Markers of serious illness in infants under 6 months old presenting to a children's hospital

P H Hewson, S M Humphries, D M Robertson, J M McNamara, M J Robinson

Abstract

Six hundred and eighty two assessments were performed on 641 babies under 6 months of age who presented to the emergency department of the Royal Children's Hospital, Melbourne, to try and determine the best markers of serious illness in young infants. Detailed, specific questions that quantified a baby's functional response to illness gave the most useful information. As a group, the six most common predictive symptoms of serious illness were: taking less than half the normal amount of feed over the preceding 24 hours, breathing difficulty, having less than four wet nappies in the preceding 24 hours, decreased activity, drowsiness, and a history of being both pale and hot. The presence of the corresponding sign on examination increased the predictive value of the symptom by 10-20%. Specific, highly predictive (though less common) signs included moderate to severe chest wall recession, respiratory grunt, cold calves, and a tender abdomen. A list of low, medium, and high risk symptoms has been constructed and the five measurements that were most useful in predicting serious illness in young infants have been detailed.

The relative importance of many signs and symptoms in young, ill infants remains uncertain.¹⁻⁵ The multicentre study of postneonatal mortality suggested that serious illness may not be recognised by parents or doctors,⁶ and Stanton *et al* highlighted 12 symptoms that seemed to be associated with sudden death.² Controversy since then illustrates both the need for a systematic study of signs and symptoms in this age group, and validation of guidelines for parents and health workers responsible for the care of infants.^{4, 5}

Studies of feverish babies have shown that specific clinical findings lack predictive value, although a physician's 'impression of sepsis' was said to be useful.⁷⁻⁹ McCarthy *et al* have shown that several detailed observations can help to identify those feverish young children (aged 3 to 24 months) who have bacterial or viral infections.¹⁰ Attention to specific, detailed questions and precise definitions may permit more accurate interpretation of symptoms, both individually and in combination, when assessing all types of serious illness in young babies.

This paper presents a univariate analysis of the symptoms and signs of babies presenting to the Royal Children's Hospital, Melbourne, for assessment of possible illness. The initial aim was to determine the most predictive and sensi-

tive markers of serious illness in babies under 6 months of age within the hospital.

Patients and methods

A total of 641 babies under 6 months of age were enrolled in a prospective study when they presented with acute illnesses of less than 15 days' duration to the emergency department, Royal Children's Hospital, Melbourne on three days of each week for a year. The hospital acts as a primary, secondary, and tertiary referral centre, and over 70 000 children are assessed in the emergency department each year. A standardised initial assessment was performed by PHH that documented the nature of the presenting problem, and the presence or absence of 28 symptoms (table 1) and 46 signs. The symptoms were the variables identified by the parents on direct questioning, and the signs were the observations of—and findings on—examination of the baby by an experienced clinician (PHH) who also documented his initial impression of the degree of illness (normal, mild, moderate, or severe) after taking the history and carrying out the examination. If admission to hospital was thought likely, the admitting officer then assessed the baby and decided whether admission was necessary.

All infants who were admitted, and those who had rectal temperatures of $>38.2^{\circ}\text{C}$, had a standard set of investigations carried out (full blood examination, estimation of concentrations of urea and electrolytes, acid base, blood cultures, microscopy and culture of the urine—suprapubic aspirate if possible), together with any special investigation deemed clinically necessary—for example, lumbar puncture, chest radiograph, or barium enema examination.

To determine the outcome of the illness, the hospital records of all infants who were admitted were reviewed independently after discharge by three experienced paediatricians (JMMcN, MJR, and DMR) and the severity of the illness was graded using a seven point score. They retrospectively classified the babies as having required (i) hospital treatment, (ii) hospital observation, or (iii) home (parental) observation or care. This review included all the medical and nursing notes, the results of investigations, and the diagnosis at discharge. The review was carried out without knowledge of the initial documentation of symptoms and signs done by PHH (which were kept separately) and without knowledge of each other's opinions. A small number of babies who were not admitted to hospital also had their

Department of
General Paediatrics,
Royal Children's
Hospital,
Parkville, Melbourne,
Victoria 3052,
Australia

P H Hewson
S M Humphries
J M McNamara
M J Robinson

Department of
Paediatrics,
University of Adelaide,
South Australia
D M Robertson

Correspondence to:
Dr Hewson.

Accepted 9 February 1990

Table 1 Definitions of symptoms

Symptom	Definition
Cold peripheries	Hands, feet, or limbs, have felt cold.
Noisy breathing	Persistent noises, including mucousy sounds, snuffles, stridor, grunt or wheeze.
Rash	Appreciable areas of inflammation, or >6 spots (birth marks excluded).
Decreased sleeping	Less sleep than usual, during the day or night.
Runny nose	Mucus seen over the philtrum (not just a blocked nose).
Sweating	Beads of sweat on forehead, or obviously wet hair when at rest or feeding.
Increased sleeping	More sleep than usual during the day or night.
Increased irritability	More fractious and difficult to settle than usual.
Increased crying	Has cried more often or for longer periods than usual.
Cough	More than five episodes of coughing/day.
Feels hot	Has felt hotter than normal.
Pallor	Has looked generally pale.
Not feeding normally	Has taken less fluids or solids, or fed more slowly. The percentage of normal intake was calculated (bottle) or estimated (breast).
Vomiting	Forceful regurgitation of a significant quantity of fluid (excluding possetting). The number of vomits of more than half the feed was recorded.
Not himself or herself	Baby has behaved differently from usual.
Diarrhoea	Excessively fluid motions. The number of stools passed during the last 24 hours was recorded.
Abnormal cry	An unusual cry. If unusual the presence of a weak or excessively strong cry was documented.
Breathing difficulty	Has worked harder to breathe, or had a heaving chest.
Less urine	Fewer wet nappies than usual or nappies that have been drier than usual. If output was reduced, the number of wet nappies was recorded.
Decreased activity	Has been moving arms and legs less than usual.
Drowsy	Less alert than usual. A 'drowsiness score' was then recorded, which allowed a more objective assessment of drowsiness: 'When the baby is awake is he (i) always alert, (ii) occasionally drowsy, (iii) occasionally alert, or (iv) never alert?'
Jaundice	Yellow skin or sclera.
Projectile vomiting	Vomit that travelled more than 45 cm.
Cyanotic episodes	Periods of obvious blueness of the tongue and lips.
Apnoeic episodes	Cessation of breathing for 20 seconds or more.
Bile stained vomiting	Episodes of green vomiting.
Blood in stools	Frank blood mixed with stools (not streaks).
Convulsion	Shaking movements with decreased awareness.

Symptoms were recorded only if they occurred within the previous 24 hours.

emergency department notes scored by the paediatricians.

All babies were seen daily for three days after the initial assessment whether in hospital or at home, and their functional state determined in a standard manner by independent research assistants. Any baby whose health was deteriorating at home was referred back to hospital for further assessment by the admitting officer.

A 50 page manual defining all symptoms and signs, procedures carried out, and study protocol was written and adhered to. Approval for the study was obtained from the hospital ethics committee.

DEFINITION OF SERIOUS ILLNESS
'Index definition' of serious illness—that is, needing observation in hospital

The illness was defined as serious if at least two of the three experienced paediatricians (JMMcN, MJR, and DMR) independently scored the infant as requiring observation in hospital after retrospective, independent review of the hospital record. If the child was not admitted to hospital and the paediatricians did not review the hospital record, then PHH's grading of the illness as severe in the emergency department was used to define serious illness.

Alternative definitions of serious illness
Because of the difficulty in defining absolute criteria (or a 'gold standard') for serious illness, the results using the index definition of serious illness were compared with results using alternative definitions of serious illness. These alternative definitions were:

(i) When two or more of the same three paediatricians independently scored the hospital record of the baby (after discharge) as indicating

the need for hospital treatment (intravenous fluids, parenteral antibiotics, oxygen, or surgery).

(ii) When a baby had a seriously abnormal laboratory result (serum concentrations of sodium >149 or <128 mmol/l, bicarbonate >27 or <17 mmol/l, or urea >7.0 mmol/l; pH >7.49 or <7.28; haemoglobin concentration <80.0 g/l, white cell count >20×10⁹/l (neutrophils >10 or <1×10⁹/l, band count >2×10⁹/l); culture of blood, urine, or cerebrospinal fluid growing a pathogen; abnormal chest radiograph (for example, segmental opacification) or an abnormal barium enema examination).

(iii) When PHH had scored the baby as being severely ill in the emergency department after documenting all the symptoms and signs. (This outcome contributed to the index definition but was also used independently as an alternative definition.)

STATISTICAL ANALYSIS
The demographic characteristics of the babies and the incidence and diagnostic measures (predictive values, sensitivity, and specificity) of each symptom and sign were determined (table 2).^{11 12} The diagnostic measures were initially calculated for the index definition of serious illness and these were then compared with those of each of the alternative definitions of serious illness. A checklist illustrating the relative risk of serious illness in the presence of various symptoms was developed. The most common (sensitive) predictive symptoms were also worked out.

Results
PATIENTS
Numbers and description

Six hundred and eighty two assessments were

Table 2 Definitions used and methods of calculation

Sensitivity	Percentage of people with disease who have positive test	$\frac{\text{True positive}}{\text{True positive} + \text{false negative}} \times 100$
Specificity	Percentage of people without disease who have negative test	$\frac{\text{True negative}}{\text{True negative} + \text{false positive}} \times 100$
Positive predictive value	Percentage of people with positive test who have disease	$\frac{\text{True positive}}{\text{True positive} + \text{false positive}} \times 100$
Negative predictive value	Percentage of people with negative test who do not have disease	$\frac{\text{True negative}}{\text{True negative} + \text{false negative}} \times 100$

True positive=test positive and disease present; false positive=test positive and disease absent; false negative=test negative and disease present; and true negative=test negative and disease absent.

made on 641 babies, 346 (54%) of whom were boys. Forty one infants had repeat assessments for different illnesses. The median age of the babies was 10 weeks and 5 days. Of the mothers, 79% were married and living with their husbands, and 9% were under 20 years of age. Eighteen per cent came from social classes I or II, 60% from class III non-manual or manual, 19% from class IV or V, and 3% were uncoded.¹³ At least one parent smoked cigarettes in 63% of the homes. Of the parents for whom the nationalities were known (n=1361), 48% were Australian, 25% southern European, 12% central or northern European, 7% Asians, and 6% Middle Eastern. The mother's educational state was recorded for the last 501 infants

assessed, and of these, 60% had not proceeded past the fourth year of secondary school.

Referral pattern

Doctors referred 130 (19% of the assessments) and the remainder were self referred.

History

Forty two (6% of 681) were born at less than 37 weeks' gestation, 16 (2%) had a serious congenital abnormality, 13 (2%) had evidence of previous developmental delay, and 55 (8%) had had a previous hospital admission.

HOSPITAL ADMISSIONS AND DIAGNOSES

One hundred and fifty six (23%) were admitted to hospital immediately, and another 22 (3%)

Table 3 Frequency, predictive values, sensitivity, and specificity of symptoms in 682 assessments (unless otherwise stated). Index definition was used for outcome and values given to nearest whole number

Symptom	Frequency (% of total assessed)	Predictive values		Sensitivity (%)	Specificity (%)
		Positive (%)	Negative (%)		
Respiratory:					
Cyanotic episode	47 (7)	70	76	18	97
Apnoeic episode	35 (5)	60	75	11	97
Breathing difficulty	228 (33)	40	79	49	72
Runny nose	235 (34)	29	74	37	66
Noisy breathing	436 (64)	27	73	64	36
Cough	351 (51)	26	72	50	48
Gastrointestinal and fluids:					
Bile stained vomit	5 (1)	100	73	3	100
Not feeding:	368 (54)	35	82	70	52
<34%	27 (5)	73*	90	17	98
<50% (n=530)	50 (9)	62	75	21	96
34%–67%	175 (26)	36*	76	34	78
67%–99%	144 (21)	25	72	19	78
Wet nappies <4 (n=654)	44 (6)	66	76	16	97
Bloody stool	11 (2)	64	74	4	99
Less urine	111 (16)	50	78	31	89
Vomiting >5 time in previous 24 hours	27 (4)	37	73	5	97
Smelly urine (n=502)	95 (19)	33	73	17	87
Projectile vomiting	55 (8)	31	73	9	92
Diarrhoea	226 (33)	26	72	31	66
Central nervous system:					
Convulsions	10 (1)	80	74	4	99
Drowsy	166 (24)	59	83	54	86
Drowsiness scale (n=669)					
Always	6 (1)	83	74	3	100
Often	65 (13)	82	80	30	98
Occasional	85 (17)	45	75	21	90
Weak cry (n=560)	28 (5)	68	75	11	98
Decreased activity	113 (20)	64	82	47	90
Increased sleep	146 (21)	55	81	44	87
Abnormal cry	389 (57)	33	82	71	48
Not him/herself	529 (78)	31	88	90	27
Increased cry	477 (70)	30	79	76	32
Increased irritability	525 (77)	29	78	82	25
Decreased sleep	346 (51)	27	73	50	49
Skin:					
Pallor	236 (35)	48	84	61	75
Feels hot	311 (46)	36	81	61	60
Jaundice	9 (1)	33	73	2	99
Sweating	248 (36)	32	76	43	66
Cold periphery	436 (64)	26	71	63	34
Rash	225 (33)	24	71	29	65
Feels hot and pale	70 (10)	51	79	38	86

*The positive predictive value of serious illness for feeding <34% of normal was 69% for bottle fed babies and 86% for breast fed babies. For feeding 34%–67% of normal, the figures were 37% and 34%, respectively.

Table 4 Frequency, predictive values, sensitivity, and specificity of the signs on examination in 682 assessments (unless otherwise stated). Index definition was used for outcome and values given to nearest whole number

Signs	No (%)	Predictive values		Sensitivity (%)	Specificity (%)
		Positive (%)	Negative (%)		
Respiratory:					
Central cyanosis	8 (1)	100	74	4	100
Grunt	11 (2)	100	74	6	100
Recession:					
Moderate to severe	33 (5)	85	76	15	99
Any	267 (40)	42	83	61	69
Mild	234 (35)	36	83	46	69
Crepitations	27 (4)	63	74	9	98
Hyperinflation	48 (7)	60	75	16	96
Stridor	15 (2)	53	74	4	99
Wheeze	65 (10)	45	75	16	93
Tympanic membrane:					
Injection	42 (6)	31	74	7	90
Acute or chronic otitis media	30 (5)	27	87	5	96
Mucousy breathing	170 (25)	29	73	27	76
Nasal discharge	34 (5)	24	73	4	95
Respiration rate (awake, breaths/minute)					
<40	68 (10)	41	71	15	88
<40-59	293 (44)	24	70	38	54
60-79	225 (33)	28	74	35	67
80-99	73 (11)	26	73	10	89
>100	15 (2)	13	73	1	97
Abdominal:					
Abdomen tender	28 (4)	96	76	15	99
Mass palpable	15 (2)	90	74	5	99
Inguinal hernia	10 (1)	80	74	4	99
Distended and tense	20 (3)	55	74	6	98
Liver size:					
>2.5 cm	312 (49)	38	77	34	81
Palpable spleen	111 (17)	28	73	17	84
Central nervous system and arousal:					
Awareness decreased	64 (9)	89	79	31	99
Cry quality weak	55 (8)	87	78	26	99
Eye fixation decreased	65 (10)	86	79	30	98
Posture abnormal	58 (9)	78	78	24	97
Hypotonia	162 (24)	48	80	44	83
Duration of cry increased	285 (42)	42	83	64	67
Skin:					
Delayed chest wall capillary return	7 (1)	86	74	3	99
Cold periphery:					
Calves	24 (4)	79	75	10	99
Feet	217 (32)	28	76	33	68
Signs of dehydration	24 (4)	75	75	10	99
Generalised pallor	95 (14)	68	80	35	94
Sweating	11 (2)	64	74	4	99
Skin mottling	38 (6)	58	75	12	97
Bleeding into skin	7 (1)	57	73	2	99
Peripheral cyanosis	47 (7)	55	75	14	96
Peripheral pallor	116 (17)	51	78	32	89
Soft tissue mass	23 (3)	47	73	5	98
Delayed peripheral return	151 (22)	41	77	34	82
Pale conjunctivae	12 (2)	33	73	2	98
Rash	96 (13)	22	72	12	85
Other:					
Rectal temperature (°C)					
<38.3	606 (89)	22	40	72	6
>38.2-38.9	39 (5)	58	75	14	96
>38.9	36 (5)	68	75	14	98
Pulse (beats/minute):					
>199	31 (5)	67	75	11	98

within three days; a wide range of diagnoses were encountered in these babies, which included 74 with upper respiratory tract infections, 62 with gastroenteritis, 45 with bronchiolitis, 44 with infant distress or colic, 17 with urinary tract infections, 11 with intussusception, nine with meningitis (seven of which were viral), six with septicaemia or bacteraemia, and six with cardiac failure, metabolic encephalopathy, or cerebral haemorrhage. Sixteen infants required operations for conditions that varied from phimosis and inguinal hernia to intestinal malrotation, perforated Meckel's diverticulum, and diaphragmatic hernia.

Two infants died in hospital, one from complex congenital cardiac disease and the other from cerebral haemorrhage complicating liver failure secondary to previously unrecognised biliary atresia. All other babies enrolled in the study were alive at 12 months of age.

CORRELATION OF PRESENTING PROBLEMS AND SYMPTOMS

Symptoms such as convulsions, coughing, vomiting, poor feeding, bloody stools, and apnoea were mentioned by the mother in over 40% of the babies in whom the symptom was present. Symptoms mentioned on less than 10% of occasions when the symptom was present were weak cry, increased sleeping, decreased activity, and drowsiness. Drowsiness was mentioned as a problem significantly more often by mothers in social classes I and II of Australian nationality ($p < 0.05$), but was not associated with maternal education, previous children, not smoking, or marital state.

NUMBER OF SERIOUSLY ILL INFANTS

Overall, 185 (27%) infants were considered to

Table 5 Checklist of symptoms present in previous 24 hours that assist in recognition of serious illness. Actual numerical values relevant only to Royal Children's Hospital

	Lower risk (positive predictive value <35%)	Medium risk (positive predictive value 35–49%)	Higher risk (positive predictive value >49%)
Feeding	>2/3 Normal	1/2–2/3 Normal	<1/2 Normal
Central nervous system and arousal	Increased irritability Decreased sleeping	Occasionally drowsy	Often drowsy Increased sleeping Weak cry Decreased activity Convulsions
Breathing	Cough	Breathing difficulty	Apnoeic episode(s) Cyanotic episode(s) Pale and hot
Skin and circulation	Cold feet Feeling hot	Pale	
Fluid output	Five or less vomits in 24 hours Diarrhoea	More than five vomits in 24 hours Less urine than usual	Vomiting green fluid Bloody stool Less than four wet nappies in 24 hours

be seriously ill when the index definition was used (needing hospital observation). Of these, 75 (11% of the total) needed hospital treatment, and 110 needed observation alone. One hundred and fourteen (17%) had at least one abnormal investigation result. PHH classified 160 (23%) as seriously ill, 232 (34%) as moderately ill, 246 (36%) as mildly ill, and 44 (7%) as normal after the initial assessment.

SYMPTOMS AND SIGNS

The frequency, predictive value, sensitivity, and specificity of each of the symptoms and signs using the index definition of serious illness are shown in tables 3 and 4.

The positive predictive values of each symptom and sign using the alternative outcome criteria were also calculated. Although the absolute value changed with each outcome criterion, it was found that the symptom's order of risk of serious illness remained the same. The main exception was that apnoea was thought to indicate a higher risk by the experienced paediatricians compared with the alternative outcome criteria.

SYMPTOMS OF LOWER, MEDIUM, AND HIGHER RISK FOR SERIOUS ILLNESS

The symptoms were graded into lower, medium, and higher risk categories by their predictive values. The cutoff level of the predictive value differed according to which outcome criterion was used, though the relative order of risk remained the same. Using the index definition (need for hospital observation), the medium to higher risk cutoff was set at 50%, and the lower medium risk cutoff was set at 35%. Checklists of lower, medium, and higher risk symptoms were thus developed, and are shown in tables 5 and 6. The predictive value of various pairs of symptoms in the medium risk group was calculated, and the combination with

a positive predictive value >49% was feeling hot and looking pale. This combination was added to the list of symptoms and its diagnostic measure is shown in table 3.

If any one of the higher risk symptoms was present (right hand column of table 5) in hospital, this system has a sensitivity of 77%, a specificity of 72%, and a positive predictive value of risk of serious illness of 50%.

If babies with inguinal hernias are excluded, only one infant was considered to require admission to hospital but not have a symptom designated either medium or high risk. The mother was, however, thought to be unreliable and the final diagnosis was 'non-accidental injury'.

COMMON PREDICTIVE MARKERS OF ILLNESS

The six most common, predictive symptoms in the seriously ill infants were: drowsiness, breathing difficulty, decreased activity, taking less than half the normal feed in the previous 24 hours, having less than four wet nappies in the previous 24 hours, and feeling hot when looking pale. Using the index definition of serious illness, 88% of the ill infants had at least one of these symptoms (sensitivity 88%); the specificity was 55%, and the positive predictive value was 41%.

SIGNS ON EXAMINATION

The signs on examination that were recorded by PHH were 10% to 20% more predictive than the corresponding symptoms (table 4).

The signs indicating the highest risk of admission to hospital (positive predictive value above 65%) were: respiratory—cyanosis, grunt, and moderatesevere recession; abdominal—tenderness, palpable mass; central nervous system and arousal—decreased awareness or eye fixation, weak cry, or hypotonic posture; skin—cold calves, generalised pallor, sunken eyes or dry mucous membranes; and other: rectal temperature above 38·9°C.

Discussion

This is to our knowledge the first large, prospective study of acute symptoms and signs in young infants. The main impediment to such a study in the past has been the lack of generally

Table 6 Specifications of the system using index definitions and with at least one group of symptoms (table 5) present

	High risk group alone (%)	High and medium risk groups (%)
Positive predictive value	50	34
Negative predictive value	88	99
Sensitivity	77	99
Specificity	72	32
False positive rate	20	50
False negative rate	6	0·2

accepted standards of serious illness. We overcame the problem by comparing the results using a main index definition (the need for observation in hospital) to several alternative definitions of serious illness. For the first time, systematically determined markers of serious illness in young infants have been established.

The limitations of the study do, however, need to be acknowledged. Firstly, the babies studied were presenting to a children's hospital for assessment of illness and the results are not necessarily applicable to other communities because of the social background, referral patterns, and disease prevalence factors. Thus further studies are required using different observers in other hospitals to confirm the results.

Secondly, different types of bias were present in all the outcome measures used.¹⁴ Total outcome independence was not possible when no objective, well recognised, persistently relevant standard was available. Diagnostic review bias, recruitment bias, 'workup' bias, and incorporation bias are all in themselves important. Although each was present to some degree it was of a different type in each case, and the order of predictive symptoms remained the same, suggesting that the results are robust enough to overcome this difficulty in design.

MOST USEFUL MEASUREMENT

Analysis of a baby's functioning was most important when assessing the presence of serious illness. The most consistently predictive and sensitive factors were, firstly, the baby's ability to feed and, secondly, the baby's ability to respond, wake normally, be active, and cry strongly—that is, the baby's ability to arouse. Certainly the often forgotten paediatric adage 'beware the quiet baby' has been validated. Coughing, vomiting, or diarrhoea were not as important unless the baby was not functioning well according to the other criteria mentioned above.

Overall the following variables proved to be the most likely to help us decide whether serious illness was present: responsiveness and activity, feeding ability, breathing, urine output, and circulation when febrile.

Specific, relevant, and detailed questions must be asked so that these variables can be quantified. For example, the feeding ability needs to be known in detail—that is, the actual percentage of feed taken during the previous 24 hours compared with the baby's normal amount of feed. When mothers who were breast feeding were asked to scale their baby's feeding ability 0–10 (considering the time of active sucking and frequency of feeds), scores of less than 4 were at least as predictive of serious illness as if a baby receiving formula feed took less than 34% of his normal 24 hour volume. Similarly, a baby said to be passing less urine than normal had a 50% risk of being thought to need admission to hospital, compared with a 66% risk if less than four wet nappies had been noted. Thus detailed, quantification of certain functions was remarkably predictive of serious illness.

The recognition of obvious (moderate to

severe) chest wall recession would greatly improve the assessment of the ability to breathe (positive predictive value 85% compared with 40%). Further studies are required to assess whether parents and inexperienced health workers are able to recognise 'obvious' chest wall recession. That increasing respiratory rate was not predictive was probably the result of several factors. Firstly, the respiratory rate was counted using a stethoscope when the baby was at rest and awake. This was invariably 20–50% higher than the respiratory rate counted by nursing staff from the side of the cot. Without the stethoscope only breaths with larger volumes of air were counted, while the stethoscope allows smaller, panting breaths to be noticed. Secondly, there is a group of well babies aged between 2 weeks and 4–5 months who consistently breathe at 70–100 breaths/minute while at rest and while awake. These babies (who were well and usually active, alert, and content) made the higher respiratory rates less predictive. Thirdly, although 45 babies had bronchiolitis only four definitely had pneumonia, thus illness prevalence factors may also have contributed to the finding.

The tendency for parents to mention the more graphic symptoms (such as convulsions, vomiting, coughing, and diarrhoea) rather than those associated with quietening may have been the results of minor language difficulty in some cases. Perception of the doctor's expectations, however, interference with their own lives, or lack of experience and knowledge, are other possible reasons. This finding itself illustrates the need to teach parents that the behavioural and functional responses of their baby to stress or illness are more important than the presence of a cough, vomit, or diarrhoea.

The lower, medium, and higher risk symptoms given in table 5 could be colour coded and—with the inclusion of definitions and suitable guidelines suggesting further action—could ultimately provide a simple reference chart to check against when assessing for illness in young infants. It has the advantage of being based on information taken from parents and so could be given back to them without any further testing. It could, however, be made more sensitive, specific, and predictive if examination signs such as chest wall recession were included. Further field trials and education of parents would then be required before it could be distributed for general use.

The actual predictive values of the individual variables (and also of the checklist) are not relevant outside the hospital. It is likely, however, that the order of risk of symptoms will be similar in the community served by that hospital. Certainly, once they have attended the hospital the ability to compare the degree of risk for triage is useful. For example, 23% of infants were initially admitted to hospital. The presence of any symptom in the high risk column increases the risk of needing admission to 50%—that is a positive predictive value of 50%. Thus by using the checklist within the hospital it is possible to more than double the rate of recognition of infants who need to be in hospital.

The low specificity of the common markers

and the checklist should not be overinterpreted. The fact that some babies with these symptoms were not regarded as having serious illness does not necessarily mean the medical assessment was not warranted. Advice about management (including the need for review) are important reasons for asking medical opinion.

In summary, by using clinically relevant definitions of serious illness, and with strict attention to detail, the most predictive and sensitive symptoms and signs of serious illness in babies presenting to a children's hospital have been determined. Further work needs to be carried out to ensure that these markers of serious illness are applicable in different communities with different observers.

This study was part of the collaborative Baby Illness Research Project undertaken in conjunction with the department of paediatrics, University of Cambridge, and we thank Drs CJ Morley, AJ Thornton, TJ Cole, R Powell, S Bechervaise, C Hewson, M Fowler and Professor PD Phelan as well as the staff of the emergency department, general clinic, medical records, and the departments of immunology, haematology, microbiology, and biochemistry, Royal Children's Hospital, Melbourne. The study was funded in Australia by the Australian Institute of Health (Australian government), Ross Trust, Felton Bequests, H and L Hecht Trust, Percy Baxter Charitable Trust and the A Williams Private Fund.

- 1 McWeeney PM, Emery JL. Unexpected post neonatal deaths (cot deaths) due to recognizable disease. *Arch Dis Child* 1975;**50**:191-6.
- 2 Stanton AN, Downham MAPS, Oakley JR, Emery JL, Knowelden J. Terminal symptoms in children dying suddenly and unexpectedly at home: preliminary report of the DHSS multicentre study of post neonatal mortality. *Br Med J* 1978;ii:1249-51.
- 3 Oakley JR, McWeeney PM, Hayes-Allen M, Emery JL. Possibly avoidable deaths in hospital in the age group one week to two years. *Lancet* 1976;ii:770-2.
- 4 Valman B. Preventing infant deaths. *Br Med J* 1985;**290**:339-40.
- 5 Thurtle OA, Cox P, Fall C, et al. Preventing infant deaths. *Br Med J* 1985;**290**:1434-5.
- 6 Knowelden J, Keeling J, Nichol JP. *A multicentre study of post neonatal mortality*. London: Department of Health and Social Security, 1985.
- 7 Waskerwitz S, Berkelhamer JE. Outpatient bacteremia: clinical findings in children under two years with initial temperatures of 39.5 degrees or higher. *J Pediatr* 1981;**99**:231-3.
- 8 Dagan R, Powell KR, Hall CB, Menegus MA. Identification of infants unlikely to have serious bacterial infection although hospitalised for suspected sepsis. *J Pediatr* 1985;**107**:855-60.
- 9 Crain EF, Shelov SP. Febrile infants: predictors of bacteremia. *J Pediatr* 1982;**101**:686-9.
- 10 McCarthy PL, Sharpe MR, Spiesel SZ, et al. Observation scales to identify serious illness in febrile children. *Pediatrics* 1982;**70**:802-9.
- 11 Selker HP. Clinical prediction rules. *N Engl J Med* 1986;**314**:714-5.
- 12 Sackett DL, Haynes RB, Tugwell P. *Clinical epidemiology. A basic science for clinical medicine*. Boston: Little, Brown and Co, 1985.
- 13 Office of population censuses and surveys. *Classification of occupations*. London: HMSO, 1980.
- 14 Ransohoff DF, Feinstein AR. Problems of spectrum and bias in evaluating the efficacy of diagnostic tests. *N Engl J Med* 1978;**299**:926-30.