Clinical predictors of admission in infants with acute bronchiolitis

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ABSTRACT

Background Bronchiolitis is a significant cause of acute morbidity in the first 12 months of life and some infants with bronchiolitis are admitted to hospital. No studies have yet devised a scoring system to predict admission for routine use in the emergency department.

Aim To identify clinical predictors of hospital admission in infants with acute bronchiolitis and to devise a simple clinical risk scoring system which could be used to aid decision making in the emergency department.

Methods All infants presenting with acute bronchiolitis to a dedicated paediatric emergency department from April 2009 to March 2010 were included in the study. Clinical predictors of admission were determined through case note review and logistic regression analysis. The strongest predictors of admission were assimilated into a simple clinical risk scoring system using widely accepted statistical methods.

Results 449 infants presented with acute bronchiolitis during the study period (298 (66%) male, mean age 23±14.5 weeks). 163 (36%) infants were admitted to hospital. The five best predictors of admission (age, respiratory rate, heart rate, oxygen saturations and duration of symptoms) were incorporated into the bronchiolitis risk of admission scoring system. The area under the receiver operator characteristic curve was 0.81 (95% CI 0.77 to 0.85) at the optimal cut-off, demonstrating good diagnostic accuracy.

Conclusions The authors have identified important clinical predictors of admission in acute bronchiolitis. This information has been used to develop a simple clinical risk scoring system to aid decision making in the emergency department.

What is already known on this topic

- The decision whether to admit an infant with acute bronchiolitis is a difficult one based on a variety of clinical features.
- There are no studies reporting a well validated admission scoring system which can be easily applied to a busy emergency department.

What this study adds

- This study identifies important clinical predictors of admission in infants with acute bronchiolitis.
- This study reports the development of a simple clinical risk scoring system to aid decision making in the emergency department.

INTRODUCTION

Bronchiolitis is a very common acute respiratory illness affecting infants and is a significant cause of acute morbidity in the first 12 months of life. The diagnosis of bronchiolitis is a clinical one. The main clinical features of bronchiolitis are difficulty breathing, coryza, poor feeding, cough, wheeze and crepitations on auscultation.[1] The disease is associated with viral infection (most commonly respiratory syncytial virus) and generally occurs in a seasonal pattern, with the highest incidence in the winter months.[2]

The decision whether bronchiolitis should be treated in hospital or in the community is a difficult one. A significant proportion of infants with bronchiolitis will be admitted and the reasons for admission vary across individual clinicians and institutions.[3] Some infants will be discharged inappropriately due to errors in clinical judgement, which can have devastating consequences.[4] One of the most common factors noted when considering admission is whether the infant is hypoxic, but the use of pulse oximetry in infants with bronchiolitis is of questionable benefit.[5 6]

A number of studies have attempted to explore the factors which are taken into account when deciding whether to admit a child with bronchiolitis,[7–12] but few have examined an exhaustive list of the potential factors which play a role in clinical decision making. In addition, no previous studies have been conducted in the UK population where the definition of bronchiolitis does not generally extend to children above the age of 12 months.[1] To our knowledge, only one study has attempted to devise a scoring system to predict the need for admission, but that tool is not applicable to a busy emergency department.[7] There is a need for a well developed clinical risk scoring system which can be used to aid decision making in the emergency department.

OBJECTIVE

In this study we aimed to determine which clinical features in the emergency department are able predict the need for hospital admission in infants with acute bronchiolitis. We set out to devise a simple clinical risk scoring system which could be used to aid decision making in the emergency department.

METHODS

Study design

All infants presenting with acute bronchiolitis to a dedicated paediatric emergency department from

April 2009 to March 2010 were included in this study, providing they met the inclusion criterion. Data for each infant were extracted through review of emergency department case files and admission notes. Clinical features at the time of admission including basic observations, baseline demographic data and clinical history were recorded from case files for each infant. Two authors (MM and JE) independently reviewed case files and extracted data on a standardised data collection form to ensure consistency and accuracy.

Study population

All infants presenting in the 12-month period were considered for inclusion in this study. Potential participants were identified through hospital emergency department records. The inclusion criterion was a clinical diagnosis of acute bronchiolitis documented by a clinician in a child under the age of 12 months. Ethics approval was obtained under institutional audit and this was confirmed by the Chair of the Riverside Research Ethics Committee. Hospital data management procedures were followed to ensure the confidentiality of patient information.

Identification of clinical predictors for admission

In order to ensure that all potentially significant predictors of admission were considered, we conducted a literature review and devised a list of 29 potentially relevant clinical predictors through expert discussion. Both objective and non-objective predictors were considered as long as they could be determined from the infant's care while in the emergency department. The full list of potential predictors can be found in box 1.

Data for each potential predictor were extracted from the emergency department case files for each infant included in this study. Data were continuous or binary, depending on the predictor in question. Where data were not available for a given predictor, this was recorded as missing data, and no attempts were made to derive data where they were not explicitly recorded. Predictors where missing data were more than 20% of the final data set were excluded from the analysis, since it was agreed that such predictors would be difficult to incorporate into a scoring system and may introduce bias, as reported in methodological studies.[13] The outcome measure was admission to the hospital or discharge from the emergency department.

Logistic regression analysis was used to determine which clinical predictors were significant in predicting admission. Univariate analysis was used due to the large number of potential predictors, but a conservative significance level of $p<0.001$ was applied to those predictors included in the scoring system to account for this. ORs with 95% CIs were calculated for each potential predictor and the significance of these was tested using the likelihood ratio test. All statistical calculations were performed in SPSS 16.0 (SPSS, Chicago, Illinois, USA).

Clinical risk scoring system development

The development of a simple clinical risk scoring system for use in the emergency department was conducted in stages. Throughout the development process, the need for an accurate scoring system was balanced against the need for a relatively simple system which could be easily used in a busy emergency department.

Stage 1

Predictors where missing data were more than 20% of the data set were excluded from the analysis. Next, non-objective clinical predictors were excluded from the list of potential predictors to be used in the scoring system due to difficulty standardising the measurement and recording of such predictors (eg, dehydration), as described in other studies.[14] Finally, the predictors which did not reach the conservative significance level ($p<0.001$) were excluded.

Box 1 Potential clinical predictors of admission in acute bronchiolitis

- Age at presentation (weeks, not corrected for prematurity)
- Respiratory rate (breaths/min)
- Heart rate (beats/min)
- Oxygen saturation (%)
- Temperature (ºC)
- Duration of symptoms (days)
- Weight at presentation (g)
- Birth weight (g)
- Gestational age (weeks)
- $PaCO_2$ on blood gas analysis (kPa)
- pH on blood gas analysis
- HCO_3 on blood gas analysis (mmol/l)
- Glasgow coma score
- Presence of cough
- Presence of wheeze
- Decreased feeding
- Clinical signs of dehydration
- Supplemental oxygen required in the emergency department
- Presence of diarrhoea
- Presence of vomiting
- Presence of coryza
- Presence of apnoeas
- Currently breastfed
- History of prematurity
- Clinically determined drowsiness
- Clinically determined increased work of breathing
- Presence of grunting
- Clinically determined abnormalities on auscultation
- Previous episode(s) of bronchiolitis

Stage 2

After consideration of remaining predictors to be included in the scoring system, the weighting to be applied to each clinical predictor was determined by calculating the area under the receiver operator characteristic curve (AUROC) for each predictor.

Stage 3

The ideal cut-off value for predictors with continuous data was determined using the receiver operator characteristic (ROC) curve, with sensitivity and specificity being given equal weighting.

Stage 4

The diagnostic accuracy of the resultant clinical risk score was calculated using the overall AUROC for the score. The optimal cut-off for the clinical risk score was determined through the ROC curve, giving equal weighting to sensitivity and specificity. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for admission were then calculated using this cut-off.

RESULTS

Overall, 464 infants presented with acute bronchiolitis during the study period and were considered for inclusion in this

study. Emergency department case files were not available for 11 children and four children were over the age of 12 months. In total, 449 infants were included in the final study population (298 (66%) male, mean age 23±14.5 weeks). Of these, 163 (36%) were admitted to hospital.

Identification of clinical predictors for admission

Table 1 shows the results for each of the 14 potential clinical predictors of admission where missing data were less than 20% of the final data set. The raw data for both continuous and binary predictors are presented, as well as the percentage of data which was missing for each predictor. The OR for continuous predictors represents the increasing odds for admission with each increase of one point in the predictor, which is therefore substantially affected by the range of the predictor. For example, the OR for respiratory rate is 1.07, so practically this means that with each increasing one point in respiratory rate there is a 7% higher risk of admission. The OR for binary predictors represents the increased odds for admission with the predictor being present rather than absent.

The significance of each predictor can be simply assessed using the p value. Using a conservative significance level of $p<0.001$, eight clinical predictors are significantly associated with admission.

Clinical risk scoring system development

Of the 29 potential predictors, 24 were excluded through the process outlined in figure 1. Oxygen requirement in the emergency department was excluded prior to the development of the final scoring system as it could not always be determined at the initial clinical assessment (an infant may develop an oxygen requirement at a later time during their emergency department stay). The final five predictors included in the scoring system can also be seen in tables 2 and 3.

A total of 421 infants (94%) had full data for all five predictors in the final scoring system, while 28 infants (6%) were missing one or more predictors and were therefore excluded from the population used for the next stage of scoring system development.

The AUROC was used to determine the weighting given to each of the five clinical predictors included in the scoring system. This can be seen in table 2, where it ranges from 0.62 to 0.72, with an overlap in the 95% CIs between the best performing predictor and the weakest predictor. Because of the similar performance between the five final predictors, it was decided that all predictors should be weighted equally in order for the clinical risk scoring system to remain simple and applicable to a busy emergency department.

The five predictors all have continuous data and so an optimal cut-off was determined using the ROC curve. This cut-off can be seen in table 3 which shows the final clinical risk scores. Table 4 shows the distribution of scores across admitted and discharged children, as well as the sensitivity and specificity of the score at the specified score cut-off value. The AUROC for the final clinical risk score was 0.81 (95% CI 0.77 to 0.85). The optimal cut-off using this score was found to be a score of ≥3 requiring admission. At this cut-off the sensitivity was 74% and specificity was 77%. The PPV was 67% and the NPV 83%.

DISCUSSION

In our study we found eight clinical predictors of admission in infants with acute bronchiolitis. We also developed a clinical risk scoring system which can be used in the emergency department to aid clinical decision making. This scoring

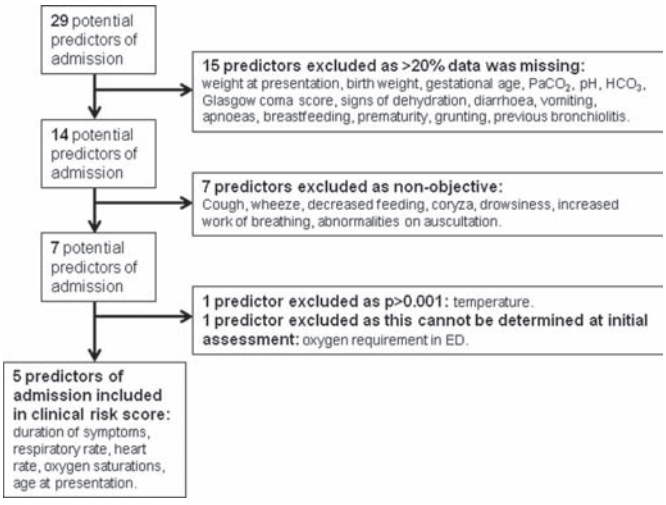

Figure 1 Flow chart showing how potential predictors of admission were excluded.

Table 1 Result of the logistic regression analysis for clinical predictors of admission in acute bronchiolitis

Clinical predictor	Result for admitted group*	Result for discharged group*	Missing data (%)	OR (95% CI)	p Value
Age at presentation (weeks)	17.9 (4 mois)	26.4 (6,5 mois)	0	0.96 (0.94 to 0.97)	<0.001
Respiratory rate (breaths/min)	54.6	46.9	2	1.07 (1.05 to 1.09)	<0.001
Heart rate (beats/min)	162.8	147.7	1	1.05 (1.03 to 1.06)	<0.001
Oxygen saturation (%)	96.4	98.4	2	0.76 (0.69 to 0.83)	<0.001
Temperature (°C)	37.4	37.2	3	1.37 (1.05 to 1.79)	0.02
Duration of symptoms (days)	2.9	4.9	2	0.82 (0.75 to 0.90)	<0.001
Presence of cough	96	98	6	0.33 (0.09 to 1.14)	0.079
Presence of wheeze	83	70	16	2.06 (1.23 to 3.45)	0.006
Decreased feeding	82	70	12	1.99 (1.21 to 3.28)	0.006
Oxygen required in ED	36	1	7	78.44 (18.82 to 326.88)	<0.001
Presence of coryza	98	95	19	2.51 (0.68 to 9.29)	0.167
Drowsiness	7	0	5	19.51 (2.49 to 152.58)	0.005
Increased work of breathing	94	65	6	9.32 (4.54 to 19.14)	<0.001
Abnormalities on auscultation	88	73	10	2.76 (1.58 to 4.82)	<0.001

*Results presented as mean for continuous predictors and % for binary predictors
ED, emergency department.

Table 2 AUROC values for the five clinical predictors of admission included in a clinical risk scoring system

Clinical predictor	AUROC (95% CI)
Age at presentation (weeks)	0.67 (0.62 to 0.73)
Respiratory rate (breaths/min)	0.69 (0.64 to 0.74)
Heart rate (beats/min)	0.72 (0.67 to 0.77)
Oxygen saturation (%)	0.64 (0.59 to 0.70)
Duration of symptoms (days)	0.62 (0.57 to 0.67)

AUROC values range from 0 to 1, with a value closer to 1 indicating higher diagnostic accuracy.
AUROC, area under the receiver operator characteristic curve.

Table 3 Bronchiolitis risk of admission score

		Points
Duration of symptoms	<5 days	1
	≥5 days	0
Respiratory rate	≥50 breaths/min	1
	<50 breaths/min	0
Heart rate	≥155 beats/min	1
	<155 beats/min	0
Oxygen saturation	<97%	1
	≥97%	0
Age at presentation	<18 weeks	1
	≥18 weeks	0
Total		5

Table 4 Distribution of scores across admitted and discharged children with sensitivity and specificity at each score cut-off

Score	Number admitted with score	Number discharged with score	Sensitivity at cut-off (%)	Specificity at cut-off (%)	LR+	LR-
0	2	33	100	0		
1	10	70	99	13	1.1	0,1
2	30	95	93	40	1.6	0,2
3	54	46	74	77	3,2	0,3
4	45	12	41	95	8,2	0,6
5	22	2	14	99	14	0,9

system is simple and easy to use, making it applicable to a busy clinical setting. It was developed in a large number of children who were consecutively recruited using a retrospective sample which eliminated any potential observer bias. It employs only objective clinical parameters, limiting the potential for variability when used by different clinicians. The scoring system was developed with clinical applicability as a priority rather than the maximisation of statistical accuracy.

While other studies have looked at predictors of admission in children with bronchiolitis, no other studies have only included infants in their study population. Although in some countries bronchiolitis is diagnosed up to the age of five, a large majority of those admitted to hospital with bronchiolitis are infants.[15] Notably, 66% of infants in our study were male. This correlates with the findings of other studies, where it has also been noted that males are more likely to be hospitalised with bronchiolitis[15] and that males are more likely to die with bronchiolitis.[16] The reason for this sex difference is still unclear.

The findings of our study are similar to those of Mansbach *et al*, although they report predictors of safe discharge rather than predictors of admission. While Mansbach's study included children up to 2 years of age, they found that an age of ≥2 months at presentation was one of the strongest factors associated with discharge. Other factors associated with discharge included a lower respiratory rate and higher oxygen saturations.[10] Some have suggested that the strongest predictor of admission is oxygen saturations below 92%,[6 10] yet it has been suggested that over-use of oxygen saturation measurement may prolong admission unnecessarily.[5] In addition, there is evidence that oxygen saturation level at admission does not correlate with length of hospital stay; in one study the provision of supplemental oxygen therapy during hospitalisation was the main determinant of length of hospital stay in infants with bronchiolitis.[17] Our study demonstrates that many different factors are considered when deciding whether to admit a child with bronchiolitis, so clinicians should avoid an over-reliance on oxygen saturation measurement alone.

Scoring systems for use in the paediatric emergency setting have been criticised for their lack of relevance and applicability.[1 18] Many are considered purely research or service management tools which have no place in routine care. We developed our clinical risk scoring system with this in mind, ensuring that it would take no longer than 1 min to complete and that only objective parameters were used in order to increase the reproducibility of results. The second generation Pediatric Risk of Admission Score (PRISA) was developed by Chamberlain *et al* and is one of the most widely accepted tools available in the paediatric emergency field.[19] Our scoring system is much simpler to use with only five parameters compared to 17, while maintaining similar discriminant validity and accuracy to the PRISA.[19 20] Our score has an AUROC of 0.81, while the PRISA has an AUROC of 0.77–0.82 (depending on the population used). The Pediatric Early Warning System (PEWS) score also has similar accuracy to our score with an AUROC of 0.83.[21] We find that our score has better accuracy compared to other respiratory scoring systems. A recent study reports that the Preschool Respiratory Assessment Measure (PRAM) has an AUROC of 0.69 and the Pediatric Asthma Severity Score (PASS) has an AUROC of 0.70.[22]

There are limitations to our clinical risk scoring system which has only been retrospectively tested for diagnostic accuracy. A further prospective study would be required to fully validate this clinical risk scoring system and to assess its applicability across different healthcare settings. When identifying clinical predictors for admission, we found that some predictors had high levels of missing data, which were subsequently excluded from the analysis in order to avoid bias. This has been reported in other paediatric emergency studies[23] and the potential for bias here is evident.[13] Fortunately, all five of the objective predictors included in our final clinical risk scoring system had negligible missing data and therefore we expect the risk of bias to be very small.

There is evidence that clinical risk scores produce different results when applied in different institutions.[18] An inherent limitation of admission scoring systems such as ours is that they look at the fact of admission, rather than a true requirement for admission, which is a difficult concept to define and will vary from one patient to another. Resource limitations and social circumstances cannot be accounted for and these will limit the utility of this scoring system in some settings. While we expect that the reproducibility of this score will be high due to the use of objective parameters, it may still be of varying value to clinicians in different settings.

It is important to emphasise that no direct conclusion regarding decision to admit or discharge should be made solely based on the score itself, for example, a child who scores 0 or 1 is

unlikely to need admission, but if they have a significant risk factor (eg, a history of bronchopulmonary dysplasia or congenital heart disease)[1 24] they are still likely to require admission. In addition, social factors and the general trend of the illness must be considered in conjunction with the score, as these factors can have a significant bearing on the requirement for hospital admission.

However, the scoring system may be particularly useful in the context of supporting those who are inexperienced in acute paediatrics. While experienced paediatricians will combine a number of objective and subjective features into their overall clinical judgement, less experienced clinicians or those who see children less frequently (eg, junior doctors or general practitioners) may be less confident in their overall judgement. The use of an objective score could support their provisional judgement, or to make them question and reconsider it.

It is widely accepted that errors occur and children are sent home from emergency departments inappropriately, despite evidence of significant illness. Clinical judgement can let these children down and some die as a result.[4] So called 'red flag' features have become an increasing part of national clinical guidelines, for example, the clinical features of dehydration in diarrhoea and vomiting[25] and warning signs of illness in the child with fever,[26] but they require clinical judgement and interpretation and can be prone to error. Furthermore, early warning scores based on a variety of physiological parameters are now in routine use in many inpatient hospital settings. These are employed to assist staff in identifying patients who may require an escalation in care.[21]

We believe our scoring system could be a useful addition to these safety net scoring systems and be employed effectively in the emergency department, particularly by inexperienced clinicians. It is simple to use and takes into account objective data, for example, a score of 3 or over could direct the clinician to seek a review of the child by a senior colleague before allowing that child to be discharged. Lesser scores could be related to other actions, for example, score of 0–1 might generate a plan to consider allowing the child home providing some high risk factors have been excluded.

The use of our scoring system is not necessarily limited to the emergency department, as its objective and simple nature makes it applicable to primary care settings. Additionally, its granularity of 0–5 could also be used, rather than simply using the cut-off of 3. Further validation in different settings is required to define its use, but a potential application could be as a referral tool for primary care with a cut-off of ≥2 to give a sensitivity of 93%.

CONCLUSIONS

This study has identified clinical predictors of admission in infants with acute bronchiolitis and has described the development of a simple clinical risk scoring system to aid decision making in the emergency department. Further work is required to validate this scoring system across different institutions and countries, but initial results show that is both applicable and valid for use in a busy clinical setting.

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Competing interests None.

Ethics approval The Chair of the Riverside Research Ethics Committee (Dr Sabita Uthaya) considered this study and decided that research ethics committee approval was not required.

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