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Meningococcal Septic Shock in Children: Clinical and Laboratory Features, Outcome, and Development of a Prognostic Score

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The clinical characteristics of and outcome for 75 children with meningococcal septic shock were studied. In addition, a new prognostic scoring system was developed. The median age of the patients was 3.2 years (range, 3 weeks to 17.9 years). The most common phenotype of *Neisseria meningitidis* was B:4:P1.4 (27%). A mortality rate of 21% was observed. Ten (17%) of the 59 survivors had serious sequelae. Calcium levels were significantly lower in patients with seizures. Disseminated intravascular coagulation occurred in 58% of the patients who were tested. Logistic regression analysis identified four laboratory features independently associated with mortality: serum C-reactive protein level, base excess, serum potassium level, and platelet count. These features were used to develop a novel scoring system with a predictive value for death and survival of 71% and 90%, respectively. The outcome was predicted correctly for 86% of the patients, which is higher than rates previously reported for scoring systems.

Septic shock and purpura or severe infectious purpura with shock is a life-threatening entity in previously healthy children. The syndrome is mainly caused by *Neisseria meningitidis,* although occasionally *Haemophilus influenzae* type b is involved. Meningococcal disease still remains a major health problem in both developing and industrialized countries. Group B is the predominant serogroup among strains causing meningococcal disease followed by group C [1].

From 1970 to 1980, the annual incidence of meningococcal disease in the Netherlands varied between 0.7 and 2.0 cases per 100,000 population. The incidence of meningococcal disease gradually increased during the 1980s and reached 3.5 cases per 100,000 inhabitants in 1990. The age-specific incidence is highest among children younger than 5 years of age (~22.8 cases per 100,000 population) [1, 2]. In addition, the percentage of patients with meningococcal sepsis without clinical meningitis increased in the same period [3, 4].

Despite the use of antibiotics and intensive care treatment, septic shock together with purpura is still associated with high mortality and morbidity rates. Mortality rates range between 25% and 50% [5–7]. A relatively small percentage of the survivors have serious sequelae, such as extensive skin necrosis requiring skin grafting and amputation.

The use of scoring systems combining data of prognostic significance in the assessment of patients with acute meningococcal disease or septic shock and purpura has attracted much interest [6–18]. According to a number of studies, signs of poor prognosis at the time of admission are the absence of meningeal inflammation and the presence of rapidly evolving hemorrhagic skin lesions, hyperpyrexia, leukocytopenia, thrombocytopenia, low plasma levels of fibrinogen, disseminated intravascular coagulation, metabolic acidosis, and rapid clinical deterioration [6–19]. Combinations of clinical and laboratory features have been used to develop scoring systems to predict mortality. However, these systems are often partly based on subjective clinical criteria.

The purpose of this study was to evaluate the epidemiology, clinical features, laboratory features, and outcome of meningococcal septic shock in children admitted to the Sophia Children's Hospital (Rotterdam, the Netherlands) between 1988 and 1995. In addition, the prognostic significance of several clinical and laboratory features was evaluated, and a new prognostic score was developed.

Patients and Methods

The records of all patients 18 years of age and younger who were admitted to the Pediatric Intensive Care Unit (PICU) of the Sophia Children's Hospital because of meningococcal septic shock from October 1988 through June 1995 were prospectively evaluated. Shock was defined as a mean arterial blood pressure of >2 SDs below the normal value for age [19] and/or poor end-organ perfusion defined by at least two of the following criteria: unexplained metabolic acidosis (pH, ≤7.3),

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base excess of ≤ -5 mmol/L, or arterial plasma lactate levels of >2.0 mmol/L; arterial hypoxia defined as Pa_{O_2} of ≤ 75 mm Hg, Pa_{O_2}–to–Fi_{O_2} (fraction of inspired oxygen) ratio of <250, or Tc_{O_2} (transcutaneous O_2 saturation) of $\leq 96\%$ in patients without overt cardiopulmonary disease; acute renal failure defined as oliguria with a urinary output of <0.5 mL/(kg · h) for at least 1 hour despite acute volume loading or evidence of adequate intravascular volume and no preexistent renal disease; and sudden deterioration of the patient's mental status.

A subset of the patients was enrolled in a randomized, double-blind, placebo-controlled trial to study the efficacy of HA-1A human monoclonal antibody (Centoxin, Centocor, Malvern, PA) against meningococcal septic shock.

Medical records were analyzed for demographic, clinical, and laboratory features and outcome. The data were abstracted by using a standard form. Patients who were initially treated at other hospitals but were transferred to this hospital for intensive care treatment were also included. Decisions regarding the use of antibiotics, intravenous fluids, and inotropic and vasopressor support and the initiation of mechanical ventilation were made by the patient's attending physician.

Definitions

The severity of illness at admission to the PICU was assessed by using the pediatric risk of mortality (PRISM) score [20]. The duration of symptoms and petechiae was estimated as precisely as possible. Meningitis was defined as a positive bacterial culture of CSF, positive gram-staining of CSF, or a positive blood culture in combination with clinical evidence of meningitis and a CSF WBC count of $>10/mm^3$. Respiratory distress was defined as a condition that required mechanical ventilation because of respiratory failure. Disseminated intravascular coagulation was defined by the combination of three of the following features: platelet count of $<150 \times 10^9$/L, fibrinogen level of <2 g/L, factor V measurement of $<60\%$, and presence of fibrinogen degradation products [21]. Patients were divided into different groups for statistical analyses. Survivors were compared with nonsurvivors.

Laboratory Studies

Bacteriologic methods. Specimens of CSF and/or blood were routinely cultured. These specimens were obtained from all patients before antibiotic therapy was initiated. Microorganisms were identified according to standard procedures [22]. Isolates from blood and/or CSF were sent to the Netherlands Reference Laboratory for Bacterial Meningitis (Department of Medical Microbiology, University of Amsterdam, Amsterdam, and the National Institute for Public Health and the Environment, Bilthoven, the Netherlands). *N. meningitidis* strains were classified into serogroups, serotypes, and subtypes on the basis of antigenic differences in their capsular polysaccharides and in class 2/3 and class 1 outer membrane proteins, respectively. Meningococci were serogrouped by means of Ouchterlony gel diffusion with use of rabbit sera containing antibodies to the capsular polysaccharides of the serogroups (these sera were produced at the Netherlands Reference Laboratory for Bacterial Meningitis) [23]. Serotyping and subtyping were performed by means of a whole-cell ELISA [1, 24].

Clinical hematology and serum chemistry studies. Laboratory studies including determination of a complete blood cell count and serum chemistry analysis were routinely performed at the time of admission. Blood samples for analysis of hematologic characteristics were collected in a microtainer containing EDTA (K_2). Blood samples for clinical serum chemistry studies were collected into sterilized siliconized Vacutainer glass tubes (Becton Dickinson, Meylan Cedex, France) and allowed to clot at room temperature. Samples were centrifuged at 1,600*g* for 10 minutes at 4°C.

Coagulation and fibrinolysis assays. All assays were performed with commercially available reagents and methods. Blood samples for coagulation and fibrinolysis assays were collected in trisodium citrate (0.109*M*; anticoagulant-to-blood ratio, 1:9 [vol/vol]). Clotting assays were used for the determination of the activated partial thromboplastin time. The measurement of factor V was determined with a one-stage assay with use of factor V–deficient plasma and fibrinogen according to the method of Clauss [25] (Behring-Werke AG, Marburg, Germany). A semiquantification of fibrinogen degradation products in plasma was performed by latex agglutination (Diagnostica Stago, Asnières-sur-Seine, France).

Statistical Analysis

Results are expressed as means ± SD unless stated otherwise. Various variables between groups of patients were compared by means of the Mann-Whitney test. Frequencies of various findings between groups were compared by Fisher's exact test. Pearson's correlation coefficient (r) or Spearman's rank correlation (r_s) was used to evaluate the relation between specific variables. Multiple regression analysis was performed to evaluate factors that might affect the difference in variables between survivors and nonsurvivors. Logistic regression analysis with backward elimination was performed to develop a prognostic score for mortality that was based on variables obtained at admission [26]. Two-tailed P values of $\leq .05$ were considered statistically significant.

Results

Patient Characteristics

Seventy-five children with meningococcal septic shock were evaluated. Forty-two were males, and 33 were females. The median age of the patients was 3.2 years (range, 3 weeks to 17.9 years). Twenty-four children (32%) were younger than 2 years of age, 35 (47%) were between 2 and 10 years of age,

Table 1. Distribution of serogroups, serotypes, and subtypes of *Neisseria meningitidis* among 71 children with meningococcal septic shock who were admitted to the Pediatric Intensive Care Unit of Sophia Children's Hospital (Rotterdam, the Netherlands).

	No. of patients infected with serogroup/ 71 patients (%)	
Sero- or subtype	B (n = 58 [82%])	C (n = 13 [18%])
Serotype		
2a	2 (3)	7 (10)
4	38 (54)	3 (4)
Other	6 (8)	1 (1)
Nontypeable	12 (17)	2 (3)
Subtype		
P1.4	24 (34)	3 (4)
P1.15	5 (7)	0
Other	16 (23)	7 (10)
Nontypeable	13 (18)	3 (4)

and 16 (21%) were older than 10 years of age. Forty-nine of the children participated in the clinical trial of the efficacy of HA-1A human monoclonal antibody (23 HA-1A recipients and 26 placebo recipients). The PRISM score at admission to the PICU ranged from 0 to 38 (median, 11). Twelve patients were directly admitted to our hospital, and 63 were referred by other hospitals. None of the patients received antibiotic treatment before or during transport to the first institution.

Hospitalization occurred within 12 hours after the onset of petechiae in 95% of the patients. In 10 patients (13%), petechiae developed during hospitalization. The transferal time from the first institution to the PICU of Sophia Children's Hospital was <12 hours for 55 of the 63 transferred patients. The mean duration ± SD of symptoms and the mean interval ± SD between the appearance of petechiae and admission to the Sophia Children's Hospital were 19.2 ± 7.3 and 7.1 ± 5.8 hours, respectively.

A lumbar puncture was performed in 53 cases at the time of admission. Meningitis was documented in 33 cases (62%). Culture of CSF from nine patients was positive. All 75 patients needed inotropic and vasopressor support. Forty-four (59%) of the 75 patients needed mechanical ventilation.

Bacteriologic Findings

Cultures of blood, CSF, or skin biopsy specimens from 75 children yielded *N. meningitidis.* Seventy-one strains of *N. meningitidis* were available for typing. Four other isolates were not sent to the Netherlands Reference Laboratory for Bacterial Meningitis. The distribution of the serogroups, serotypes, and subtypes of *N. meningitidis* is shown in table 1. Fifty-eight (82%) of 71 strains were serogroup B, and 13 (18%) were serogroup C. The most common phenotype of *N. meningitidis* in this study was B:4:P1.4 (27%). The distribution of the serogroups according to age differed. The mean age ± SD of children infected with serogroup C meningococci was significantly higher than that of those infected with serogroup B meningococci (4.6 ± 4.6 years vs. 7.7 ± 5.3 years, respectively; P = .04).

Outcome

Survivors vs. nonsurvivors. The mortality rate was 21% (95% CI, 12%–32%). We did not observe a difference between the mortality rates among HA-1A and placebo recipients (five [22%] of 23 vs. seven [27%] of 26, respectively; P = .75). Fourteen children died of irreversible septic shock. Two patients died of CNS complications. Fifty percent of the deaths occurred within the first 24 hours, and nearly 90% occurred within 48 hours. The median duration from the onset of symptoms until death was 40 hours (range, 11–143 hours).

The demographic and clinical characteristics of the 59 survivors and the 16 nonsurvivors at admission to the PICU are shown in table 2. The mortality rate was higher among children younger than 4 years of age than among those 4 years of age or older (13 [33%] of 40 vs. three [9%] of 35, respectively; P = .02). The mortality rate among patients admitted primarily to the Sophia Children's Hospital was higher than that among transferred patients (five [42%] of 12 vs. 11 [17%] of 63, respectively; P = .12]). The PRISM score for the primary patients was worse than that for the transferred patients (14.3 ± 5.2 vs. 11.7 ± 7.9, respectively; P = .21). The interval between the onset of petechiae and admission to the PICU was shorter for nonsurvivors.

Complications and sequelae in survivors. The median hospital stay was 13 days (range, 10–207 days) for the survivors. Twenty-eight of the 59 survivors were mechanically ventilated for a median duration of 7 days (range, 1–24 days). Most survivors recovered without sequelae. Two patients had serious neurological sequelae. Dermatologic or orthopedic sequelae requiring skin grafting or amputations occurred in nine of the 59 survivors. Two patients required hemofiltration because of renal failure; one patient developed osteomyelitis. Seizures occurred in seven patients.

Laboratory Findings

Demographic and laboratory features of survivors and nonsurvivors are shown in tables 2 and 3. Occasionally, laboratory data were missing, but this never occurred for more than 11 patients for a given characteristic.

Initially, 16 patients (21%) had a peripheral WBC count of $<5 \times 10^9$/L. Platelet counts were $<50 \times 10^9$/L in 13 (18%) of 74 patients. The acid-base status and the arterial serum lactate levels showed striking abnormalities that were more severe in nonsurvivors. Serum glucose levels were significantly lower in the nonsurvivors, but hypoglycemia (<2.5 mmol/L) was observed in seven children. Hypokalemia (<3.5 mmol/L)

Table 2. Characteristics of 75 children with meningococcal septic shock at the time of admission to the PICU of Sophia Children's Hospital (Rotterdam, the Netherlands).

Characteristic	No. of observations	Mean value ± SD or value (%)		*P* value
		Survivors (n = 59)	Nonsurvivors (n = 16)	
Age (y)	75	5.8 ± 5.0	3.6 ± 3.7	NS
Sex*	75	33 (56)	9 (56)	NS
Transferred	75	52 (88)	11 (69)	NS
Interval (h) from				
Onset of symptoms to PICU admission	72	19.5 ± 7.1	18.0 ± 8.3	NS
Appearance of petechiae to PICU admission	73	7.6 ± 5.9	5.5 ± 5.1	.06
PRISM score	75	10.1 ± 7.1	18.6 ± 5.1	<.001
Hematology analysis				
Hb level	75	6.6 ± 0.9	6.1 ± 1.2	NS
WBC count ($\times 10^9$/L)	75	14.5 ± 10.0	9.0 ± 9.6	.02
Platelet count ($\times 10^9$/L)	74	110 ± 51	63 ± 37	.001
Serum chemistry analysis				
Sodium level (mmol/L)	75	135 ± 5	137 ± 4	NS
Potassium level (mmol/L)	75	3.4 ± 0.6	4.1 ± 0.7	<.001
Calcium level (mmol/L)	70	1.92 ± 0.24	1.83 ± 0.26	NS
Glucose level (mmol/L)	65	6.6 ± 2.9	4.6 ± 2.8	.02
Lactate level (mmol/L)	70	5.1 ± 3.3	7.3 ± 4.1	.005
Creatinine level (μmol/L)	70	87 ± 55	118 ± 67	NS
CRP level (mg/L)	66	135 ± 69	80 ± 53	.006
Albumin level (g/L)	67	33 ± 6	34 ± 10	NS
Acid-base balance				
pH	75	7.37 ± 0.08	7.27 ± 0.12	.003
BE (mmol/L)	74	−6.2 ± 3.9	−11.4 ± 4.4	<.001
Bicarbonate level (mmol/L)	75	17.4 ± 3.5	13.9 ± 3.1	.001

NOTE. BE = base excess; CRP = C-reactive protein; Hb = hemoglobin; NS = not significant; PICU = Pediatric Intensive Care Unit; PRISM = pediatric risk of mortality.

* No. (%) of males.

was observed in 52% of the patients. Serum potassium levels were highly correlated with the arterial pH (r_s = −.46; P < .001). Analysis of covariance showed that serum potassium levels were significantly higher in nonsurvivors than in survivors irrespective of the arterial pH (figure 1).

Serum calcium concentrations were measured in 70 cases (93%). Hypocalcemia (<2.2 mmol/L) was detected in 62 patients (89%). Ionized calcium levels were available only in a limited number of patients and are therefore not shown. It is of interest that serum calcium levels were lower in patients with seizures than in those without seizures (1.69 ± 0.12 mmol/L vs. 1.92 ± 0.03 mmol/L, respectively; P = .03). The serum levels of C-reactive protein (CRP) were significantly lower in nonsurvivors than in survivors and correlated strongly with the interval between the onset of symptoms and petechiae and the time of blood sampling (r = .62, P < .001; and r = .54, P < .001; respectively).

Table 3. Coagulation and fibrinolysis characteristics of 75 children with meningococcal septic shock who were admitted to the PICU of Sophia Children's Hospital (Rotterdam, the Netherlands).

Characteristic	No. of observations	Reference range or value	Median value (range) or mean value ± SD		*P* value
			Survivors (n = 59)	Nonsurvivors (n = 16)	
Coagulation					
APTT (s)	66	28–40	54 (29–>200)	104 (53–200)	<.001
Factor V measurement (%)	64	70–140	40 ± 21	21 ± 14	.002
Fibrinogen level (g/L)	67	1.8–3.5	2.6 (<0.4–5.8)	1.1 (<0.4–5.4)	.001
Fibrinolysis					
FDP level (mg/L)	65	<5	50 (<5–>300)	110 (35–>300)	.003

NOTE. APTT = activated partial thromboplastin time; FDP = fibrin or fibrinogen degradation product; PICU = Pediatric Intensive Care Unit.

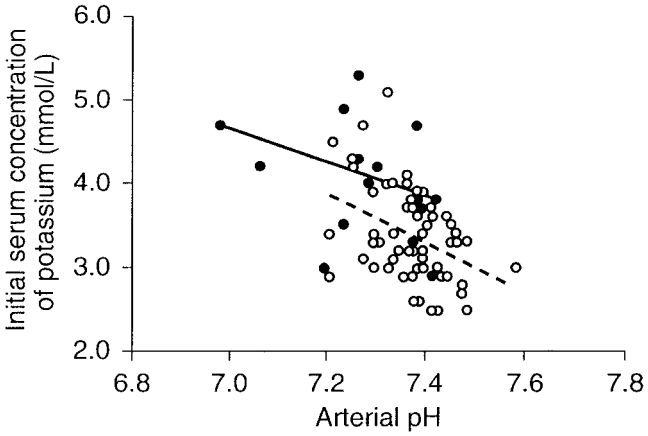

Figure 1. Relation between initial serum concentrations of potassium and arterial pH in 75 children with meningococcal septic shock who were admitted to the Pediatric Intensive Care Unit of Sophia Children's Hospital in Rotterdam, the Netherlands. Dashed and solid lines indicate the regression lines through the values for survivors (○) and nonsurvivors (●), respectively. Slopes between the regression lines for the survivors and nonsurvivors did not significantly deviate from parallelism.

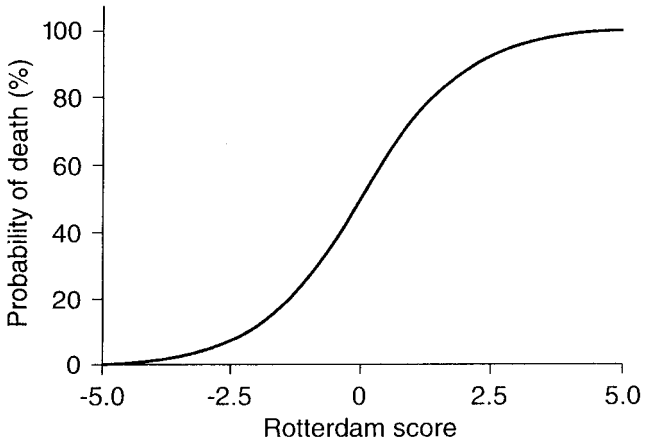

Figure 2. Probability of death in the Pediatric Intensive Care Unit of Sophia Children's Hospital (Rotterdam, the Netherlands) according to the Rotterdam score that predicts the outcome for patients with meningococcal septic shock on the basis of four laboratory variables (serum C-reactive protein level, serum potassium level, base excess, and platelet count).

Coagulation studies were performed for most patients (table 3). Fibrinogen levels were ⩽1.5 g/L in 17 (25%) of 67 patients. The presence of disseminated intravascular coagulation could be determined for 60 patients; it occurred significantly more often in nonsurvivors than in survivors (12 [92%] of 13 vs. 23 [49%] of 47, respectively; $P = .005$).

Prognostic Analysis

Most variables listed in tables 2 and 3 that were documented at the time of admission were associated with a poor prognosis. Factors that appeared to discriminate according to the univariate analysis were considered for inclusion in a prognostic scoring system. Logistic regression analysis identified four independent variables predicting the likelihood of survival. These variables were serum CRP level, serum potassium level, base excess, and platelet count. Two of these variables were significantly associated with the duration of petechiae (base excess: $r = .32$, $P = .007$; serum CRP level: $r = .54$, $P < .001$). However, logistic regression analysis including the duration of petechiae did not improve the predictive value of the new prognostic scoring system—the Rotterdam score.

The mathematical expression of the probability of death in the PICU in this study was $e^{RS}/1 + e^{RS}$, where the Rotterdam score (RS) = 1.01 + (1.21 × serum potassium level) − (0.29 × base excess) − (0.024 × platelet count) − (3.75 × log serum CRP level). The graphic representation of the model is shown in figure 2. This new prognostic score was compared with five other scoring systems. Each scoring system was applied to data for our patients. Our score had the highest predictive value for death and survival (table 4). The newly developed Rotterdam score highly correlated with the PRISM score ($r = .58$; $P < .001$).

Discussion

The clinical picture of septic shock and purpura is induced by meningococci (or occasionally other bacteria) and by their products (lipopolysaccharides) and mediated by a multitude of inflammatory mediators. The inflammatory response may develop into irreversible circulatory collapse, renal failure, adult respiratory distress syndrome, and death.

Table 4. Prediction of outcome for children with meningococcal septic shock who were admitted to the PICU of Sophia Children's Hospital (Rotterdam, the Netherlands) that was based on different prognostic scoring systems.

Score [reference]	No. of patients	Predictive value (%) for		Accuracy (%)
		Survival	Death	
Niklasson [17]	53	88	25	45
Leclerc [6]	63	93	61	84
CRP [11]	66	91	39	66
Giraud [7]	67	90	47	78
PRISM [20]	75	88	72	85
Rotterdam* [PR]	65	90	71	86

NOTE. CRP = C-reactive protein; PICU = Pediatric Intensive Care Unit; PR = present report; PRISM = pediatric risk of mortality.

* The Rotterdam score predicts the outcome for patients with meningococcal septic shock on the basis of four laboratory features (serum CRP level, serum potassium level, base excess, and platelet count).

In the present study, we showed that meningococcal septic shock is associated with a mortality rate of 21% and serious sequelae in 17% of the survivors. The mortality rate among patients directly admitted to the Sophia Children's Hospital was higher than that among transferred patients. This result was probably due to patient selection, since extremely ill patients died before transfers could be organized. The clinical conditions of transferred patients were relatively better, as can be inferred from the lower PRISM scores. In contrast, Tesoro and Selbst [12] observed that the mortality rate among patients transferred from another hospital was higher.

In our study, the mortality rate was also higher among children younger than 4 years of age than among older children. The lower plasma levels of the naturally occurring circulating anticoagulants proteins C and S in children younger than 4 years of age may contribute to the worse outcome for these patients [27]. Long-term morbidity was observed in 17% of the survivors and was caused by deforming amputation or large areas of soft-tissue destruction secondary to coagulopathy and by neurological sequelae. A similar percentage was observed by Madden et al. [28] and Naess et al. [29].

The incidence of meningococcal disease in the Netherlands gradually increased from 1.1 cases per 100,000 inhabitants in 1982 to 4.3 cases per 100,000 inhabitants in 1993. Strain B:4:P1.4 was most frequently isolated from our patients. This strain was not found before 1980 but became the most prevalent strain in 1990 (21% of all isolates) [1].

Striking differences in clinical and laboratory characteristics between survivors and nonsurvivors were observed. The shorter interval between the appearance of petechiae and admission and the lower serum level of CRP in nonsurvivors suggest a shorter disease course. These data indicate that the conditions of nonsurvivors deteriorate more quickly because they accumulate more native lipopolysaccharides per interval that trigger all mediator systems more intensively or because they have a higher responsiveness to lipopolysaccharides or proinflammatory cytokines [30].

Complex abnormalities were observed in electrolyte levels and acid-base status. Metabolic acidosis and increased arterial serum lactate levels are the inevitable consequence of poor end-organ perfusion leading to glycolysis. The serum sodium level was usually normal. It is interesting that we found hypokalemia rather than hyperkalemia in patients with septic shock. Hypokalemia was more severe in survivors than in nonsurvivors, even when we adjusted for the degree of acidosis (which would normally be expected to result in a shift of potassium from the intracellular space). Hypokalemia may be caused by the release of catecholamines leading to an increased intracellular shift of potassium into skeletal muscle [31]. The relatively higher serum potassium levels in nonsurvivors may be caused by metabolic derangements [31], more severe renal impairment, or rhabdomyolysis.

Hypocalcemia was also seen in a large number of patients as observed by other investigators [32–34]. It is of interest that patients who had seizures during their initial disease course had lower serum calcium levels than did the other children. Hypotension, acidosis, and electrolyte abnormalities may play a major role in the deterioration of myocardial function and may predispose to arrhythmias and cardiac arrest.

Scoring systems for disease severity or a prognostic score has been useful in the assessment of care requirement, efficacy of therapy, and prognosis. Previously, several scoring systems were developed for patients with acute meningococcal infections or septic shock and purpura. Most of these systems included the presence or absence of meningeal irritability or an elevated WBC count in CSF [13, 15–18, 35]. The assessment of neck stiffness, however, is unreliable for severely ill patients. Tesoro and Selbst [12] concluded that the absence of meningeal involvement is not an important predictor of mortality. A CSF WBC count is not always available since lumbar puncture is usually not performed because of the unstable clinical condition at the time of presentation. Other scoring systems require variables such as the erythrocyte sedimentation rate and the difference between skin and rectal temperatures, which are not always available [10, 18].

We therefore developed a simple score for patients with meningococcal septic shock that requires only objective variables available at any emergency department or pediatric intensive care unit soon after admission. Logistic regression analysis revealed four laboratory features, including low serum potassium levels, a negative base excess, a low platelet count, and a low serum CRP level (which were all significantly associated with fatal outcome). Base excess and serum potassium levels both reflect the degree of metabolic abnormalities. Low platelet counts are highly predictive for disseminated intravascular coagulation. Serum CRP levels reflect the duration of illness since these levels correlate positively with the duration of petechiae and other symptoms in patients with septic shock and purpura [30]. Only simple laboratory procedures that are routinely performed are needed for the predictor of risk for mortality that we developed. The prognostic value of our scoring system was higher than that reported for previously developed scoring systems; however, since we validated this new score for patients with meningococcal septic shock with use of the same group of patients who were used to develop this score, a slight overestimate of the utility of the score in predicting mortality may have occurred.

This score will enable accurate prediction of mortality risk for individuals or provide a relative scale for severity of illness. This score can also be used to evaluate the effects of future therapeutic interventions and to assess the evolution of disease in the first 24 hours.

In the present study, beneficial effects of HA-1A human monoclonal antibody on the outcome for children with meningococcal septic shock were not shown. This observation is in accordance with a recent study that did not find a reduction in the 14-day mortality rate among patients with bacteremia due to gram-negative organisms and septic shock [36].

We conclude that meningococcal septic shock in children is associated with a mortality rate of 21% (95% CI, 12%–32%). The mortality rate was even higher among children younger than 4 years of age. Seventeen percent of the survivors had serious sequelae, such as skin necrosis requiring skin grafting or amputation, osteomyelitis, and neurological sequelae. Logistic regression analysis identified four laboratory features that were used in a prognostic score to predict outcome. The predictive value for death and survival were 71% and 90%, respectively. The overall outcome was predicted correctly in 86% of the cases.

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