Chapter 6

Improvements of the Manchester Triage System for paediatric emergency care. A prospective observational study

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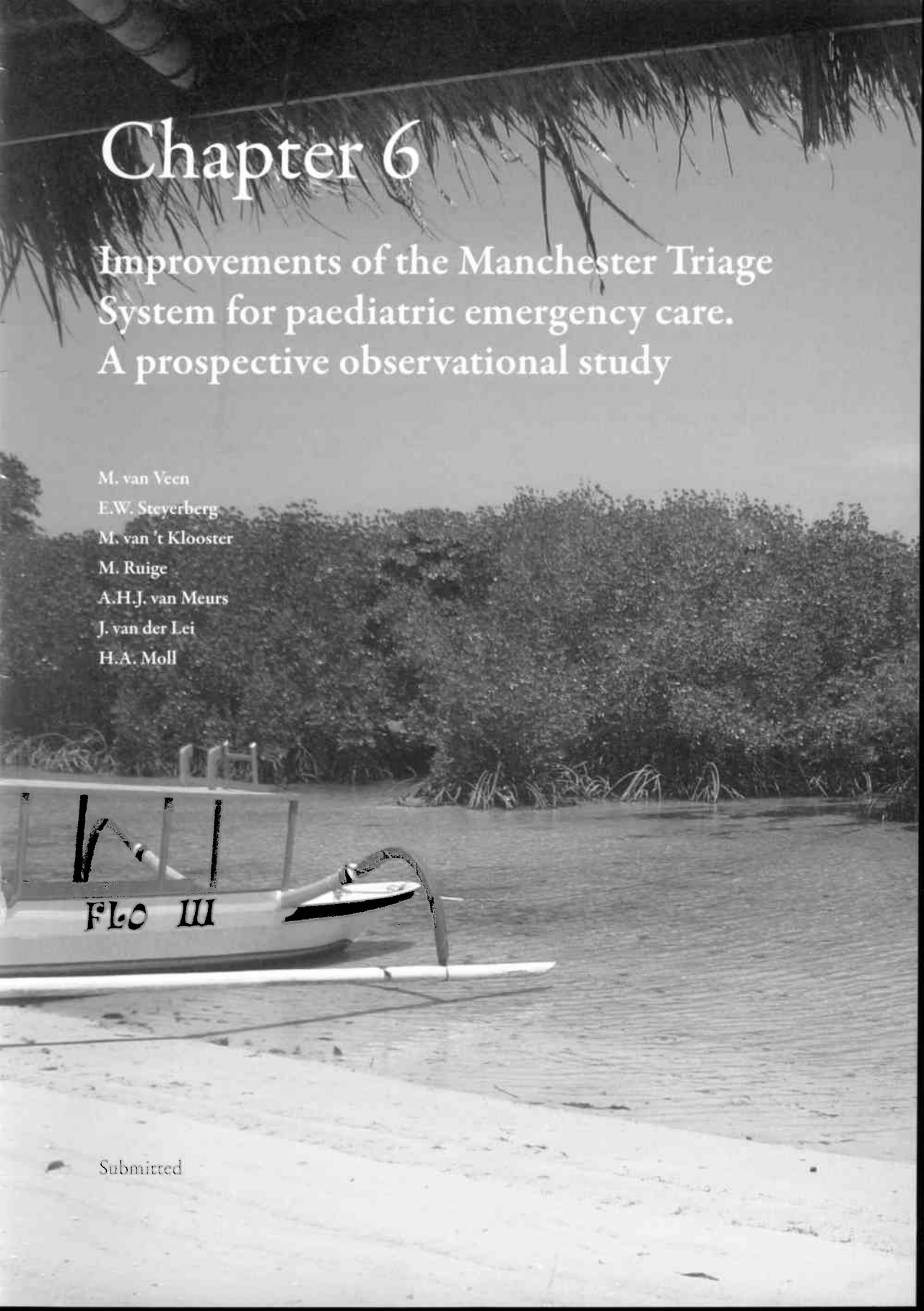

Submitted

ABSTRACT

Objective To improve the Manchester Triage System in paediatric emergency care

Methods We performed a prospective observational study at the emergency departments of a university and teaching hospital in The Netherlands and included children attending in 2007 and 2008 during 12 and 5 months, respectively. We developed and implemented specific age dependent modifications for the Manchester Triage System, based on patient groups where the system's performance was low. Nurses applied the modified system in 11,481 (84%) patients. The reference standard for urgency defined five levels based on a combination of vital signs at presentation, potentially life-threatening conditions, diagnostic resources, therapeutic interventions and follow-up. The reference standard for urgency was previously defined and available in 11,260/11,481 (96%) patients.

Results Compared to the original Manchester Triage System specificity improved from 79%, (95% C.I. 79 to 80%) to 87% (95% CI 86 to 87%) while sensitivity remained similar (63%, 95% CI 59 to 66%) versus (64%, 95% CI 60 to 68%). The diagnostic odds ratio increased. (4.1, 95% CI 3.2 to 5.1 versus 11, 95% CI 9.6 to 14)

Conclusions Modifications of the Manchester Triage System for paediatric emergency care resulted in an improved specificity while sensitivity remained unchanged.

Further research should focus on the improvement of sensitivity.

INTRODUCTION

Triage is an important tool to manage patient flow safely when clinical need exceeds capacity.[1] Several triage systems have been developed and applied in emergency care. The Manchester Triage System (MTS), the Emergency severity Index (ESI), the Canadian Triage and acuity scale (CTAS) and the Australasian Triage scale (ATS) are commonly used triage systems.[1-6] They all use specific criteria to triage children.

The MTS consists of 52 flowcharts, which present reasons of encounter, of which 49 are applicable for children. Each flowchart contains discriminators of which selection leads to one out of the five urgency levels. In adults the MTS was shown to be sensitive for early detection of seriously ill patients and for the detection of high-risk chest pain. The MTS showed a substantial to good inter-rater agreement in adults and children.[7,8]

We studied validity of the MTS in children and showed a moderate validity with a sensitivity of 63% (95% C.I. 59 to 66%) and a specificity of 79% (79 to 80%) for identifying high urgency patients. Performance was especially low for patients with a non-traumatic presenting problem, for patients with a young age and for patients with fever. Modifications for patient groups with a low performance may improve the MTS.[9]

The aim of this study was to improve the MTS for paediatric emergency care based on modifications in patient groups in which the MTS performance was low and to evaluate its performance in a new population.

METHODS

Study design

We performed an observational prospective study. Modifications were developed according to patient groups where the MTS performance was low.[9] The modified MTS was implemented at two emergency departments. We evaluated performance by comparing the MTS urgency levels to a predefined reference standard for urgency. Improvements were evaluated by comparing performance of the modified MTS to performance of the original MTS, as evaluated in our previous study.[9]

Setting and selection of participants

The Erasmus MC-Sophia Children's hospital in Rotterdam, The Netherlands is a university hospital with a specific pediatric emergency department that receives 9,000 patient-visits

per year. The Haga hospital-Juliana children's Hospital at The Hague, a large urban teaching hospital with a full spectrum of patients, encounters 15,000 paediatric patient visits per year. Patients aged less than 16 years were included between May 2007 – April 2008 and August – December 2007, respectively.

Methods of measurement: Manchester Triage System

ED nurses performed a short assessment and triaged patients using the MTS. MTS flowcharts contain six key discriminators (life threat, pain, haemorrhage, acuteness of onset, level of consciousness, and temperature) as well as specific discriminators, which are relevant to the presenting problem. Selection of a discriminator indicates one of the five urgency categories, with a maximum waiting time ("immediate" 0 minutes, "very urgent" 10 minutes, "urgent" 60 minutes, "standard" 120 minutes, and "non-urgent" 240 minutes). Pain is scored on a scale from 0–10 and can assign patients to a higher urgency level. Nurses used a digital version of the MTS to triage patients.

Outcome measures

Prior to the study a reference standard was defined based on literature and expert opinion.[9] It consists of a combination of vital signs, diagnosis, diagnostic and therapeutic interventions and hospitalisation/follow-up. It was developed prior to the onset of the study in an expert meeting by paediatricians and a paediatric surgeon.

Patients were considered to be **category 1**, if their vital signs were deviated according to the PRISM (Pediatric Risk of Mortality Score)[10] or in case of hyperthermia (temperature >41°C). Patients with hyperthermia have a higher risk for a severe bacterial infection.[11] Deviations in temperature, respiratory rate or pulse oximetry and mental status are related to resource use and hospitalization.[12,13] Patients were assigned to **category 2** if they had normal vital signs and their presumed diagnosis at the end of their ED consultation was defined as a potential life-threatening conditions.[9] Most of these conditions are associated with a high morbidity and mortality and are discussed in the Advanced Paediatric Life Support workbook as an emergency.[14,15] The expert panel discussed aorta dissections and high-energy traumas as being potentially life-threatening. In a systematic review, it was suggested to monitor patients with an apparently life-threatening event (ALTE) for 24 hours.[16]

Patients were allocated to **category 3 or 4** depending on the performed diagnostics, administered therapy, hospitalization and if a follow-up visit was scheduled.

Category 5 was defined if patients did not require any of the resources. Previous studies on other triage systems for paediatric patients showed an association between urgency level

and resource use and follow-up. Resource use is associated with the urgency level of the Emergency Severity Index (ESI).[17,18]

A classification matrix of the reference classification and detailed definitions of the reference standard urgencies were published before.[9] We defined the reference standard for each patient independent of the Manchester Triage System urgency and based on a computerised application of the classification matrix. If vital signs were not recorded, they were assumed to be normal. We defined over-triage and under-triage when the MTS urgency level was higher and lower, respectively, than the reference standard urgency level.

Modifications

We studied patient characteristics and their relation to agreement between the MTS and the reference standard urgency distribution.[9] The aim of modifying the MTS was to increase correct triage and decrease over-triage without increasing under-triage.

Modifications focused on the patient characteristics: (1) age, referral status and presenting problem (traumatic or medical) (2) frequently used MTS flowcharts (3) frequently used MTS discriminators and (4) combination of 1-3. The proportion of number of categories over-, and under-triage was calculated for subgroups based upon these patient characteristics to evaluate whether attributing a higher or a lower MTS urgency category could result in a better agreement between the MTS and the reference standard urgency.

The MTS had a low performance for patients with fever, in particular.[9] As an example, the rationale for the modification for patients with fever is shown in figure 1. According to the original MTS, all patients triaged using the fever discriminator (which is present in several flowcharts) are attributed to the 'very urgent' urgency category (level 2). The reference standard distribution is shown for different MTS flowcharts and age subgroups. Modifications were created for subgroups if in >=80% of the patients the reference urgency category was lower than 'very urgent'.

For example, in the subgroup of patients triaged using the flowchart 'Worried parent', aged 3 months–2 years, 20% had an 'urgent' (level 3) level and 75% had a 'standard' (level 4) or 'non-urgent' level (level 5) according to the reference standard. By allocating this subgroup to the 'urgent' level, more patients will be triaged correctly and under-triage will not increase.

One new discriminator was inserted based on expert opinion. For the flowchart 'Rashes', a new discriminator 'Petechiae' was inserted in the 'very urgent' (level 2) category, in order to detect patients with petechiae who are highly suspect of meningococcal septiceamia.[20]

Other modifications were developed using the same method. However, other cut off levels, as discussed by experts were used for allocating patients in lower urgency categories. An overview of the modifications with cut off levels is provided in the appendix.

External validation

The modified MTS was implemented at the ED of both hospitals. Before implementation, meetings were conducted to instruct the ED nurses. A detailed description of the modification was provided. We performed monthly audits on the compliance. The results were discussed with the heads of the EDs.

We checked reliability by assessing the inter-rater agreement when 21 ED nurses triaged 30 case scenarios using the modified MTS. We used the intraclass correlation coefficient (ICC) which can be used for multiple raters and can be interpreted as quadratic weighted kappa, as was used before to study reliability of the original MTS in children.[8] The written case scenarios were obtained and selected from other studies on reliability of triage systems for children[21,22] and six local scenarios were added. We aimed to evenly distribute age, presenting problems and acuity level (according to the ESI). The inter-rater agreement in acuity level (quadratic weighted kappa) 0.77 (95% C.I.0.67–0.86) was similar to the reliability of the original MTS (0.83, 95% C.I.:0.74–0.91).[8]

Data collection

Patient characteristics, selected MTS flowchart, MTS discriminator and the urgency category were recorded in the computerized triage system. Urgency levels according to the original MTS could be determined by the selected MTS flowchart and discriminator. Nurses or physicians recorded data concerning vital signs, diagnosis, diagnostic and therapeutic interventions, hospitalisation and follow-up on structured electronic emergency department forms. Trained medical students gathered and entered the data for the reference standard, independent of the triage outcome, using SPSS-Data Entry version 4 (Chicago, IL, USA). The database was checked for consistency and outliers. Data on laboratory tests were obtained from the hospital information system.

Primary data analysis

To assess performance of the modified MTS we calculated percentage over- under and correct triage. Secondly we calculated sensitivity, specificity, and the diagnostic odds ratio. Patients were categorised as high urgent (level 1 or 2) or low urgent (level 3, 4 or 5). The diagnostic odds ratio (DOR) describes the odds of a MTS high urgency in high urgency patients, according to the reference standard as compared with the odds of a MTS high urgency in low urgency patients, according to the reference standard. (DOR=(sensitivity/1-sensitivity)/(1-specificity/specificity)).[23]

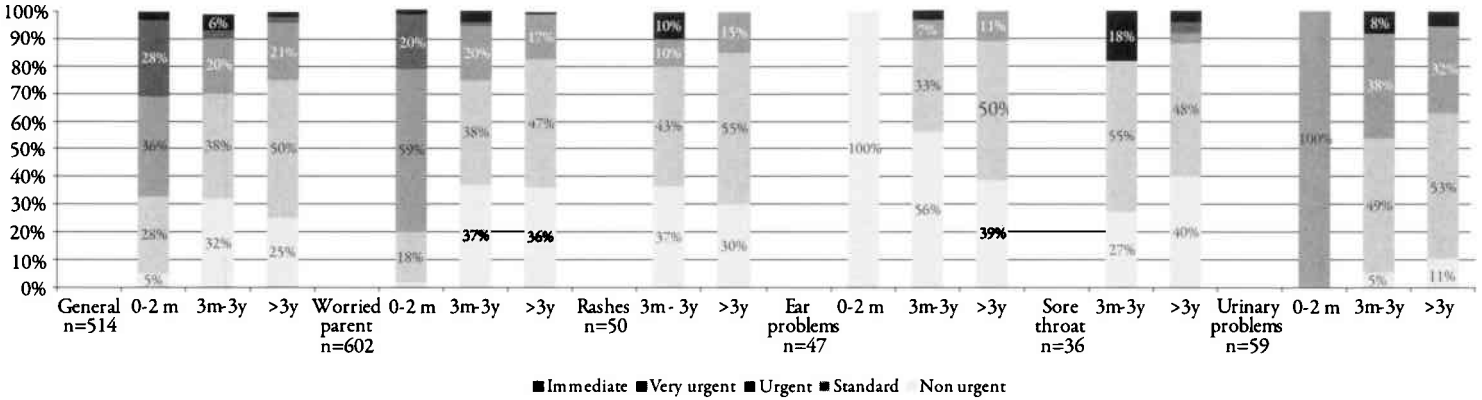

Figure 1 | Reference standard urgency distribution for MTS flowcharts and age subgroups, for patients in which a fever discriminator was selected.

Modifications on MTS flowchart and age subgroups (m=months, y=years) were developed for patients with fever. All patients were triaged into the 'Very urgent' (gray) category according to the original MTS. Modifications were created for subgroups if in >=80% of the patients the reference urgency category agreed with a lower urgency category. (No patients were included aged <3 months with the MTS flowchart 'Rashes' or 'Sore throat'.) Percentages above 4% are shown in the figure.

A risk stratification table shows the extent to which high urgency patients, according to the reference standard, are assigned to MTS high urgency categories and low urgency patients, according to the reference standard are assigned to MTS low urgency categories[24] (table 2). Improvement in reclassification was expressed by calculating the Net Reclassification Index (NRI). It estimates the net proportion of cases that move to a higher urgency and non-cases that move to a lower urgency.[25] The risk stratification table was made for the dataset II (application modified MTS). SPSS 15.0 (Chicago, IL) was used for statistical analysis.

RESULTS

Characteristics of study subjects

In total 13,654 patients presented at the ED of the Sophia Children's Hospital and Juliana Children's Hospital during the study period. 11,481 (84%) were triaged using the modified MTS. The reference standard for urgency could be determined in 11,260 patients (96%).
The median age was 3.4 years (95% CI 1.2–8.2), 4,748 (42%) were female and 5,994 (53.2%) were not referred by a health care professional but presented on their own initiative. Patients were triaged using the flowchart Shortness of breath in children in 13.9%, flowchart General in 11.2%, Vomiting or diarrhea in 8.7%, Worried parent in 7.8%, Abdominal pain in children in 5.9%, Rashes in 2.7%, Fits in 2.7%, Urinary problems in 2.4%, Ear problems in 1.7% and 13.7% of the patients were triaged with other medical flowcharts. Flowcharts for traumatic problems were applied in 29.3%. These characteristics were comparable to patients included in the first dataset.[9]

Main results

The urgency levels of patients triaged using the modified MTS were compared to the five reference standard urgency levels. The modified MTS agreed in 37% (n=4,204) with the reference standard urgency. 36% (n=4,091) were over-triaged by 1 category and 11% (n=1,276) by more than one category. 13% (n=1,477) were under-triaged by one category and 2% (n=212) by more than one category.
Sensitivity was 64% (95% CI 60 to 68%) and specificity 87% (95% CI 86 to 87%), resulting in a DOR of 11.5 (95% CI: 9.6 to 14) (table 1).
Due to the modifications 930 patients (8.2%) were reclassified to other urgency categories. For the three highest original MTS urgency categories, all reclassified patients were allocated to a lower urgency category. The reclassified patients who were allocated to a lower urgency

Table 1 | Performance of original and modified MTS.

Data	Hospital	Patients (n)	High urgency MTS*	High urgency reference standard*	Sensitivity (95% C.I.)	Specificity (95% C.I.)	DOR** (95% C.I.)
Original MTS							
Dataset 1[9]	Overall	13,554	23	5.2	63 (59–66)	79 (79–80)	6.5 (5.5–7.6)
(2006/2007)	University hospital	6,631	19.6	5.9	67 (63–72)	83 (82–84)	10.5 (8.3–13.1)
	General hospital	6,923	26.1	4.6	57 (51–62)	75 (74–76)	4.1 (3.2–5.1)
Modified MTS							
Dataset 2:	Overall	11,260	16.1	5.4	64 (60–68)	87 (86–87)†	11.5 (9.6–14)†
(2007/2008)	University hospital	6,153	15.7	5.2	67 (62–72)	87 (86–88)†	14 (15–18)†
	General Hospital	5,107	16.6	5.5	60 (54–66)	86 (85–87)†	9.2 (7.2–12)†

* Numbers present percentages, the five urgency levels are dichotomized into high urgency (1-2) and low urgency (3-5)
** DOR = Diagnostic Odds Ratio = (sensitivity/1-sensitivity)/(1-specificity/specificity)
† $p<0.05$ modified MTS versus original MTS, all comparisons are made for both hospitals and per hospital

Table 2 | Original MTS compared to modified MTS and proportion high urgency patients as classified by the reference standard for urgency in data set 2 (2007/2008).

	Modified MTS						
Original MTS	**Immediate (1)**	**Very urgent (2)**	**Urgent (3)**	**Standard (4)**	**Non urgent (5)**	**Total**	**Reclassified****
Immediate (1)	232	0	0	0	0	232	0
High urgency (%)*	127 (54.7)					127 (54.7)	
Very urgent (2)	0	1,576	402	53	0	2,031	455 (22)
High urgency (%)		258 (16.4)	10 (2.5)	0 (0)		268 (13.2)	
Urgent (3)	0	0	3,600	184	0	3,784	184 (4.9)
High urgency (%)			123 (3.4)	4 (2.2)		127 (3.4)	
Standard (4)	0	0	53	4,720	238	5,011	291 (5.8)
High urgency (%)			4 (7.5)	68 (1.4)	5 (2.1)	77 (1.5)	
Non urgent (5)	0	0	0	0	152	152	0
High urgency (%)					3 (2.0)	3 (2.0)	
Total	232	1,576	4,055	4,957	390	11,210	930 (8.2)
High urgency (%)	127 (54.7)	258 (16.4)	137 (3.4)	72 (1.4)	8 (2.0)	620 (5.4)	

* High urgency, according to reference standard, 'Immediate' or 'very urgent' urgency

** N and % of patient reclassified into a different urgency category per original MTS urgency category

category had a lower incidence of high urgency cases according to the reference standard, compared to patients who were not reclassified (2.2% versus 5.7%). Table 2 provides the reclassification of patients from the original MTS urgency to the modified MTS urgency per urgency level. The Net Reclassification Index was (0.7%–3.2%) – (0.5%–8.1%) = 5.1%. (Chi square test, df=1, p=0.027)

Limitations

We developed a proxy for urgency, determined out of characteristics of the patients ED consultation (vital signs, life threatening conditions, performed diagnostics and therapy, scheduled follow up or hospitalization). The individual items predict severity of disease and were combined by expert opinion to define a reference standard for urgency (five levels). Although it is not a real 'gold standard', it is a proxy for "real urgency".[9] No other outcome measure for urgency that defines five urgency levels is previously described in the literature. Modifications were developed after applying the original MTS in 17,600 patients in 2006/2007 who visited the emergency department of a large teaching hospital or a university children's hospital in the Netherlands. Evaluation of performance of the modifications was done in a new population. The modified MTS was applied in 13,654 patients in 2007/2008. Therefore our results are representative for a wide population of children presenting at the ED. However, since the modified MTS was applied in the same setting as in which the modifications were developed, the modifications should be validated in different settings as well.

DISCUSSION

This study shows that some small modifications resulted in an improved version of the MTS in paediatric emergency care. Specificity improved and sensitivity remained similar. The diagnostic odds ratio improved. The modifications reclassified 8.2% of the patients resulting in a net improvement in classification of 5.1%.

Misclassification may partly be explained by incorrect application of the system. Therefore we checked the reliability of the modified MTS. The inter-rater agreement was similar when compared to the inter-rater agreement of the original MTS (K_w 0.77, 95% C.I.0.67–0.86) indicating that the modified MTS was correctly applied in most cases.

Since triage systems are usually developed by expert opinion,[1,26,27] it is important to evaluate its performance and modify the system if performance is not optimal.

We identified patient groups where the MTS has a low performance for children and developed modifications based on and for these patient groups. The modifications were implemented and evaluated in a new population in two ED settings. As was shown for clinical prediction models, even if a model is derived from patient data (instead of expert opinion), it is important to validate it in a new population since generalizability of models with good internal validation measures can be very disappointing. This can be caused by inadequate development of the model or major differences between the populations in which the model was developed and validated.[28] Our validation set was comparable to the first dataset (2006/2007) on age, gender, flowchart distribution, and reference standard urgency classification. Therefore we can assume that improvement in performance is mostly due to the modification and less to a change in population characteristics.

The Manchester triage group developed modifications in 2006 to improve the system for children and adults.[4] These modifications were developed by comments from users and were not validated.

Specific modifications for children were developed in other common used triage systems in paediatric emergency care as well. To our knowledge only one study evaluated the effects of one of these modifications. For the paediatric version of the 5 level Canadian Triage and Acuity Scale (pedCTAS)[3] children with fever were assigned to a lower urgency category (urgency category 4 instead of urgency category 3) if they had no signs of toxicity (defined as unexplained crying before examination, difficulty awakening or poor response to the physical evaluation) **and** were older than six months of age. Admission rates were compared between patients who remained in level 3 and the modified patients. The modified patients had lower admission rates and none died or required Intensive Care Unit (ICU) admission.[29]

Other studies evaluated performance of triage systems in children and used resource use, hospitalization, length of stay or ICU admission as outcome.[17,18,30,31] However, these studies did not aim to identify specific patient groups in which the studied triage system performed less. Two studies evaluated performance of triage systems in adults. They identified patient groups based on age, sex, presenting problem and vital signs, in order to develop modifications that could improve performance of triage systems.[32,33]

After modification the performance of the MTS improved. We would recommend incorporation of our modifications for children in the next version of the Manchester Triage System. The modified MTS showed a specificity of 87% and a sensitivity of 64%. Users should realize that although the high specificity indicates that the system has a good ability to identify low urgent patients, the sensitivity is only moderate.

Although we improved the systems, further improvement in performance, especially sensitivity, remains a challenge. Since the MTS uses descriptions of vitally threatened patients instead of concrete limits for vital signs to be concerned as deviated, some high urgency patients will be missed. For example patients with 'shock' are defined as level 1 ("immediate"), patients with a tachycardia, arrhythmia or deviated blood pressure without shock are not considered as high urgent, unless other high urgent discriminators are present.[4] Large datasets are necessary to identify patient characteristics and discriminators which predict urgent with a high discriminative value.

CONCLUSION

Modifications of the Manchester Triage System for paediatric emergency care resulted in an improved specificity while sensitivity remained similar. The DOR also improved substantially. The modified MTS should be validated in different settings to further evaluate its performance. 8.2% of the cases were reclassified according to the modified MTS, therefore extended data collections are necessary to further improve the MTS in paediatric emergency care.

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Appendix | Modifications for the Manchester Triage System in paediatric emergency care

		Original MTS		Modification		
General discriminator	MTS Flowchart	MTS Discriminator	Urgency	Age group**	Urgency	Cut off level†
Fever*	General & Urinary Problems	Hot child	Very urgent	0–2 m	Very urgent	80%
				> 3 m	Urgent	80%
	Worried parent			0–2 m	Very urgent	80%
				3 m–3 y	Urgent	80%
				4–15 y	Standard	80%
	Sore throat, Rashes & Ear problems			0–2 m	Very urgent	80%
				3 m–15 y	Standard	80%
Time since onset of symptoms	Falls, Worried parent, Sore throat, Headache, Rashes, Eye problems	Recent problem‡	Standard	–	Non urgent	45%
Persistent vomiting	General & Vomiting & Diarrhoea	Persistent vomiting	Urgent	0–2 m	Urgent	–
				3 m–15 y	Standard	75%
Specific discriminator	Shortness of breath in children	Unable to talk in sentences	Very urgent	–	Urgent	80%
		Wheeze	Standard	–	Urgent	60% (higher urgency than Standard)
	Head injury	Scalp hematoma	Standard	< 1 y	Standard	
				> 1 y	Non urgent	65%
	Worried parent	Not feeding	Urgent	< 1 y	Urgent	
				> 1 y	Standard	77%
		Prolonged or uninterrupted crying	Urgent	< 1 y	Urgent	
				> 1 y	Standard	100%
	Rashes	Moderate pain/itch	Urgent	–	Standard	90%
		Rash that does not fade when pressed / Petechiae§	–	–	Very urgent	–

* Fever is defined as body temperature above 38.5 °C; ** m, months y, years ; Proportion of patients that were allocated to a lower urgency level, according to the reference standard, as compared to the original MTS urgency level; ‡ Recent problem is defined as a problem arising in the last week; § New discriminator