diagnosis (N=125).

Among the 38 children in the age group of 2 to 12 years, 17 were diagnosed with meningitis. Of these children, 10 (58.8%) exhibited neck stiffness, 5 (29.4%) had a positive Kernig's sign, 2 (11.7%) had a positive Brudzinski's sign, and 2 (11.7%) had a positive Johny Vincent sign. Among the meningeal signs, the Johny Vincent sign and neck stiffness had higher sensitivities (100% and 71.4%, respectively) with diagnostic accuracies of 50.0% and 52.3%, respectively, while Kernig's sign was the most specific (60%) with a diagnostic accuracy of 57.8% [Table/Fig-4]. The overall Positive Predictive Value (PPV) of meningeal signs was 62.5%, the Negative Predictive Value (NPV) was 68.1%, with an overall accuracy of 65.7%.

Meningeal signs	n	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic accuracy (%)
Neck stiffness	10	71.4	33.3	62.5	42.9	52.3
Kernig's sign	5	55.5	60	71.4	42.9	57.8
Brudzinski's sign	2	40	50	40	50	45.0
Johny Vincent sign	2	100	0	100	0	50.0

[Table/Fig-4]: Sensitivity, Specificity, PPV, NPV of meningeal signs.
NPV: Negative predictive value; PPV: Positive predictive value

DISCUSSION

The present cross-sectional study was conducted to analyse the epidemiological trends of LP performed in children and to evaluate the accuracy of meningeal signs in predicting the presence of meningitis in paediatric patients. The findings of present study indicate that the decision to perform an LP should not rely solely on clinical signs, as some patients without meningeal signs were found to have CSF results indicative of meningitis. The total number of LPs performed at the Institution was 4%, comparable to reference studies such as Herbert G et al., in East Africa [12], where out of 8,741 paediatric admissions, 607 (6.9%) had an LP performed. The most common indications for LP were convulsions, neck stiffness, and prostration. In present study, the most frequent indication for LP was fever with seizures, occurring in 42.4% of cases; fever was reported in 92.8% of the cases.

In a study by Sadek ARA et al., an examination of CSF was performed in 85 cases to detect CNS infections and to determine the prevalence of CNS infections in infants and children presenting with fever and convulsions [13]. The CSF examination indicated that 20% of the individuals had abnormal physical findings, while 23.5% exhibited an abnormal white blood cell count (CSF pleocytosis). The present study showed that 27.2% had neutrophils and 66.4% had lymphocytes in the CSF, and CSF pleocytosis was significantly associated with meningitis ($p<0.005$).

The study by Mahmoudvand G et al., demonstrated a significant relationship between the diagnosis of meningitis and the levels of protein ($p<0.001$) and glucose in the CSF (p-value=0.005) [14]. Similarly, the present study also established a statistically significant association between high CSF protein (p-value=0.01) and low CSF sugar ($p<0.0001$) with the diagnosis of meningitis.

Culture positivity rates were comparable, at 1.6% versus 3%. The absence of organisms on CSF culture may be attributed to pretreatment with antibiotics. Conversely, it is also postulated that many of these cases may be due to viral meningitis, suggesting that such infections could be a common cause of meningitis. Additionally, the current study indicates that in infants, modalities like neurosonograms (of the 14 performed, 6 (42.9%) showed features of meningitis) may aid in diagnosis. Only 4% of patients experienced complications from LP in one of the reference studies [12]. The complication profile in the present study was also comparable, at 4%.

A study in Tehran by Shiva F and Hashemian HR examined 111 children with fever and seizures to document the pattern of illness and to define the indications for performing an LP in children with fever and convulsions [15]. Meningitis was diagnosed in 6 (5.4%) of the patients, while febrile seizures were observed in the remaining 105 children [15]. In present study, out of 125 LPs performed, 53 were conducted on patients with fever and seizures. Total 16 (30.1%) of these were diagnosed with meningitis, which is a significantly higher rate than that reported in the reference study [15]. This further emphasises the need to maintain a lower threshold for performing LPs in children when clinical features are suggestive of meningitis.

The publication by Mijovic H and Sadarangani M concluded that new diagnostic tests have improved pathogen detection, but confirmation of bacterial meningitis still relies on a high degree of clinical suspicion followed by the prompt performance of a LP [16]. The incidence of bacterial meningitis among children in countries with routine childhood immunisation programs has declined significantly. However, in children hospitalised with suspected bacterial meningitis, a causative pathogen is not identified in 77% of cases [12]. This is also evident in the present study, as no organisms were isolated in 98.6% of the cases.

In a literature review by Carroll W and Brookfield D, it was found that the overall incidence of bacterial meningitis was 0.8%, and the percentage of children with meningitis at the institution was 1.2% of total admissions (3125), which is again comparable [17]. In the absence of clear contraindications, patients suspected of having meningitis should undergo an LP [18]. Bacterial meningitis without associated signs (irritability, lethargy, and/or bulging fontanelle) is extremely uncommon [17]. However, the classic triad of fever, neck stiffness, and altered mental status is present in only a minority of patients with meningitis. Kernig's and Brudzinski's signs are poorly sensitive but relatively specific physical examination maneuvers for identifying meningitis [18]. Ala A et al., assessed the diagnostic accuracy of meningeal signs in adult patients and found that the sensitivity of neck stiffness, Kernig's sign, and Brudzinski's sign for detecting meningitis was 64.4%, 55.5%, and 53.3%, respectively [19]. The specificity for these signs in the same study was 70.6%, 89.3%, and 90.6%, respectively, which aligns with the findings of the present study [19]. In contrast, Nakao JH et al., reported significantly lower sensitivity for neck stiffness, Kernig's sign, and Brudzinski's sign in detecting pleocytosis in CSF analysis (13%, 2%, and 2%, respectively). However, the specificity of neck stiffness, Kernig's sign, and Brudzinski's sign in that study was 97%, 98%, and 80%, respectively, which is similar to the present study [20]. Among the meningeal signs, the Johny Vincent sign and neck stiffness had better sensitivity (100% and 71.4%, respectively), while Kernig's sign was the most specific (60%). The overall PPV of meningeal signs was 62.5%, the NPV was 68.1%, and the accuracy was 65.7% in present study. Newer diagnostic modalities, such as Polymerase Chain Reaction (PCR) amplification and antigen and antibody detection studies on the CSF, will help in diagnosing meningitis more accurately.

Limitation(s)

The study's sample size may limit the generalisability of the findings to the broader paediatric population. Additionally, since the study

was conducted at a single Institution, the results may not account for variations in patient demographics and healthcare practices in other regions. The evaluation of meningeal signs, with their low sensitivity, specificity, and accuracy, underscores the need for additional diagnostic markers beyond clinical signs to reliably predict meningitis.

CONCLUSION(S)

The study concluded that LP remains a crucial procedure in paediatrics for distinguishing between patients with and without meningitis, particularly in children under two years of age who present with non specific symptoms. In older children, clinical markers such as meningeal signs and seizures at admission showed lower sensitivity and PPV, underscoring the importance of LP for an accurate diagnosis. The analysis of CSF protein and sugar levels further supported the significance of LP, with abnormal values strongly correlating with meningitis.

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