Alarming Signs in the Manchester Triage System: A Tool to Identify Febrile Children at Risk of Hospitalization

Yvette van Ierland, MD, MSc, Nienke Seiger, MD, MSc, Mirjam van Veen, MD, PhD, Henriëtte A. Moll, MD, and Rianne Oostenbrink, MD, PhD

Objectives
To assess whether the flowcharts and discriminators of the Manchester Triage System (MTS) can be used as indicators of alarming signs of serious febrile illness to predict the risk of hospitalization for febrile children who present at the emergency department (ED).

Study design
Observational study, which included 2455 children (<16 years) who came to the ED of a university hospital with fever as their main complaint (May 2007-July 2009). Alarming signs for serious febrile illness were matched with MTS flowcharts and discriminators. At triage, the percentage of alarming signs positive was calculated. The diagnostic ability of the percentage of alarming signs positive to identify children at risk of hospitalization was assessed by calculating positive and negative likelihood ratios.

Results
Thirty percent of children had at least 1 alarming sign positive at triage. Twenty-three percent were hospitalized. Positive likelihood ratios of hospitalization were 5.0 (95% CI: 3.9-6.5) for children with >20% of alarming signs positive at triage and 12.0 (95% CI: 5.2-27.6) for those with >40% of alarming signs positive. Negative likelihood ratios were 0.8 (95% CI: 0.8-0.8) and 1.0 (95% CI: 0.9-1.0), respectively.

Conclusions
By alternatively using the flowcharts and discriminators of the MTS as alarming signs, rather than urgency classifiers, the MTS can function as a simple, readily available tool to identify febrile children at risk of hospitalization early in the care process. This knowledge may help to improve ED throughput times as well as admission and discharge management at pediatric EDs. (J Pediatr 2013;162:862-6).

Pediatric emergency departments (EDs) are becoming more and more crowded. Febrile children constitute one of the major patient groups at pediatric EDs and are at risk of serious illnesses, like meningitis, sepsis, or pneumonia. Prevalence of such infections ranges from about 7%–15%. Early detection of serious febrile illnesses is important, because delaying or missing such diagnoses may lead to morbidity or even mortality and hospitalization is often required. Recently, a systematic review has identified several alarming signs for serious illnesses in children with fever.

Because the need for strategies to improve patient flows at pediatric EDs is growing, Asplin et al have proposed a conceptual input-throughput-output model to find areas for improvement of ED work flows. One of the model’s suggestions is that if one can already predict whether a patient will likely be admitted during the intake-phase (eg, triage), timeliness of admission to the ward or discharge management can be improved.

The Manchester Triage System (MTS) is implemented in a large scale and used to prioritize patients according to acuity. The MTS contains flowcharts (presenting problem) and discriminators (other signs and symptoms) for triage of both adult and pediatric patients and collects clinical information at the moment of arrival at the ED.

This study aimed to assess whether the flowcharts and discriminators of the MTS can be used as indicators of alarming signs of serious febrile illness, rather than urgency classifiers alone, to predict the risk of hospitalization for febrile children who present at the ED.

Methods

This observational study is part of an ongoing study on validation of the MTS, for which standardized clinical information is prospectively and electronically collected. The institution’s medical ethics committee approved the study and the requirement for informed consent was waived.

We included all children up to 16 years of age who had came to the ED of the Sophia Children’s Hospital, Rotterdam, The Netherlands, from May 2007-July 2009. This ED is part of the Erasmus University Medical Center and provides care to approximately 9000 children annually (ie, 50% general pediatrics, 40% general surgery, 10% subspecialties).
surgery, 10% other specialties). Eligible contacts were those who had general pediatric problems and: (1) fever as the reason for contact; (2) fever selected as triage discriminator; or (3) a rectal temperature ≥38.5°C measured at the ED. Revisits for the same complaint within 7 days were excluded, as were children who died at the ED.

All children who presented at the ED were routinely triaged with the MTS. The MTS consists of 49 flowchart-diagrams which represent main problems with which children present to the ED (eg, ‘crying baby’ or ‘shortness of breath’). Each flowchart is built up of a specific combination of discriminators (ie, signs and symptoms that often go hand-in-hand with the presenting problem). Within each flowchart, the discriminators are arranged from most urgent (U1, top) to least urgent (U5, bottom) (Figure 1; available at www.jpeds.com). At triage, trained nurses first have to select the most appropriate flowchart for the child. Next, the patient’s urgency level is assessed by selection of the most relevant discriminator, starting from the top of the flowchart moving downwards.

For the purpose of this study, triage nurses also had to indicate whether the other discriminators within the flowchart were present or absent (‘triage remaining items’). In our hospital, a modified version of the first edition of the MTS (official Dutch translation) was used, which contained several adjustments for triage of febrile children. Compliance with triage was 97% (7311/7573). Inter-rater agreement (agreement in triage urgency level if multiple nurses triage one patient) and intra-rater agreement (agreement in triage urgency level if 1 triage nurse triages 1 case scenario at different time points) have been shown to be good for the MTS, both at our own ED and other settings and were not influenced by nurses’ work experience.

Patient’s characteristics, selected flowchart, selected discriminators, urgency category, and hospitalization were extracted from the computerized MTS. Medical records were checked manually for children who missed 1 or more triage remaining items (N = 262; 3.5%). For 47 (1.8%) patients, some triage remaining items remained missing and were assumed to be absent. Among all evaluated in the ED, 0.5% left before being seen by a physician. These patients were not followed up, because this number was very small and will not have influenced our results.

We matched alarming signs for serious illness, as identified in a systematic review (positive likelihood ratio >5 or negative likelihood ratio <0.2), with flowcharts and discriminators of the MTS. Three flowcharts and 20 discriminators were considered as valid proxies for 14 alarming signs (Table 1). The alarming signs ‘child moaning’, ‘crackles’, and ‘decreased breathing sounds’ could not be matched with any flowchart or discriminator. Two alarming signs were excluded from the analysis: ‘decreased skin elasticity’ was specific for only gastro-enteritis with subsequent dehydration and ‘any abnormal finding in history or physical examination’ we found too unspecific for triage purposes.

Because every flowchart contains a unique combination of discriminators, relevant for the presenting problem, the maximum number of alarming signs that could have been selected at triage of a child was dependent on the assigned flowchart and ranged from 1-7. For example, in the flowchart ‘crying baby’ (Figure 1), 8 discriminators are valid proxies for 6 alarming signs in total. To correct for the difference in the maximum number of alarming signs between flowcharts, we calculated the percentage of alarming signs positive at triage as follows:

\[
\text{Percentage of alarming signs positive} = \frac{\text{number of alarming signs present at triage, given the assigned flowchart}}{\text{maximum number of alarming signs available in the assigned flowchart}}
\]

The primary outcome measure of this study was hospitalization. At our study ED, the admission policy was based on medical indications only: (1) abnormal or threatened vital signs; (2) requirement of intravenous (IV)-medication or IV-fluids; or (3) failure to ingest medication (eg, need for a nasogastric tube). To validate our assumption that hospitalization could be used as a proxy for serious febrile illness, we evaluated the number of diagnostic and therapeutic interventions performed during hospital admission and the definite diagnosis in a random subsample of admitted children (January 2008-July 2009; N = 356).

Statistical Analyses
The majority of patients (77%) were assigned to flowcharts in which the maximum number of alarming signs that could be selected was 5 (flowcharts ‘general,’ ‘shortness of breath,’ and ‘vomiting and diarrhea’) or 7 (flowcharts ‘worried parent’ and ‘fits’). In our analyses, we, therefore, categorized the percentage of alarming signs positive as such that for children assigned to these flowcharts the categories corresponded with ‘no alarming signs positive at triage’ (0%; ‘none’), ‘1 alarming sign positive at triage’ (≤20%, ‘low’), ‘2 alarming signs positive at triage’ (≤40%, ‘intermediate’), and ‘3 or more alarming signs positive at triage’ (>40%, ‘high’).

Two-by-two contingency tables were constructed to show the distribution of hospitalizations among the 4 percentage groups. To determine the diagnostic value of the percentage of alarming signs to assess the need for hospitalization, as if it were a diagnostic test, we calculated sensitivity, specificity, and positive and negative likelihood ratios with 95% CIs (VassarStats Clinical Calculator; http://vassarstats.net/clin1.html). To indicate a ‘positive’ and ‘negative’ test result, we dichotomized the percentage of alarming signs at the 3 cut-off points: (1) >0% versus no alarming signs; (2) more than 20% of alarming signs positive (>20% vs ≤20%); or (3) more than 40% of alarming signs positive (>40% vs ≤40%). For descriptive statistics we used SPSS PASW statistics software (v. 17.0.2; SPSS Inc, Chicago, Illinois).

Results
In total, 2455 (32%) of 7573 children were eligible for analyses (Figure 2). No differences in age, sex, temperature, and frequency of hospitalization were found between children
included in the study and those with missing flowchart (N = 262; data not shown). Patient’s and triage characteristics of the study population are shown in Table II. Hospitalization was required for 563 (23%) children. Main reasons for hospitalization were: (1) a diagnosis of serious bacterial infection (32%); (2) requirement of IV-medication/fluids or oxygen/dose-aerosol treatment (42%); (3) failure of therapy compliance at home (4%); (4) observation, awaiting diagnostic test results (14%); and (5) other reasons (7%). Eleven percent of children had a revisit for the same complaint within 7 days. Hospitalization after a revisit occurred in 77 (3%) of children.

Alarming Signs for Serious Illness and Hospitalization
For 733 (30%) children, at least 1 alarming sign was selected at triage. Among these, 544 (74%) had 1 alarming sign positive, 158 (22%) had 2, 20 (3%) had 3, 9 (1%) had 4, and 2 (0.3%) had 5. For children assigned to the 5 most commonly used flowcharts, the relation between the percentage of alarming signs positive and hospitalization is depicted in Figure 3 (available at www.jpeds.com). Table III shows the diagnostic performance of the percentage of alarming signs positive, as if we would use it as a diagnostic tool. The presence of more than 20% alarming signs at triage showed a high specificity (>95%) for hospitalization. The positive likelihood ratios for patients with more than 20% and more than 40% of alarming signs positive at triage indicate that hospitalization is 5 and 12 times as likely to be required for children in these groups compared with those who had lower percentages. Negative likelihood ratios were approximately one for all three cut-off levels.

Discussion
Over the past years, much effort has been put into finding alarming signs, which identify febrile children at risk of a serious illness.2-4 This study showed that by alternatively using the flowcharts and discriminators of the MTS, as indicators of alarming signs rather than urgency classifiers, the system has the potential to identify children at risk of hospitalization early in the ED care process. We found the majority of alarming signs for serious illness to be represented in flowcharts or as discriminators in the MTS. A percentage of alarming signs positive at triage above 20% was useful for ‘ruling-in’ hospitalization (high specificity and positive likelihood ratio). For children with more than 40% of alarming signs positive the likelihood of hospitalization was even higher, although this analysis was based on small numbers. On the contrary, a low percentage or absence of alarming signs was not helpful in excluding (‘ruling-out’) hospitalization, as shown by the low sensitivities and high negative likelihood ratios. These patients should still be
assessed with caution and one should look for other clinical measures to judge their risk of serious illness.

In principal, triage systems have been developed to prioritize patients according to their acuity upon arrival at the ED. Others have previously demonstrated that a high MTS urgency level could not well discriminate between children with or without serious bacterial infections.3,5 Both authors explained this limited discriminative ability by the fact that assessing a patient’s level of urgency is different from predicting severity of illness or diagnosing a disease.3,5,22 In this study, we focused on the more specific and detailed information available in the MTS (ie, the presence of alarming signs of serious febrile illness specifically instead of a high urgency classification only), which resulted in a higher diagnostic value to predict the need for hospitalization.

We certainly realize that the MTS may not be the most optimal tool for recognizing children at risk for hospitalization. However, more sophisticated tools, such as computerized decision support systems, often require additional clinical characteristics not available from the triage assessment.23 Besides, such tools are scarce for general complaints such as fever, because their development and implementation is difficult and time-consuming.23,24

In practice, the percentage of alarming signs can be automatically calculated by the computerized MTS or by hand. Next, the observed likelihood ratios can be applied to Bayes nomogram25 to calculate the post-test probabilities of hospitalization for febrile children at comparable ED settings. For example, in a particular ED-setting with a pre-test probability of hospitalization of 15%, the probability of hospitalization will increase to 45% for a febrile child with >20% of alarming signs positive and 70% in case >40% of alarming signs are positive at triage (Figure 4; available at www.ipeds.com).

Early identification of children at risk of hospitalization, as a proxy for serious illness, may be useful in further prioritizing patients at the ED, accelerating the application of diagnostic or therapeutic interventions, or deciding to perform interventions after the patient is first admitted to the in-hospital ward.1,9 Before broad implementation in practice, our findings should be validated in other settings where the MTS is used for triage of febrile children. Subsequently, impact studies must evaluate the improvement of throughput and output flows of febrile children at the pediatric ED.

Our study population comprised a good case mix of nearly 2500 children, selected from a multicultural, inner-city ED population. Even though in The Netherlands we have a well-preserved primary care system (general practitioners), which functions as a gatekeeper for specialist care, nearly one-half of our ED population was self-referred.26 Therefore, we think our results are likely to be generalizable to other Western pediatric EDs with a case mix population of referred and nonreferred children. Besides, hospital admission was defined for medical indications only at our study ED. From this perspective, the choice of being admitted is independent of referral status or the prevalence of disease.

Selection bias seems unlikely, because compliance with triage was high and general patients’ characteristics and hospitalization frequencies of children excluded because of missing values were comparable with those of children included in the study.

We only had information on revisits, which had taken place at our study ED, even though in practice patients may have visited other health care facilities subsequently. Because our study ED is the major pediatric emergency care facility of the Rotterdam district with 24/7 availability, we do not expect to have missed many revisits.

Selection of alarming signs at triage was restricted by the flowchart chosen. It might have been possible that

### Table II. Patients’ and triage characteristics of the total study population (N = 2455)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (N = 2455)</th>
<th>Within group (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex (N; %)</td>
<td>1423 (58)</td>
<td>335 (13)</td>
</tr>
<tr>
<td>Age in y (median; IQR)</td>
<td>2.2 (1.0-4.6)</td>
<td>2.3 (1.0-4.6)</td>
</tr>
<tr>
<td>Temperature in °C (median; IQR)</td>
<td>38.9 (38.1-39.5)</td>
<td>39.0 (38.1-39.5)</td>
</tr>
<tr>
<td>MTS urgency (N; %)</td>
<td>Immediate</td>
<td>Very urgent</td>
</tr>
<tr>
<td></td>
<td>64 (3)</td>
<td>725 (30)</td>
</tr>
<tr>
<td></td>
<td>Urgent</td>
<td>1232 (50)</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>422 (17)</td>
</tr>
<tr>
<td></td>
<td>Nonurgent</td>
<td>12 (1)</td>
</tr>
</tbody>
</table>

### Table III. Diagnostic performance of alarming signs for serious illness positive at triage of febrile children (N = 2455)

<table>
<thead>
<tr>
<th>Alarming signs positive*</th>
<th>N (% of total population)</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>LR+ (95% CI)</th>
<th>LR- (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1722 (70)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt;0%-20%</td>
<td>523 (21)</td>
<td>40.5 (36.4-44.7)</td>
<td>73.3 (71.2-75.3)</td>
<td>1.5 (1.3-1.7)</td>
<td>0.8 (0.8-0.9)</td>
</tr>
<tr>
<td>&gt;20%-40%</td>
<td>178 (7)</td>
<td>22.4 (19.1-26.1)</td>
<td>95.6 (94.5-96.4)</td>
<td>5.0 (3.9-6.5)</td>
<td>0.8 (0.8-0.8)</td>
</tr>
<tr>
<td>&gt;40%</td>
<td>32 (1)</td>
<td>4.4 (3.0-6.6)</td>
<td>99.6 (99.2-99.8)</td>
<td>12.0 (5.2-27.6)</td>
<td>1.0 (0.9-1.0)</td>
</tr>
</tbody>
</table>

LR+, positive likelihood ratio; LR-, negative likelihood ratio.

*Cut-off levels for a ‘positive test’ to calculate sensitivity, specificity, and likelihood ratios: >0%: at least one alarming sign positive at triage versus none; >20%: >20% of alarming signs positive at triage versus ≤20%; >40%: >40% of alarming signs positive at triage versus ≤40%.
additional alarming signs were present at triage, which could not have been selected because of the absence of these discriminators in that particular flowchart. Because we primarily focused on alternative use of the available content of the MTS, rather than the exact number of alarming signs present at triage, this will not have influenced our results and its clinical implications.

Lastly, some alarming signs were strongly associated with the outcome (e.g., abnormal vital signs) and mainly applied to children classified as ‘immediate (U1).’ Analyses without this patient group resulted in comparable findings (data not shown), which indicates that inclusion of these children in our main analyses was of no major threat to the validity of our results.

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Reprint requests: Rianne Oostenbrink, MD, PhD, Department of General Pediatrics, Erasmus MC/Sophia Children’s Hospital, P.O. Box 2060, 3000 CB Rotterdam, The Netherlands. E-mail: r.oostenbrink@erasumscmc.nl

References

Figure 3. Hospitalization per percentage group of alarming signs positive at triage for the most commonly chosen flowcharts. The intermediate and high percentage groups are displayed as one group because of small group numbers.
Figure 4. Example of the calculation of post-test probabilities of hospitalization using Bayes nomogram.