

The role of healthcare delivery in the outcome of meningococcal disease in children: case-control study of fatal and non-fatal cases

Nelly Ninis, Claire Phillips, Linda Bailey, Jon I Pollock, Simon Nadel, Joseph Britto, Ian Maconochie, Andrew Winrow, Pietro G Coen, Robert Booy, Michael Levin

Abstract

Objective To determine whether suboptimal management in hospital could contribute to poor outcome in children admitted with meningococcal disease.

Design Case-control study of childhood deaths from meningococcal disease, comparing hospital care in fatal and non-fatal cases.

Setting National statistics and hospital records.

Subjects All children under 17 years who died from meningococcal disease (cases) matched by age with three survivors (controls) from the same region of the country.

Main outcome measures Predefined criteria defined optimal management. A panel of paediatricians blinded to the outcome assessed case records using a standardised form and scored patients for suboptimal management.

Results We identified 143 cases and 355 controls. Departures from optimal (per protocol) management occurred more frequently in the fatal cases than in the survivors. Multivariate analysis identified three factors independently associated with an increased risk of death: failure to be looked after by a paediatrician, failure of sufficient supervision of junior staff, and failure of staff to administer adequate inotropes. Failure to recognise complications of the disease was a significant risk factor for death, although not independently of absence of paediatric care ($P = 0.002$). The odds ratio for death was 8.7 (95% confidence interval 2.3 to 33) with two failures, increasing with multiple failures.

Conclusions Suboptimal healthcare delivery significantly reduces the likelihood of survival in children with meningococcal disease. Improved training of medical and nursing staff, adherence to published protocols, and increased supervision by consultants may improve the outcome for these children and also those with other life threatening illnesses.

Introduction

Meningococcal disease remains the most common infectious cause of death in children in many developed countries.^{1,2} Although treatment on a paediatric intensive care unit improves outcome,^{3,4} most patients present to their nearest emergency department and many deteriorate so rapidly that death from shock and multiorgan failure often occurs before transfer to a specialist paediatric intensive care unit. The speed with which the diagnosis is made, antibiotics administered, and the complications of shock and multiorgan failure treated is likely to be a major determinant of outcome.⁵ To test the hypothesis that outcome depends on the quality of health care early in the disease

we undertook a national, blinded, case-control study of healthcare delivery in the first 24 hours after admission to hospital in children who died from meningococcal disease compared with those who survived.

Methods

We used the network of regional public health epidemiologists and consultants in communicable diseases in England, Wales, and Northern Ireland and data from the Office for National Statistics to identify cases of meningococcal disease in children aged 0-16 years between 1 December 1997 and 28 February 1999. We used definitions from the Public Health Laboratory Meningococcus Working Group for possible, probable, and confirmed cases of meningococcal disease.⁶ These definitions are primarily for public health use but we used them to recruit patients through the public health network. We discussed cases of possible or probable meningococcal disease with consultants in disease control and the consultant responsible for the patient. We excluded cases in which it was thought that meningococcal disease was unlikely. For each death (case), we identified three survivors (controls) from the same region of the country matched for age (<1, 1-4, 5-14, and 15-16 years), corresponding to different risks of mortality.⁷

A major problem in both the design and analysis of this study was how to control for the expected differences in severity of disease between fatal and non-fatal cases. The children who died were probably more ill than those who survived and would therefore require more medical interventions, which in itself could give rise to greater opportunity for treatment failure. At presentation to hospital, however, children who eventually die are not always sicker than those who survive. Patients presenting with mild disease (for example, with petechial rash and fever only) might progress to severe illness and death if the disease is not recognised and treated early with antibiotics (fig 1). Patients who developed critical illness in hospital or present critically ill might survive or die depending on the speed and quality of care (fig 1). To study failures of healthcare delivery at both stages we identified children who initially presented with mild disease or severe illness and then controlled for the differences in severity of disease in multivariate analysis. To obtain a large enough group of survivors who were severely ill we recruited three controls for each case.

To control for disease severity we used the Glasgow meningococcal septicaemia prognostic score, a well validated severity score that has been shown in numerous studies to predict outcome.⁸ We also controlled for known factors such as

Table 1 Standardised assessment tool for diagnosis of meningococcal disease and complications

Complications	Standard management
Haemorrhagic rash and fever (suspected meningococcal disease)	Laboratory investigations (including full blood count, urea, creatinine, and electrolytes, coagulation screen, base deficit, blood culture). Start intravenous antibiotics
Respiratory failure (PaO ₂ <10 in air, O ₂ saturations <95% in air, raised PCO ₂ >6)	Supplemental oxygen initially. Intubation and mechanical ventilation if respiratory failure persists or progresses
Cardiovascular failure (hypotension if blood pressure below normal range for age, if no hypotension then signs of two organ failures; CNS failure, respiratory failure, metabolic acidosis >5, capillary refill time >3 seconds, or toe-core temperature gap >3°)	Fluid therapy: 40 ml/kg in first hour given in aliquots of 20 ml/kg. If signs of shock persist then intubate and start mechanical ventilation. Start peripheral inotropes (dopamine or dobutamine). If poor response to volume resuscitation and peripheral inotropes start adrenalin infusion through central line
Neurological failure (GCS ≤8, responsive only to pain, rapidly deteriorating neurological scale (>3 points in 1 hour), seizure and failure to regain normal consciousness within 1 hour)	Elective intubation and mechanical ventilation. Keep head in midline at 30° to horizontal, keep PCO ₂ normal or low, avoid insertion of central venous catheters into neck
Raised intracranial pressure (unconscious or deterioration of three points in GCS in past hour AND at least one of abnormal posture, unilateral or bilateral dilated pupil, abnormal respiratory pattern, bradycardia, and hypertension)	Mannitol and elective intubation and mechanical ventilation. Keep head in midline at 30° to horizontal, keep PCO ₂ normal or low, avoid insertion of central venous catheters into neck
Abnormal signs only (signs of serious illness but insufficient information in notes to be able to confirm the presence of any specific complication, heart rate and respiratory rate outside normal range for age, capillary refill time >3 seconds)	Investigations and observations of vital signs. Give 20 ml/kg fluids if features of compensated shock (increased capillary refill and tachycardia but patients not meeting full definition for cardiovascular failure)

CNS=central nervous system; GCS=Glasgow coma score.

disease presentation (septicaemia or meningitis) and meningococcal serogroup. Furthermore we included the presence of organ failure (see table 1) as a covariate in the multivariate analysis because it is a reliable indicator of disease severity. Finally we assessed failings of fluids and inotrope management in a subgroup of patients who developed cardiovascular failure.

Copies of the complete hospital medical and nursing records were received. Some patients were excluded at this stage (because of no microbiological confirmation, absence of any inflammatory markers, atypical clinical presentation, or other confirmed bacterial or viral cause for the illness). All data extracted from clinical material were anonymised and stored with a unique study number.

Standardised evaluation of emergency medical care

Development of a standardised assessment tool

To provide an objective assessment of the promptness and quality of emergency medical care provided, we developed a standardised assessment tool using published and widely accepted criteria for diagnosis and management of meningococcal disease and its complications (table 1).⁹ Following guidelines in the UK advanced paediatric life support manual,¹⁰ we defined the following disease complications (organ failures) namely: cardiovascular failure (shock), respiratory failure, neurological failure, raised intracranial pressure, and haemorrhagic rash. When patients were admitted with tachycardia or tachypnoea

but, because of inadequate documentation in the notes, we could not diagnose or rule out a specific organ failure, we categorised the patient as having “abnormal signs only.”

Panel

An assessment panel—comprising a consultant in paediatric emergency medicine, a consultant in paediatric infectious diseases, and two consultants in paediatric intensive care—reviewed data on all cases.

Blinded evaluation of patient records using the standardised assessment tool

Vital signs and laboratory results recorded in each patient’s notes in the first 24 hours after admission were transcribed on to flow charts in one hour time periods with the time of arrival at hospital taken as time 0 hours. The treatments initiated were also recorded for each hour. The clinical findings and laboratory results were then presented to the panel by revealing the information available at each hour after admission. On the basis of the information available at each hour, the panel members assessed each patient for the presence of diagnostic features of meningococcal disease and its complications. Using the agreed protocol¹¹ they recommended standard management of each complication. CP recorded the panel’s decisions and recommended management for each hour. The panel members became aware of the outcome (fatal or not) only after their scoring had been recorded.

By comparing the time after admission at which the panel diagnosed the disease and complications with the time that the hospital team caring for the child reached the diagnosis, and comparing the recommended management of each complication with that which the patient received, we evaluated the actual hospital management, both in terms of timing and the actions undertaken. Delay of more than an hour between the action recommended by the panel and what actually occurred was defined as a failure of care and delay of more than 24 hours in being seen by a consultant as a failure in supervision. The panel assessed whether the failure in care resulted from a failure to recognise the complication or a failure to recognise the severity and to adhere to the protocol. For example, in a hypotensive patient if fluid resuscitation was never instituted at all this was considered a failure to recognise the complication of shock. If fluid resuscitation was started but was inadequate in speed of administration or quantity this was considered to be a failure to appreciate the severity of shock.

The assessment panel scored all patients on admission with the Glasgow meningococcal septicaemia prognostic score,⁸ and

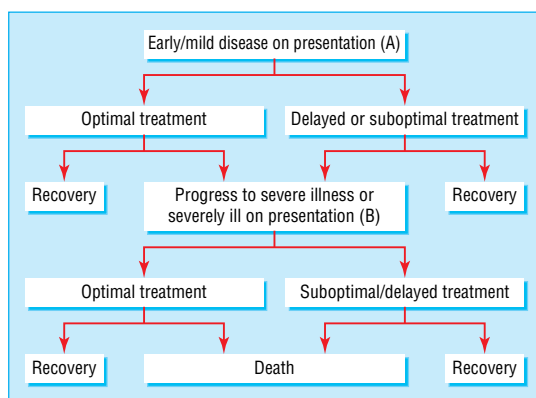


Fig 1 Stages in presentation and progression in children with meningococcal disease. Patients with mild disease on presentation to hospital (A) may progress to severe illness or recover; adequacy of treatment may influence outcome. Patients who are severely ill on presentation to hospital (B) or develop severe illness after presentation at point A may recover or die; adequacy of treatment at point A may influence the outcome

Table 2 Demographics of children admitted to hospital with meningococcal disease who died (cases) or survived (controls). Figures are number (percentage) of children

	Cases (n=143)	Controls (n=355)
Meningococcal group:		
B	50 (35)	129 (36)
C	57 (40)	101 (28)
Y/135W	0	8 (2)
Non-culture diagnosis*	14 (10)	34 (10)
Culture +ve/no group	5 (3)	11 (3)
Clinical diagnosis only†	17 (12)	73 (21)
Age group (years):		
<1	37 (26)	84 (24)
1-4	51 (36)	126 (35)
5-14	25 (17)	66 (19)
15-16	30 (21)	79 (22)

*Polymerase chain reaction or microscopy of skin rash scrapings.

†Not microbiologically proved.

patients were assigned to three groups based on objective clinical features: meningitis (depressed Glasgow coma score, stiff neck, photophobia, and central nervous system failure), septicaemia (shock or multiorgan failure, absence of meningitis), or a mixed picture (some features of meningitis and septicaemia). We also recorded what sort of team (paediatric or adult) primarily cared for the child.

Statistical methods

All statistical analyses were carried out in Stata 8.0 (StataCorp, College Station, TX). We used multivariate conditional logistic regression on matched data with death/survivor status as the outcome variable and failures of care as explanatory variables. Children who died (cases) were matched to survivors (controls) by age group and region of origin. We evaluated a "full" model, which included all the failures of care as well as the effects of potential confounders such as disease severity (Glasgow meningococcal septicaemia prognostic score), disease type, serogroup, organ failure, and whether the patient needed fluid or inotrope therapy. We then used the likelihood ratio test to compare this full model with nested models comprising a subset of failure variables.¹² Correlations between explanatory variables were explored by means of univariate logistic regression and Fisher's exact test for contingency tables.

Results

During the study period 190 deaths and 755 survivors were notified (fig 2). We excluded 47 children who died (alternative diagnosis n=2, death occurred outside hospital n=28, and incomplete sets of notes n=17) and 400 survivors (alternative diagnosis n=106, incomplete sets of notes n=75, and lack of parental consent n=219). This left 143 cases and 355 controls to include in the study. Table 2 shows the demographic characteristics of both groups. Organ failure was present in 141 children who died and 169 survivors. For two children who died information in the notes was inadequate for the panel to be able to diagnose any specific organ failure.

Univariate analysis

Table 3 shows the frequency of management failures in cases and controls along with the univariate odds ratios for death. Failures in management were significantly more common in children who died than in survivors. With the exception of serogroup, probability of death was significantly correlated with Glasgow meningococcal septicaemia prognosis score, presence of organ

failure, and disease type. Failure to recognise complications, failure to appreciate disease severity, failure in supervision, lack of involvement of a paediatric team in care, and inadequacies of fluid and inotrope administration were all significantly associated with death. Multiple treatment failures significantly increased the risk of death (table 4).

Multivariate analysis

We excluded sex from the model as it was not significant at the univariate level. We included Glasgow meningococcal septicaemia prognostic score, organ failure, disease type (septicaemia or meningitis), meningococcal serogroup, and the need for fluid or inotrope therapy as potential confounders. The full model indicates that not being under the care of a paediatrician (odds ratio 66.0, 95% confidence interval 3.6 to 1210; P=0.005), failure of supervision (19.5, 1.8 to 213; P=0.015), and failure to administer inotropes (23.7, 2.6 to 213; P=0.005) are independent risk factors for death (table 5). Not being under paediatric care was highly correlated with a failure to recognise complications (P=0.002; Fisher's exact test). When we removed absence of paediatric care from the model, failure to recognise disease complications became highly significant (6.1, 1.7 to 22; P=0.006, table 5). This association suggests that failure to recognise complications is one of the consequences of absence of paediatric care. We used the risk factors identified in the multivariate analysis to assess the effect of multiple failures of care on the risk of death. The odds ratio for death with one failure was 8.7 (2.3 to 33) and increased with additional failures (table 6).

Discussion

In this investigation of management of children admitted to hospital with meningococcal disease we found a highly significant increase in the frequency of departures from optimal care in children who died compared with those who survived. This sug-

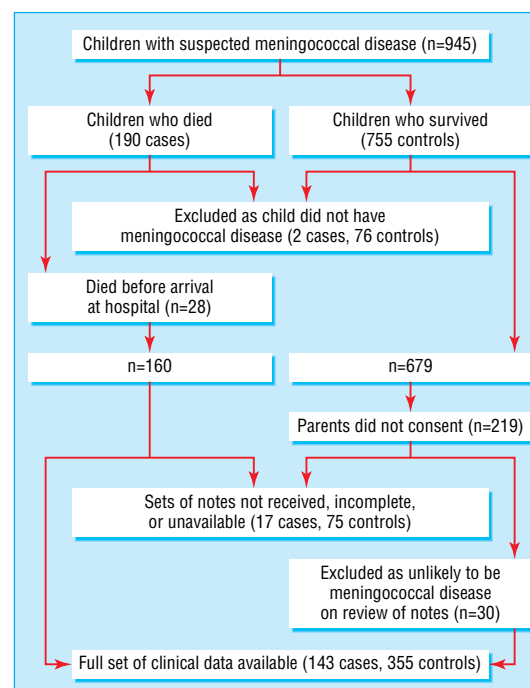


Fig 2 Selection of fatal and non-fatal cases for inclusion in the study. Of 945 children with suspected meningococcal disease, we included 143 who died (cases) and 355 who survived (controls)

Table 3 Univariate analysis of potential risk factors in management of meningococcal disease

Variable	Cases (%)	Controls (%)	Odds ratio (95% CI)	P value
Disease severity (GMSPS score) (n=411)				
As continuous variable	—	—	1.6 (1.4 to 1.7)	<0.001
As dichotomous variable (≥ 8 v < 8)	109/133 (82)	64/306 (21)	18.0 (8.6 to 38)	<0.001
Categorical variable:				
6-10 v 0-5	63/133 (47)	93/306 (30)	9.7 (4.6 to 21)	<0.001
11-15 v 0-5	58/133 (44)	25/306 (8)	38 (15 to 97)	<0.001
Organ failure v no organ failure	141/143 (99)	169/355 (48)	111 (15 to 800)	<0.001
Disease classification (n=488)				
Septicaemia v meningitis	123/143 (86)	229/353 (65)	2.6 (1.4 to 4.6)	0.001
Both v meningitis	2/143 (1)	39/353 (11)	0.2 (0.1 to 1.1)	0.064
Serogroup (n=490)				
C v B	51/143 (36)	101/355 (28)	1.7 (1.0 to 2.8)	0.059
Others v B	52/143 (36)	126/355 (35)	1.3 (0.8 to 2.1)	0.35
Sex (n=490)				
Girls v boys	64/143 (45)	166/355 (47)	0.9 (0.6 to 1.4)	0.64
Management failures (n=490)				
Absence of paediatric care	30/143 (21)	33/355 (9)	4.6 (2.1 to 11)	<0.001
Failure in supervision by consultant	36/143 (25)	50/355 (14)	2.1 (1.2 to 3.5)	0.007
Failures in assessment of patients:				
Failure to recognise disease complications	57/143 (40)	79/355 (22)	2.1 (1.3 to 3.2)	0.001
Failure to recognise disease severity	54/143 (38)	76/355 (21)	2.2 (1.4 to 3.4)	0.001
Failures in clinical practice:				
Too little fluid v adequate fluid therapy*	32/131† (24)	27/246† (11)	2.5 (1.4 to 4.7)	0.004
Too much fluid v adequate fluid therapy*	7/131† (5)	6/246† (2)	2.8 (0.8 to 10)	0.12
Inadequate inotropes‡	54/122§ (44)	13/91§ (14)	5.8 (2.3 to 14)	<0.001

GMSPS=Glasgow meningococcal septicaemia prognostic score.

*Bivariate analysis controlled for needing fluid.

†Denominator is number needing fluid.

‡Bivariate analysis controlled for needing inotropes.

§Denominator is number needing inotropes.

gests that differences in healthcare delivery may play a part in adverse outcome from meningococcal disease. Significant independent risk factors for death included not being treated by a paediatric team, not being supervised by a consultant, and inadequate inotrope therapy. Our multivariate analysis also suggests that failure to recognise complications was a significant risk factor for death, although not independently of absence of treatment by a paediatric team. Given that these two failures are highly correlated we suggest that failure to recognise complications is one of the consequences of absence of paediatric care.

The criteria used by the panel to diagnose the complications of meningococcal disease (such as shock or respiratory or central nervous system failure) were based on widely accepted and published criteria, which depend on clinical observation easily determined by any medical and nursing team. They also use simple biochemical (blood gases) or monitoring (pulse oximetry) technologies, which are readily available in all district hospitals. All treatments recommended by the panel were based on published protocols of management.^{10 11 13} The panel used objective findings recorded in the clinical notes to assess the disease and its complications. It therefore seems that when the panel

decided failures had occurred, these resulted from a medical team either not appreciating the importance of clear physical signs or laboratory results or not following published management protocol.

Why care may be suboptimal

There were often obvious reasons for suboptimal care. Vital signs were often inadequately documented in the nursing records. If signs of compensated shock were recorded but not appreciated, delays in diagnosis and treatment were inevitable. In children there are age related differences in normal values for blood pressure, heart rate, and respiratory rate, which were often not appreciated by medical teams. Many children had extreme increases in pulse rate and respiratory rate without apparently attracting the attention of the medical team. The recognition of compensated shock in children is more difficult than in adults as hypotension is a late sign and blood pressure is often maintained by compensatory vasoconstriction and tachycardia until late into the illness. Many children with signs of shock were not recognised as seriously ill. Often this seemed to be due to their care being undertaken mainly by doctors trained to recognise serious illness in adults—emergency teams, intensive care

Table 4 Multiple failures in treatment of 480 children with fatal (cases) and non-fatal (controls) meningococcal disease

No of failures	Cases (%)	Controls (%)	OR* (95% CI)	P value
0	36 (25.2)	197 (55.5)	1	
1	30 (21.0)	80 (22.5)	2.3 (1.2 to 4.1)	0.08
2	26 (18.2)	50 (14.1)	3.1 (1.7 to 5.8)	0.001
3	29 (20.3)	16 (4.5)	9.5 (4.2 to 21)	<0.001
4	16 (11.2)	10 (2.8)	9.5 (3.6 to 25)	<0.001
5	6 (4.2)	2 (0.6)	38 (4.0 to 360)	0.002

*Controlled for needing fluid and inotropes.

Table 5 Multivariate models of treatment of children with meningococcal disease who died or survived. Odds ratios (OR) are for death

Variable	Full model (R ² =79%)		Model 1 (R ² =72%)		Model 2 (R ² =68%)	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Potential confounders						
GMSPS:						
6-10 v 0-5	8.53 (1.4 to 53)	0.021	6.35 (3.7 to 73)	<0.001	4.68 (1.5 to 14)	0.006
11-15 v 0-5	18 (2.3 to 139)	0.006	16.4 (3.7 to 72)	<0.001	11.1 (2.9 to 43)	0.001
Septicaemia v meningitis	0.1 (<0.01 to 3.9)	0.19	0.34 (0.04 to 3.2)	0.34	0.35 (0.1 to 2.6)	0.30
Both v meningitis	0.01 (<0.01 to 0.8)	0.039	0.03 (0.0 to 0.6)	0.025	0.03 (0.0 to 0.5)	0.017
Serogroup C v B	2.1 (0.6 to 8.1)	0.27	1.07 (0.4 to 3.1)	0.90	0.84 (0.3 to 2.3)	0.73
Other serogroup v B	1.6 (0.5 to 5.1)	0.45	1.37 (0.5 to 4.0)	0.56	1.29 (0.5 to 3.6)	0.62
Organ failure	1070 (0.7 to ∞)	0.063	62.5 (2.7 to 1440)	0.026	63.9 (3.9 to 1060)	0.004
Need inotropes	19.6 (2.5 to 151)	0.004	5.70 (1.5 to 22)	0.012	4.60 (1.3 to 16)	0.018
Need fluid	18.9 (0.2 to 1490)	0.19	3.49 (0.3 to 41)	0.32	2.69 (0.3 to 24)	0.38
Management failures						
Not under care of paediatrician	66.0 (3.6 to 1210)	0.005	—	—	—	—
Failure of supervision by consultant	19.5 (1.8 to 213)	0.015	—	—	—	—
Patient assessment failures						
Recognise complications	3.33 (0.7 to 17)	0.14	6.11 (1.7 to 22)	0.006	—	—
Recognise severity	0.51 (0.1 to 2.5)	0.40	0.57 (0.1 to 2.3)	0.44	—	—
Clinical practice failures						
Administration of inotropes	23.7 (2.6 to 213)	0.005	16.5 (3.0 to 91)	0.001	10.6 (2.5 to 44)	0.001
Administration of fluids:						
Too little v adequate	1.49 (0.2 to 12)	0.59	0.86 (0.2 to 4.1)	0.85	1.38 (0.3 to 5.7)	0.65
Too much v adequate	19.4 (0.2 to 1560)	0.19	0.67 (0.03 to 13)	0.80	1.32 (0.1 to 19)	0.84

GMSPS=Glasgow meningococcal septicaemia prognostic score.

specialists, and anaesthetists—who documented but did not seem to appreciate the importance of signs of serious illness.

We found that children being looked after by doctors without paediatric training were at increased risk of dying. Lack of supervision by a consultant was also an independent risk factor for death. Unsupervised junior doctors managing sick children may lack the experience to recognise the speed of disease progression, the need for paediatric intensive care, and the need for inotrope therapy. The significantly increased odds ratio for death associated with failure to administer appropriate inotrope therapy emphasises the importance of protocols for management of meningococcal disease.

The procedure developed for this study helped to ensure that the panel's diagnosis and management decisions were applied to cases and controls in a similar manner. Panel members were blinded to outcome while they assessed clinical and laboratory

information, available in hour time periods from the case records.

Conclusions

Earlier recognition of the signs and symptoms of meningococcal infection may lead to earlier diagnosis, earlier treatment intervention, and reduced risk of a fatal outcome. Meningococcal disease shares many features with other life threatening acute illnesses. The difficulties in recognition of the seriously ill child and in treatment of shock and organ failure that we have examined in the context of meningococcal disease might be equally apparent in the management of children with other life threatening disorders, including multiple trauma, respiratory and cardiac failure from any cause, and acute neurological conditions. The implications from our study for improved training of medical and nursing teams in the management of life threatening illnesses and for better supervision might thus be generalised to many other settings.

We dedicate this paper to the late Professor David Baum. We thank Roddy McFaul for his help; all local hospital staff and regional paediatric intensive care; public health staff at CDSC including Mary Ramsay, Norman Begg, and James Stuart; Ed Kaczmarek of the Meningococcal Reference unit in Manchester; the district consultants in communicable disease control; and the regional epidemiologists. We are grateful to all the parents who participated, especially those recently bereaved.

Contributors: NN played a leading role in the conduct of the study, data collection, data analysis, and writing of the manuscript. CP participated in data collection, scoring of panel meetings, data analysis, and revision of the manuscript. LB participated in preparing clinical material for panel meetings, data collection, and presentation of patients at panel meetings. SN contributed to the design of the study and the development of assessment tools, scoring of patients, and revision of the manuscript. JB, IM, and AW participated in the panel assessment of patients and revision of the manuscript. JJP contributed to the design of the study and revision of the manuscript. RB contributed to the epidemiological design of the study, conduct of study, and revision of the manuscript. PGC was responsible for statistical analysis of data and writing the manuscript. ML designed the study, oversaw the conduct of the study and methodology, wrote the initial draft, and is guarantor.

Funding: This study was supported by a grant from the Meningitis Research Foundation.

Table 6 Multivariate model for multiple failures, with odds ratios for death in children presenting with meningococcal disease

Variable	OR (95% CI)	P value
Potential confounders:		
GMSPS:		
6-10 v 0-5	8.15 (1.8 to 37)	0.007
11-15 v 0-5	17.6 (3.4 to 92)	0.001
Septicaemia v meningitis	0.16 (0.01 to 2.1)	0.16
Both v meningitis	0.02 (<0.01 to 0.6)	0.024
Serogroup C v B	1.76 (0.5 to 6.0)	0.37
Other serogroup v B	1.50 (0.5 to 4.6)	0.48
Organ failure	245 (2.4 to ∞)	0.019
Need inotropes	15.6 (3.1 to 79)	0.001
Need fluid	5.33 (0.3 to 99)	0.26
No of failures:		
0	1.0	—
1	8.74 (2.3 to 33)	0.001
2	34.2 (5.9 to 198)	<0.001
>2	113 (8.4 to 1510)	<0.001

GMSPS=Glasgow meningococcal septicaemia prognostic score.

What is already known on this topic

Overall mortality from meningococcal disease has not changed significantly in the past few decades, though recent studies have shown improved outcomes in children treated aggressively in paediatric intensive care units

Meningococcal disease can progress very rapidly

Most children with meningococcal sepsis present to their local hospital and many die before they can be transferred to specialist intensive care units

What this study adds

The quality of healthcare delivery in hospital for children with meningococcal disease differs in fatal and non-fatal cases

Optimal early management of septicaemia and meningitis at the admitting hospital can improve outcome

Improved outcome is associated with children being managed by paediatric teams and junior doctors being supervised by consultants

Doctors should follow published protocols of care for fluid resuscitation, inotrope therapy, and referral to paediatric intensive care units

Conflict of interests: None declared.

Ethical approval: South Thames multi-research ethics committee and all local research ethics committees in England, Wales, and Northern Ireland approved the study.

- 1 Office for National Statistics. *Mortality statistics*. London: ONS, 2000. (Series DH2 No 26.)
- 2 Jones D. Epidemiology of meningococcal disease in Europe and the USA. In: Cartwright K, ed. *Meningococcal disease*. New York: John Wiley, 1995:147-57.
- 3 Booy R, Habibi P, Nadel S, De Munter C, Britto J, Morrison A, Levin M. Reduction in cases fatality rate from meningococcal disease associated with improved healthcare delivery. *Arch Dis Child* 2001;85:386-90.

- 4 Thorburn K, Baines P, Thomson A, Hart CA. Mortality in severe meningococcal disease. *Arch Dis Child* 2001;85:382-5.
- 5 Nadel S, Britto J, Booy R, Maconochie I, Habibi P, Levin M. Avoidable deficiencies in the delivery of healthcare to children with meningococcal disease. *J Accid Emerg Med* 1998;15:298-303.
- 6 Ramsay M, Kaczmarski E, Rush M, Mallard R, Farrington P, White J. Changing patterns of case ascertainment and trends in meningococcal disease in England and Wales. *Commun Dis Rep CDR Rev* 1997;7:R49-54.
- 7 Stuart JM, Monk PN, Lewis DA, Constantine C, Kaczmarski EB, Cartwright KAV. Management of clusters of meningococcal disease. *Commun Dis Rep CDR Rev* 1997;7:R3-5.
- 8 Thomson APJ, Sills JA, Hart CA. Validation of the Glasgow meningococcal septicaemia prognostic score: a 10 year retrospective survey. *Crit Care Med* 1991;19:26-30.
- 9 Nadel S, Levin M, Habibi P. Treatment of meningococcal disease in childhood. In: Cartwright K, ed. *Meningococcal disease*. New York: John Wiley, 1995:207-43.
- 10 Advanced Life Support Group. *Advanced paediatric life support manual*. London: BMJ Publishing Group, 2001.
- 11 Pollard AJ, Britto J, Nadel S, DeMunter C, Habibi P, Levin M. Emergency management of meningococcal disease. *Arch Dis Child* 1999;80:290-6.
- 12 Hosmer DW, Lemeshow S. *Applied logistic regression*. Chichester: John Wiley, 1989 (Wiley series in probability and mathematical statistics).
- 13 Pathan N, Nadel S, Levin M. Pathophysiology and management of meningococcal septicaemia. *J R Coll Physicians London* 2000;34:436-44.

(Accepted 20 April 2005)

bmj.com 2005;330:1475

Infectious Diseases Unit, Department of Paediatrics, Faculty of Medicine, Imperial College of Science, Technology and Medicine, London W2 1PG

Nelly Ninis *clinical research fellow*

Michael Levin *professor of paediatric infectious diseases*

Research Unit, Royal College of Paediatrics and Child Health, London W1W 6DE

Claire Phillips *research assistant*

Linda Bailey *research nurse*

Faculty of Health and Social Care, University of the West of England, Bristol

BS16 1DD

Jon I Pollock *principal lecturer in epidemiology*

Paediatric Intensive Care Unit and Paediatric Accident and Emergency

Department, St Mary's Hospital, London W2 1PG

Simon Nadel *consultant in paediatric accident and emergency*

Joseph Britto *consultant in intensive care*

Ian Maconochie *consultant in paediatric accident and emergency*

Department of Paediatrics, Kingston Hospital, Kingston upon Thames KT2 7QB

Andrew Winrow *consultant paediatrician*

Centre for Child Health, Queen Mary's School of Medicine and Dentistry,

University of London, London E1 1BB

Pietro G Coen *research assistant statistician*

Robert Booy *professor of child health*

Correspondence to: N Ninis ninisin@gosh.nhs.uk