Diagnosing and Prognosticating Acute Meningitis in Young Infants within 24 Hours of Admission

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Abstract

***Introduction**: The early diagnosis and prognosis of acute meningitis in young infants (infants 90 days old or younger) have not been well studied. We therefore investigated the diagnostic and prognostic factors for acute meningitis obtainable within 24 hours of admission. **Methods**: Data were obtained through a retrospective case review of 55 young infants from 1991 to 1999 inclusive. **Results**: The 3 commonest symptoms of acute meningitis were fever, abnormal activity and decreased feeding. The 3 commonest signs were temperature >38.0°C, irritability/crying and abnormal tone/reflexes. The best predictor of acute bacterial meningitis (ABM) was the cerebrospinal fluid (CSF)-to-blood glucose ratio. A glucose ratio of ≤0.8 can be used to diagnose ABM with 100% sensitivity and 100% negative predictive value. Furthermore, a ratio ≤0.3 can be used to diagnose ABM with 100% specificity and 100% positive predictive value. The best predictor of unfavourable neurological outcome (UFNO) was also the CSF-to-blood glucose ratio. A glucose ratio of ≤0.3 again can be used to prognosticate for UFNO with 100% sensitivity and 100% negative predictive value. **Conclusions**: Diagnosis of acute meningitis by history and physical examination alone is difficult. However, with the aid of laboratory tests, in particular the CSF-to-blood glucose ratio, one can diagnose ABM and prognosticate for unfavourable neurological outcome with high sensitivity and high negative predictive value within 24 hours of admission.*

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Key words: Aseptic meningitis, Bacterial meningitis, Cerebrospinal fluid-to-blood glucose ratio, Viral meningitis

Introduction

Meningitis is an important cause of fever in young infants (infants 90 days old or younger).[1] Most cases of meningitis are acute meningitis which present with a short history of symptoms and are caused by either bacteria (acute bacterial meningitis, ABM) or viruses (acute aseptic meningitis, AAM). Both ABM and AAM are associated with long-term neurological sequelae. While many studies on the diagnostic and prognostic difficulties of acute meningitis in older children and adults have been published, few papers have specifically addressed these problems in young infants.

Primary care physicians and paediatricians often face the dilemma of deciding which young infants with fever or other symptoms require urgent admission to hospital. For initial screening, it is crucial to identify the most common symptoms and signs of acute meningitis. The next problem encountered is that of the need and choice of antibiotics in treating a child with meningitis.

Definitive identification of the infectious organism by culture requires about 48 hours or more.[2] It would be ideal if one could have definitive criteria to distinguish ABM from AAM so as to avoid overuse of antibiotics in view of emerging microbial resistance and rising health care costs. Unfortunately, previous studies have shown conflicting results on the efficacy of early criteria (those accessible within 24 hours of admission) for the differential diagnosis of ABM and AAM.[3-7]

Previous prospective studies in adults have shown that early clinical parameters like the Glasgow Coma Scale and cerebrospinal fluid (CSF) protein level correlated with outcome severity.[8] No such studies have been conducted for young infants. Given that many cases of acute meningitis do resolve without permanent neurological complications, it is useful to identify these cases early for the purpose of counselling and reassuring worried caregivers.

This study thus aimed to investigate and to compare an assortment of candidate diagnostic and prognostic factors

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for acute meningitis obtainable within 24 hours of admission. From our data, we suggest the best factors for early diagnosis and prognosis of acute meningitis.

Materials and Methods

Study Definitions

Acute meningitis is defined as inflammation of the meninges,[9] with a clinical history not longer than 2 weeks before admission. Causes of chronic meningitis such as tuberculosis and cryptococcosis were excluded.

ABM is defined as an acute infectious meningitis due to bacterial agents, other than mycobacteria. ABM was diagnosed if one of the following criteria were fulfilled:[10,11]

1. A positive bacterial culture of the CSF.
2. A positive blood culture for a usual pathogen (e.g., group B streptococcus) in the presence of CSF pleocytosis of more than 10 leukocytes/uL.[12,13]

AAM: Diagnosed if CSF pleocytosis was present in an appropriate clinical context, and blood cultures, CSF cultures, CSF gram stains and CSF latex agglutination tests were negative for bacterial growth or bacterial antigens.[10,14] CSF cultures, stool cultures, throat swab cultures or serologic tests might have been done to reveal the causative virus.[11]

Young infants: Infants 90 days old or younger. This cut-off age was selected so as to be in line with the World Health Organization (WHO) Young Infants Study, which recognised the unique pattern of infection and poor disease outcome in patients of around the neonatal age.[1,15] In addition, a young infant tends to present with non-specific symptoms and signs of meningitis compared to an older child such as the presence of a bulging anterior fontanelle and the lack of obvious neck stiffness and Kernig's sign.

Prematurity: Less than 37 completed weeks of gestation according to dates.

Low birth weight: Birth weight less than 2500 g.

Recurrent meningitis: Meningitis occurring with a similar past history.

Neurological outcome: As some patients had multiple neurological deficits, the most severe neurological deficit for each patient determined the overall outcome. Minor neurological deficits were those that resolved before the last follow-up visit. Severe neurological deficits were those that persisted beyond the last follow-up visit. Patients without neurological deficits during their hospital stays were followed-up for 2 weeks after discharge. Patients with seizures during their hospital stays took anticonvulsants for at least 2 months post-discharge and ceased follow-up if no further seizures occurred during that time. If further seizures did occur, paediatricians extended follow-up to 2 years or more. For the purpose of this study, the final status (minor or severe) of all deficits was determined at the end of follow-up or at 2 years post-discharge, whichever was earlier. Cases with inadequate follow-up were not considered for the purpose of studying prognosis.

Favourable neurological outcome (FNO): Sum of cases without neurological deficits and cases with minor neurological outcome.

Unfavourable neurological outcome (UFNO): Sum of cases with severe neurological deficits and cases that died from acute meningitis or its complications.

Inclusion and Exclusion Criteria

Clinical data and laboratory results were extracted from case records of all young infants with the diagnosis of meningitis or meningoencephalitis admitted to the National University Hospital, Singapore between 1991 and 1999 inclusive. Patients not satisfying the diagnostic criteria for ABM/AAM, those with pre-morbid neurological deficits, those with pre-existing congenital or acquired structural neural defects (e.g., neural tube defects, congenital sinus tracts, intracranial devices), those with prior neurosurgery and those with penetrating head wounds (e.g., from fetal scalp blood sampling) were excluded. Prior antibiotic therapy given within 3 days of admission is a common presenting feature in clinical practice. As such, this study did not exclude young infants who received such treatment.[11,13,14] Nonetheless, in our study population, prior antibiotic therapy did not influence the differential diagnosis of ABM versus AAM ($P = 0.708$).

Determination of Clinical Parameters

All symptoms and signs were those recorded at initial presentation. Temperatures were assessed at the axilla with the Terumo™ Digital Clinical Thermometer Axillary Model C202 (Terumo Corporation, Japan) before the administration of any antipyretics or sponging. Blood pressures were measured in the supine position using the automated Dinamap™ XL Vital Signs Monitor (Johnson & Johnson Medical Inc., USA). Fontanelle tensions were determined when infants were not crying.

The National University Hospital Department of Laboratory Medicine, which is fully accredited by the College of American Pathologists, performed all the laboratory tests. Positive viral cultures were confirmed by the Singapore General Hospital Reference Laboratory. CSF leukocyte counts and protein concentration were both corrected for traumatic taps.[16] CSF-to-blood glucose ratios were calculated using simultaneous capillary blood values only, which were measured at the time of lumbar puncture with the Reflolux™ S bedside glucometer (Boehringer Mannheim, Germany). Other blood and CSF chemistries were assayed using calorimetric methods on the Vitros™

950 system (Ortho Clinical Diagnostics, USA). Sensorineural hearing loss was confirmed with auditory brainstem responses and audiology assessment, with a hearing threshold of 50 dB nHL used to determine hearing loss. Visual impairment was verified by the use of visual evoked potentials and by ophthalmology review.

Statistical Analysis

All analyses were done using the SPSS for Windows software. A 2-tailed P <0.01 was considered highly significant (HS), P <0.05 was considered significant (S), and P <0.10 was considered approaching significance (AS). Fisher's exact test was used to investigate the relationships between dichotomous variables. The Mann-Whitney U test was employed for non-parametric analysis of variance. Receiver operator characteristic (ROC) curves were plotted for factors with P <0.05 and the areas under the curves (AUCs) calculated.

Results

As this is a retrospective study, no control could be obtained over the choice of diagnostic tests actually performed for patients. Consequently, some tests were not done for particular patients, resulting in some parameters having slightly fewer analysable cases than the total number of patients studied. For each parameter examined, the actual number of cases evaluated is as stated.

Characteristics of the Study Population

The total number of patients studied was 55. The median age was 28 days (range from 3 to 90 days). Nine (16.4%) young infants were born premature, while 7 (12.7%) had low birth weight. Thirty (54.5%) young infants were male and 25 (45.5%) were female. Racial distribution was roughly representative of the local demographics with 36 (65.5%) Chinese, 12 (21.8%) Malays, 6 (10.9%) Indians and 1 (1.8%) Caucasian.

Five (9.1%) patients had predisposing conditions to meningitis. Three had maternal group B streptococcus carriage,[17] 1 had grossly poor bottle hygiene leading to *Salmonella* sepsis and meningitis and 1 had premature rupture of membranes for more than 24 hours. Sixteen (29.1%) patients had one or more co-morbid diseases. Recognised cases included 9 with neonatal jaundice, 5 with urinary tract infection, 1 with septic arthritis of the shoulder joint, 1 with pneumonia and 1 with gastroenteritis. None had recurrent meningitis. Eleven (20.0%) had prior antibiotic therapy within 3 days of admission.

Diagnoses and Aetiologic Agents

Fifteen (27.3%) ABM cases were diagnosed: 7 with group B streptococcus, 3 with *Salmonella* sp., 1 with *Escherichia coli*, 1 with *Flavobacterium* sp., 1 with *Streptococcus pneumoniae*, 1 with *Proteus vulgaris* and 1 with *Streptococcus viridans*. The remaining 40 (72.7%) were AAM cases: 9 with Coxsackie B, 3 with echovirus, 2 with enterovirus and 26 with unknown aetiologies. No patient was infected by multiple aetiologic agents.

Neurological Outcome

Fifty-one young infants were studied for neurological outcome, with 4 excluded due to inadequate follow-up. Forty-one (80.4%) patients recovered uneventfully. Five (9.8%) suffered minor neurological deficits. The maximum duration required for the resolution of minor neurological deficits was 3 months post-discharge. Another 5 patients (9.8%) suffered severe neurological deficits. None died. As such, 46/51 (90.2%) had FNO whereas 5/51 (9.8%) had UFNO. The types of neurological deficits were clinical seizures (8 cases; 5 resolved, 3 persistent), sensorineural hearing loss (4 cases), developmental delay (3 cases, all persistent), hydrocephalus (3 cases; 2 resolved, 1 persistent), cerebral palsy (2 cases), visual impairment (2 cases) and paresis/paralysis (1 case).

Duration of Hospitalisation and Intensive Care

Young infants eventually diagnosed with ABM required longer hospitalisation and more intensive care than those eventually diagnosed with AAM. The differences were highly significant (Table I). This reflects the greater severity of ABM compared to AAM.

Symptoms and Signs of Acute Meningitis

The 3 commonest symptoms were fever, abnormal activity (includes any behaviour change, irritability, crying, lethargy and drowsiness) and decreased feeding (Table II). The 3 commonest signs were temperature >38.0°C, irritability/crying and abnormal tone/reflexes (Table III).

TABLE I: COMPARISON OF THE DURATION OF HOSPITALISATION AND INTENSIVE CARE BY DIAGNOSIS

Factor	All cases (n = 55) Median	ABM (n = 15) Median	AAM (n = 40) Median	*P* value* (ABM vs. AAM)
Duration of hospitalisation (days)	11.0 (8.0-15.0)	21.0 (15.0-40.0)	10.0 (7.0-11.0)	0.000 (HS)
Duration of intensive care (days)	0.0 (0.0-0.0)	2.0 (0.0-7.0)	0.0 (0.0-0.0)	0.000 (HS)

AAM: acute aseptic meningitis; ABM: acute bacterial meningitis; HS: highly significant

(Numbers in brackets represent interquartile range)

*Using the Mann-Whitney U test

TABLE II: SYMPTOMS OF ACUTE MENINGITIS (IN DECREASING ORDER OF FREQUENCY)

Symptom	No.	%
Fever	53/55	96.4
Abnormal activity (includes behaviour change, irritability, crying, lethargy, drowsiness)	38/55	69.1
Decreased feeding	27/55	49.1
Vomiting	18/55	32.7
Fits	4/55	7.3
Coma	0/55	0.0

TABLE III: SIGNS OF ACUTE MENINGITIS (IN DECREASING ORDER OF FREQUENCY)

Signs	No.	%
Temperature >38.0°C	38/55	69.1
Irritability/crying	28/55	50.9
Abnormal tone/reflexes	14/55	25.5
Depressed sensorium (includes lethargy, drowsiness, paediatric GCS <15) (patients not on sedatives prior to assessment)	13/55	23.6
Tense/bulging anterior fontanelle	11/55	20.0
Terminal neck stiffness	6/55	10.9
Clinical dehydration	5/55	9.1
Opisthotonus	4/55	7.3
Kernig's sign	1/55	1.8
Petechial/purpuric rash	0/55	0.0
Papilloedema	0/55	0.0

GCS: Glasgow Coma Scale

Differential Diagnosis of Acute Meningitis

Seventeen possible factors useful in differentiating ABM from AAM were investigated. All were obtained within 24 hours of admission. Seven factors reached or approached statistical significance (Table IV), namely, age, low birth weight, blood P-to-L ratio (ratio of polymorphs to lymphocytes in blood), CSF P-to-L ratio, CSF-to-blood glucose ratio, CSF protein concentration and CSF lactate concentration.

Nine factors had *P* values >0.10: gender, presence of predisposing conditions to meningitis, prior antibiotic use within 3 days of admission, prematurity, temperature >38°C, total leukocyte count in blood, CSF leukocyte count, CSF chloride concentration and blood glucose concentration.

ROC curves were drawn for factors in Table IV with *P* <0.05. The data from the curves are shown in Table V. As can be seen, the factor with the greatest AUC is CSF-to-blood glucose ratio. This means that it is probably the best factor among those studied for the diagnosis of ABM. As the aim of safe ABM prediction is to achieve maximum sensitivity and negative predictive value (NPV) for ABM,[11] a cut-off CSF-to-blood glucose ratio of 0.8 (i.e., one cannot exclude ABM with a glucose ratio less than or equal to 0.8) was adopted based on its ROC curve (Fig. 1). With a cut-off of 0.8 for the prediction of ABM, sensitivity was 100.0%, NPV was 100.0%, specificity was 11.4% and positive predictive value was 27.9%. With a cut-off of 0.3, sensitivity was 75.0%, NPV was 92.1%, specificity was 100.0% and positive predictive value was 100.0% i.e., the diagnosis of ABM was definite with a glucose ratio less than or equal to 0.3.

Prognosis (Neurological Outcome) of Acute Meningitis

Twenty-six possible factors useful in the prognosis (neurological outcome) of acute meningitis were tested. All were acquired within 24 hours of admission. Eight

TABLE IV: FACTORS USEFUL IN THE DIFFERENTIAL DIAGNOSIS OF ACUTE MENINGITIS

Factor	Total no. analysed	No. of ABM	ABM	No. of AAM	AAM	*P* value*
Age (days)	55	15	14.0 (4.0-29.0)	40	32.0 (22.8-51.8)	0.007 (HS)
Low birth weight	55	15	4/15 (26.7)	40	3/40 (7.5)	0.079 (AS)
Blood P-to-L ratio (ratio of polymorphs to lymphocytes in blood)	55	15	2.26 (1.45-5.28)	40	0.95 (0.64-1.37)	0.000 (HS)
CSF P-to-L ratio (ratio of polymorphs to lymphocytes in CSF)	52	12	3.42 (0.65-9.54)	40	0.60 (0.14-2.00)	0.052 (AS)
CSF-to-blood glucose ratio	47	12	0.231 (0.127-0.343)	35	0.544 (0.464-0.643)	0.000 (HS)
CSF protein (g/L)	51	13	2.59 (1.25-4.07)	38	1.09 (0.68-1.26)	0.000 (HS)
CSF lactate (mmol/L)	54	14	4.20 (1.65-11.03)	40	1.95 (1.70-2.28)	0.005 (HS)

AAM: acute aseptic meningitis; ABM: acute bacterial meningitis; AS: approaching significance; CSF: cerebrospinal fluid; HS: highly significant
(Numbers in brackets represent percentage for dichotomous variables and interquartile range for continuous variables)
*Using Fisher's exact test for dichotomous variables and Mann-Whitney U test for continuous variables

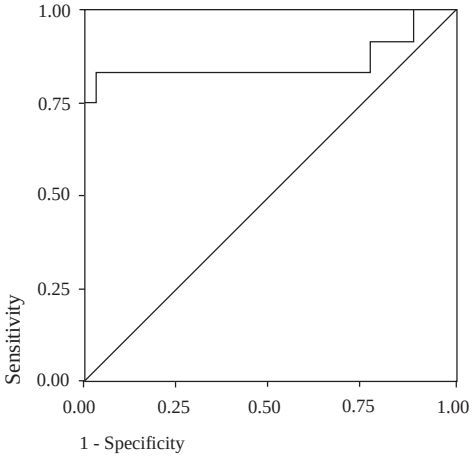

Fig. 1. Receiver operator characteristic (ROC) curve for CSF-to-blood glucose ratio (test variable) vs. ABM (state variable).
ABM: acute bacterial meningitis; CSF: cerebrospinal fluid

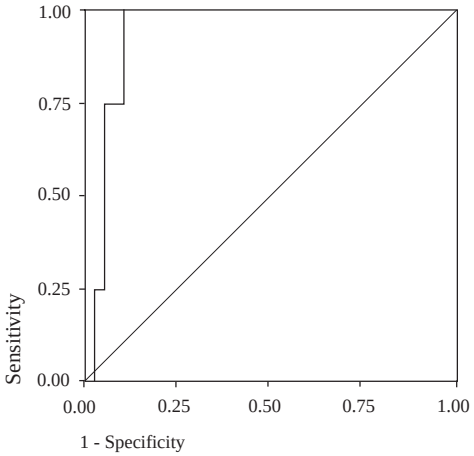

Fig. 2. Receiver operator characteristic (ROC) curve for CSF-to-blood glucose ratio (test variable) vs. UFNO (state variable).
CSF: cerebrospinal fluid; UFNO: unfavourable neurological outcome

factors arrived at or approached statistical significance (Table VI). These factors included depressed sensorium at admission, clinical dehydration, systolic blood pressure, blood polymorphs-to-lymphocytes ratio (ratio of P to L in blood), CSF P-to-L ratio, CSF chloride concentration, CSF-to-blood glucose ratio and CSF lactate concentration.

Eighteen factors had *P* values >0.10: age, gender, prior antibiotic use within 3 days of admission, prematurity, low birth weight, presence of predisposing conditions to meningitis, presence of co-morbidity, irritability/crying, history of fits, temperature >38°C, respiratory rate, pulse rate, haematocrit, total leukocyte count in blood, platelet count in blood, CSF leukocyte count, blood glucose concentration and CSF protein concentration.

ROC curves (not shown) were drawn for factors in Table VI with $P < 0.05$. The data from the curves are displayed in Table VII. As can be seen, the factor with the greatest AUC is CSF-to-blood glucose ratio. This means that it is probably the best factor among those studied for the prognosis of UFNO. One can often reassure the patient's family with sufficient confidence of a favourable neurological outcome. In these situations, a cut-off with maximum sensitivity and NPV will be required. Such a cut-off was determined to be 0.3 (i.e., glucose ratio more than 0.3 allows one to exclude UFNO and to reassure the patient's family of favourable neurological outcome with confidence) from the ROC curve (Fig. 2). With a cut-off of 0.3 for the prediction of UFNO, sensitivity was 100.0%, NPV was 100.0%, specificity was 87.1% and positive predictive value was 44.4%. No cut-off value existed for which 100.0% specificity could be obtained.

Discussion

Acute meningitis is one of the most worrying infections in the neonatal period. Incidence of neonatal sepsis/meningitis in the industrialised world is about 0.5 to 3.0/1000 live births.[18-20] Acute meningitis is also associated with high morbidity and mortality. In a local review of 36 paediatric cases done between 1984 and 1987, 4 (11.1%) paediatric patients suffered neurological sequelae while 5 (13.9%) died.[21]

In the diagnosis of acute meningitis in young infants, the 3 commonest symptoms are fever, abnormal activity (includes any behaviour change, irritability, crying, lethargy and drowsiness) and decreased feeding. The 3 commonest signs are temperature >38.0°C, irritability/crying and abnormal tone/reflexes. Such clinical clues are generally non-specific for meningitis, though abnormal tone/reflexes

TABLE V: RECEIVER OPERATOR CHARACTERISTIC CURVE INFORMATION

Factor	No. of cases analysed	Area under the curve (AUC)	SE (standard error of AUC)	95% confidence interval for AUC
Age (days)	55	0.738	0.091	(0.561,0.916)
Blood P-to-L ratio (ratio of polymorphs to lymphocytes in blood)	55	0.823	0.068	(0.690,0.957)
CSF-to-blood glucose ratio	47	0.860	0.090	(0.683,1.036)
CSF protein (g/L)	51	0.854	0.063	(0.730,0.978)
CSF lactate (mmol/L)	54	0.752	0.101	(0.553,0.951)

CSF: cerebrospinal fluid

TABLE VI: FACTORS USEFUL IN THE PROGNOSIS (NEUROLOGICAL OUTCOME) OF ACUTE MENINGITIS

Factor	Total no. analysed	No. of FNO	FNO	No. of UFNO	UFNO	*P* value*
Depressed sensorium at admission	51	46	10/46 (21.7%)	5	3/5 (60.0%)	0.098 (AS)
Clinical dehydration	51	46	3/46 (6.5)	5	2/5 (40.0)	0.069 (AS)
Systolic blood pressure (mmHg)	48	43	91.05 (81.0-101.0)	5	67.0 (60.0-94.0)	0.054 (AS)
Blood P-to-L ratio (ratio of polymorphs to lymphocytes in blood)	51	46	1.11 (0.71-2.08)	5	2.79 (1.53-5.33)	0.037 (S)
CSF P-to-L ratio (ratio of polymorphs to lymphocytes in CSF)	48	44	0.74 (0.16-3.88)	4	6.61 (2.58-11.47)	0.052 (AS)
CSF chloride concentration (mmol/L)	48	44	118 (115-124)	4	111 (100-117)	0.040 (S)
CSF-to-blood glucose ratio	43	39	0.535 (0.423-0.651)	4	0.159 (0.103-0.252)	0.004 (HS)
CSF lactate concentration	50	46	2.10 (1.70-3.13)	4	7.30 (2.23-14.40)	0.085 (AS)

AS: approaching significance; CSF: cerebrospinal fluid; FNO: favourable neurological outcome; HS: highly significant; S: significant; UFNO: unfavourable neurological outcome
(Numbers in brackets represent percentage for dichotomous variables and interquartile range for continuous variables)
*Using Fisher's exact test for dichotomous variables and Mann-Whitney U test for continuous variables

TABLE VII: RECEIVER OPERATOR CHARACTERISTIC CURVE INFORMATION

Factor	No. of cases analysed	Area under the curve (AUC)	SE (standard error of AUC)	95% confidence interval for AUC
Blood P-to-L ratio (ratio of polymorphs to lymphocytes in blood)	51	0.787	0.120	(0.551,1.023)
CSF chloride concentration (mmol/L)	48	0.813	0.123	(0.572,1.053)
CSF-to-blood glucose ratio	43	0.942	0.036	(0.871,1.013)

CSF: cerebrospinal fluid

may indicate raised intracranial pressure and meningeal irritation. Nonetheless, when found in combination, they indicate serious infections in young infants[12,22] and point towards early admission into a tertiary facility. Further, absence of these symptoms and signs practically eliminates the prospect of acute meningitis. As expected, classical signs like neck stiffness (10.9% cases presented with this sign) and Kernig's sign (1.8%) were rare in the study population.

In the differential diagnosis of acute meningitis, 7 factors reached or approached statistical significance i.e., age, low birth weight, blood P-to-L ratio (ratio of polymorphs to lymphocytes in blood), CSF P-to-L ratio, CSF-to-blood glucose ratio, CSF protein concentration and CSF lactate concentration. This is generally in keeping with findings from earlier studies involving neonates, older children and adults. CSF-to-blood glucose ratio proved to be a safe predictor of ABM when used at a cut-off value of 0.8, and a definitive predictor of ABM when used at a cut-off value of 0.3.

For the prognosis of acute meningitis, it is axiomatic that decreased cerebral perfusion can lead to neurological damage. In meningitis, lowered perfusion can occur in 2 main ways, especially when meningitis impairs cerebral blood flow autoregulation:[23,24] (1) increased intracranial pressure and (2) decreased arterial pressure. The latter mechanism may be secondary to decreased intravascular volume. Data from this study substantiate the proposed pathophysiology. Decreased systolic blood pressure (as shown too by a large study on adults[25]) and CSF chloride concentration (a marker of dehydration and electrolyte loss[16]) were found to be significant factors related to UFNO by bivariate analysis. In addition, clinical dehydration approached statistical significance ($P = 0.069$). CSF lactate concentration, which reflects the presence of anaerobic metabolism and cerebral ischaemia,[26,27] was also higher in the UFNO group ($P = 0.085$).

Moreover, hypoglycorrhachia can result in cerebral glycopenia and brain damage. Indeed, diminished CSF-to-blood glucose ratio was another significant factor associated with UFNO.[28] Lastly, inflammation and associated cerebral oedema can produce both increased intracranial pressure as well as direct neurological damage from cerebral vasculitis.[29] Data from this study showed that a raised blood P-to-L ratio ($P = 0.037$) and an elevated CSF P-to-L ratio ($P = 0.052$) were other important factors. Depressed sensorium at admission was also associated ($P = 0.098$) with poor outcome, as was shown by other studies involving adults.[8,30]

Interestingly, the CSF-to-blood glucose ratio again proved to be the most useful predictor of UFNO.

A major constraint of this study was the small number of patients involved. However, this does not erode the importance of the various statistically significant variables found, many of which have been proven by other studies. Unfortunately, this does mean that some variables that may be significant were found not to be. Furthermore, some cases of partially treated ABM may be misclassified as AAM. Even so, such cases can be justifiably regarded as AAM. Analysis of the data showed that an eventual diagnosis of AAM (according to the study definition) was significantly less likely to lead to UFNO (P = 0.001). Finally, another limitation of this study, faced by many other investigators, was the limited follow-up period post-discharge. Some long-term neurological complications like learning difficulties may not be detected until the children reach school age.

Conclusions

In brief, differentiating acute bacterial and aseptic meningitis by history and physical examination alone is difficult. However, with the aid of laboratory tests, in particular the CSF-to-blood glucose ratio, one can diagnose ABM and prognosticate for unfavourable neurological outcome with high sensitivity and NPV within 24 hours of admission.

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