The Manchester Triage System in paediatric emergency care

Mirjam van Veen

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Het Manchester Triage Systeem op de spoedeisende hulp bij kinderen

Proefschrift

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CONTENTS

Aims and outline

AIMS

1. To provide an overview of the current literature on triage systems for children at the emergency department
2. To evaluate the reliability and validity of the Manchester Triage System (MTS) for children and to identify specific discriminators for which validity is less optimal
3. To improve the predictive value of the MTS in children, for true urgency defined by a reference standard and to validate the modified MTS in a new population
4. To evaluate effects on safety, cost and compliance when low urgent children, who attend the emergency department are referred to the general practice cooperative

OUTLINE

In the first part of the thesis performance of the Manchester Triage System in paediatric emergency care was evaluated.
In **chapter 1** we reviewed the literature to evaluate realibility and validity of triage systems in paediatric emergency care. The Manchester Triage System was used to triage patients when presenting at the emergency department of a general teaching hospital and the emergency department of a university paediatric hospital. The system's reliability was evaluated in **chapter 2**. Its validity and specific patients groups for which validity was not optimal were discussed in **chapter 3**. **Chapter 4** evaluates patient problems for which the MTS performs severe under-triage. The second part focuses on improvements of the MTS. **Chapter 5** focuses on the value of temperature as discriminator in triage systems. The MTS was modified for patient groups with a low validity and the effect of the modification on the reliability and validity are studied in **chapter 6.**

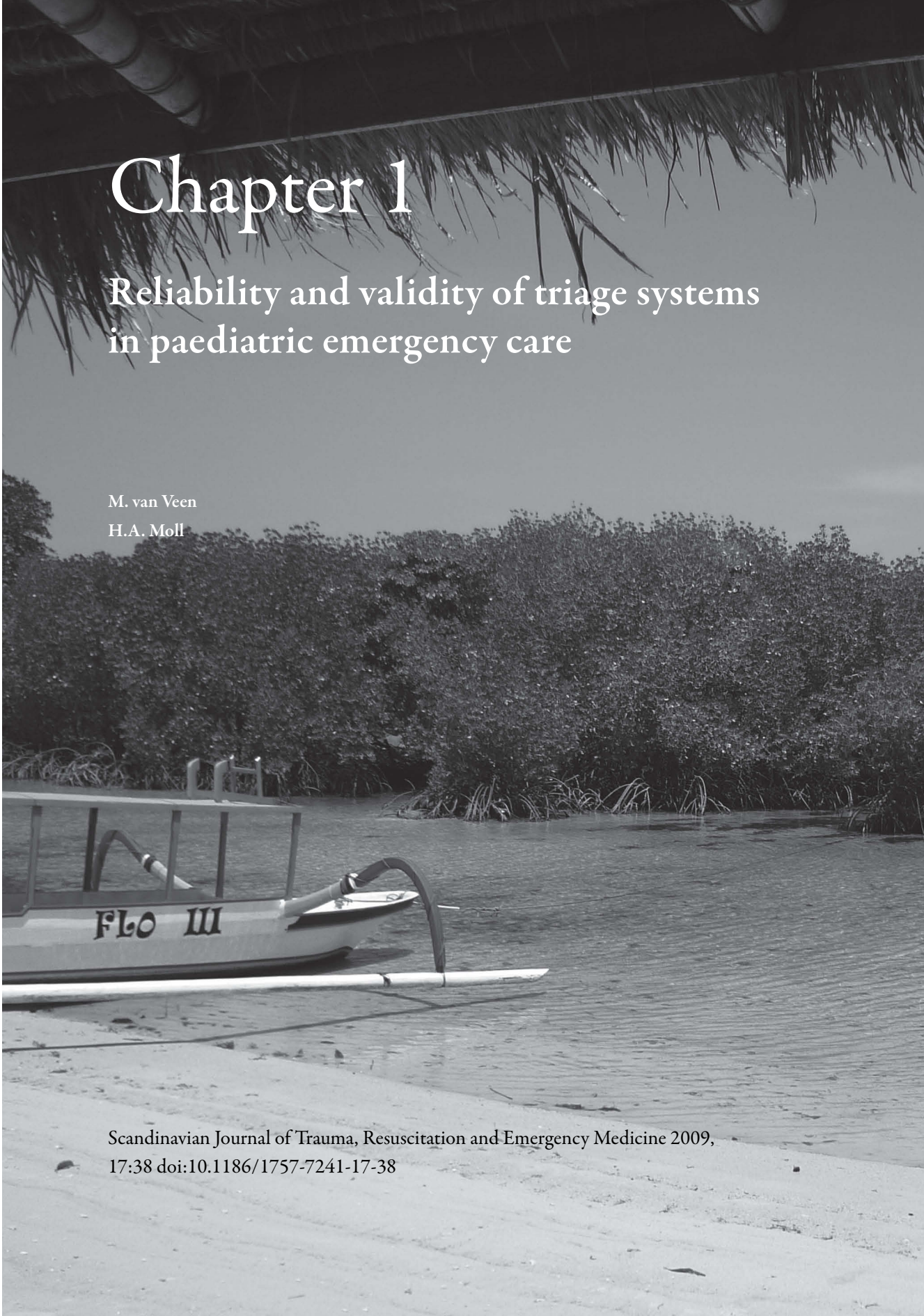
In the third part of this thesis we assess the ability of the MTS to safely identify low urgent patients. In **chapter 7** determinants of hospitalisation for low urgent patients were evaluated. **Chapter 8** reports about compliance and effect on costs when low urgent children, when presenting to the ED are referred to the general practitioner cooperative.

Chapter 9 provides a summary of the findings and the future prospects.

Chapter 1

Reliability and validity of triage systems in paediatric emergency care

M. van Veen
H.A. Moll



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ABSTRACT

Background Triage in paediatric emergency care is an important tool to prioritize seriously ill children. Triage can also be used to identify patients who do not need urgent care and who can safely wait. The aim of this review was to provide an overview of the literature on reliability and validity of current triage systems in paediatric emergency care

Methods We performed a search in Pubmed and Cochrane on studies on reliability and validity of triage systems in children

Results The Manchester Triage System (MTS), the Emergency Severity Index (ESI), the Paediatric Canadian Triage and Acuity Score (paedCTAS) and the Australasian Triage Scale (ATS) are common used triage systems and contain specific parts for children. The reliability of the MTS is good and reliability of the ESI is moderate to good. Reliability of the paedCTAS is moderate and is poor to moderate for the ATS.

The internal validity is moderate for the MTS and confirmed for the paedCTAS, but not studied for the most recent version of the ESI, which contains specific fever criteria for children.

Conclusion The MTS and paedCTAS both seem valid to triage children in paediatric emergency care. Reliability of the MTS is good, moderate to good for the ESI and moderate for the paedCTAS. More studies are necessary to evaluate if one triage system is superior over other systems when applied in emergency care.

BACKGROUND

Large numbers of patients visit the emergency department (ED). Consulting patients in the order of attending will, in a crowded emergency department, lead to long waiting times for seriously ill patients. It is important to prioritise patients who are seriously ill and would be at increased risk of morbidity or even mortality due to delay in the initiation of treatment.
The aim of triage is to determine and classify the clinical priority of patients visiting the ED.[1] During a short assessment the nurse will identify signs and symptoms that determine the patient's urgency. The physician will see the patients in order of their urgency level. Patients requiring immediate care are identified. Moreover, patients are identified who can safely wait longer or who can be seen by another caregiver such as the general practitioner or nurse practitioner.
Triage systems are developed by expert opinion[2-5], the lowest level of evidence, and are mainly based on the adult population visiting the ED. The Paediatric Canadian Triage and Acuity Scale (PaedCTAS) was especially modified for the paediatric population.[3] Several studies have investigated the reliability and validity of triage systems in children.[6-17]
The aim of this review is to provide an overview of the current scientific knowledge of triage systems for the broad population of children visiting the ED.

METHODS

We performed a search for literature in May 2009 using Cochrane and the following MeSH terms in Pubmed, "triage" [MeSH Terms] AND "emergency medical services" [MeSH Terms] AND ("infant" [MeSH Terms] OR "child" [MeSH Terms] OR "adolescent" [MeSH Terms]) AND (validity [All Fields] OR accuracy [All Fields]). Secondly we performed a wider search for "triage" [MeSH Terms] AND system [All Fields] AND "emergency medical services" [MeSH Terms] AND ("infant" [MeSH Terms] OR "child" [MeSH Terms] OR "adolescent" [MeSH Terms]).
Studies were selected if they described a triage system for the broad population visiting the emergency care or reported about a study on reliability or validity of a triage system for emergency care, applied to the paediatric population. Studies on triage for a subpopulation were not included as well as for triage systems applied in the developing world. We included papers published between 1999 and 2009. Finally, reference lists of the included papers were checked for relevant publications using the same selection criteria.

RESULTS

The narrow search gave 44 hits, of which 12 were selected because of the title; one article was excluded following reading of the abstract. The broad search resulted in 112 hits of which six extra articles were selected.

Triage systems in paediatric emergency care

Worldwide, the Manchester Triage System (MTS)[1,5,18], the Emergency Severity Index (ESI)[19,20] the Canadian triage and acuity scale (CTAS)[3] and the Australasian triage scale (ATS)[2] are consensus based and commonly used triage systems in emergency care. Although different criteria per triage system are used, they all sort patients into five urgency categories.

Manchester Triage system

The MTS contains 52 flowcharts presenting different presenting problems. Some flowcharts are specific for children, such as 'Worried parent', 'Abdominal pain in children', 'Crying baby', 'Shortness of breath in children', 'Limping child', 'Unwell child' and 'Irritable child'. The flowcharts contain general as well as specific discriminators, which are presenting signs or symptoms of the patient. General discriminators are life threat, pain, haemorrhage, conscious level, temperature and acuteness.[1] Specific discriminators are related to the presenting problems such as 'Increased work of breathing' (flowchart 'Shortness of breath in children') or 'Persistent vomiting' (flowchart 'Abdominal pain in children'). An example of a flowchart is provided in figure 1. (MTS flowchart 'Shortness of breath in children').[5] The selected discriminator leads to an urgency level. Medical care should be delivered immediately for level 1, within 10 minutes for level 2, within 60 minutes for level 3, within 120 minutes for level 4 and within 240 minutes for level 5.

A second version of the MTS was published by the Manchester Triage group in 2006.[5] Some discriminators were modified or added (for example 'pain' in level 4 was modified to 'recent pain' for flowcharts in which pain is one of the discriminators).[5]

In a large validation study we identified subgroups of patients in which the validity of the MTS for children was low, such as young patients, patients with a non-traumatic presenting problem and older patients with fever.[16]

Emergency Severity Index

The ESI is a 5-level triage system, developed in the United States. Level 1 stands for the highest acuity level and level 5 for the lowest acuity. Patients requiring immediate life saving interventions are allocated into level 1 and must be seen immediately. Patients in a high

risk situation, who are confused, lethargic, disoriented, have severe pain or distress or have deviated vital signs/PO2 are attributed to level 2. A physician should see these patients within ten minutes. Level 3 is for patients who are expected to require two or more resources. Level 4 is attributed if one resource is expected to be required and 5 if no resources are expected to be required. Resources can be diagnostics (for example lab tests, ECG, X-rays, CT scan etc), treatment (for example IV fluids, laceration repair) or specialty consultation. Patients triaged as level 3–5 can safely wait for several hours.[4]

In the fourth version of the ESI, a specific flowchart for children with fever was added. It uses age, the height of fever, the cause of fever and whether the child is immunized to determine urgency. Children younger than 28 days with a temperature >38.0°C are allocated to level 2. Children with fever aged 28 days – 3 months are assigned to level 2 or 3, depending on the hospital's institutional protocol. Children aged 3–36 months who are under immunized or who have no obvious source of fever and a temperature >39.0°C are allocated to level 3.[4]

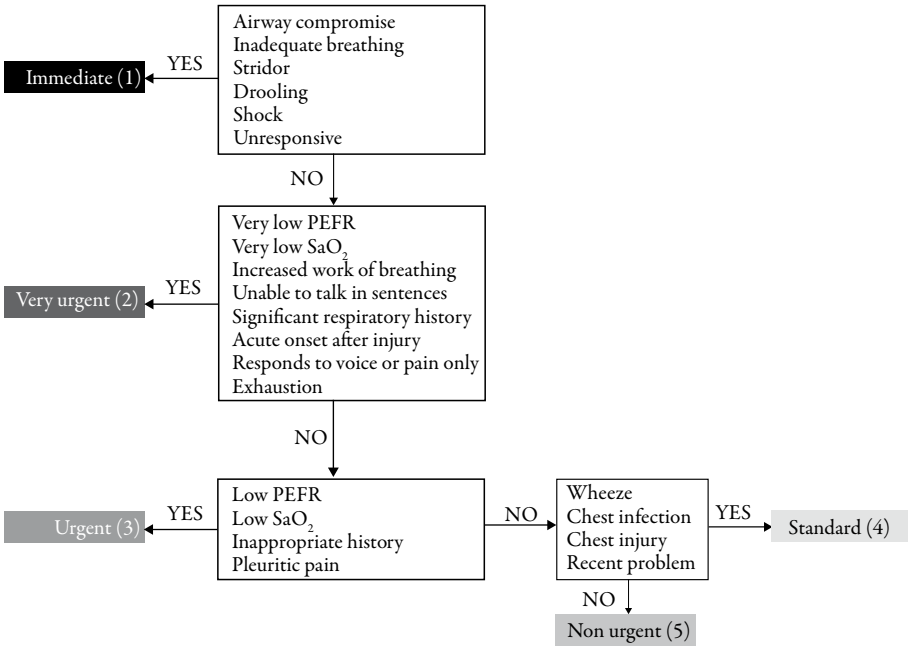

Figure 1 | Manchester Triage System flowchart Shortness of breath in children (Second edition). Reprinted with permission from Mackway-Jones K et al. Emergency Triage, Manchester Triage Group. Second edition. Oxford: Blackwell Publishing Ltd; 2006, p 134.[5]

Canadian Triage and Acuity Scale

In 2001 a specific guideline to triage children was added to the CTAS, (paedCTAS). Per presenting problem, specific criteria are provided to allocate patients to different urgency levels. For example for children presenting with respiratory distress, for level 1 signs are: inability to speak, cyanosis, lethargy or confusion, tachycardia or bradycardia, and hypoxemia with O2 saturation <90%. For level 2 the signs audible stridor, intermittent respiratory distress and audible wheezing, tachypnea, or cough are listed in order to select patients with respectively upper respiratory distress, congenital vascular anomalies and foreign bodies or lower airway concerns. Level 3 is for patients with moderate respiratory distress such as patients with pneumonia, bronchiolitis or croup. Level 4 and 5 do not contain criteria for patients with respiratory distress.

Medical care should be delivered immediately for level 1, within 15 minutes for level 2, within 30 minutes for level 3, within 60 minutes for level 4 and within 120 minutes for level 5.[21] A detailed recent description of the paedCTAS can be found at the website http://www.caep.ca/tem plate.asp?id=B795164082374289BBD9C1C2BF4B8 D32

Australasian triage scale

Formerly known as the National Triage Scale, the ATS provides criteria per urgency level. Most criteria are general but three criteria are specific for children: shocked child/infant should be allocated to level 1, all 'stable neonates' are allocated to level 3 as well as 'children at risk'.[22]

Pain in triage

In the MTS as well as the paedCTAS pain plays an important role in urgency classification. Both systems allocate patients with severe pain to a level 2 urgency. Patients with moderate pain and patients with mild/acute pain (paedCTAS) or recent pain (MTS) are triaged into level 4.[3,5] The ESI allocates patients with severe pain to level 2. A lower pain score does not influence the ESI urgency level.[4] The Manchester pain scale correlated well with the Oucher pain scale, which is a common used and validated pain scale in emergency care.[23]

Referral of low urgency patients to other caregivers

Besides prioritising urgent patients, triage systems are used to identify patients with a low urgency. These patients can safely wait, do not need urgent care and could as well be seen by another health professional. One study showed that the CTAS, when applied to adults and children is not valid to safely identify low urgency patients with the aim to refer them to

other caregivers.[24] For other triage systems such as the MTS and the ESI, this question still needs to be answered.

Research on reliability and validity of triage systems

Validity of a triage systems is determined by reliability (inter-rater agreement and intra-rater agreement) and whether or not the triage system can predict the true urgency (internal validity) The external validity determines the value of the system in different settings.[25] The inter-rater agreement is determined by the agreement in triage urgency level if multiple nurses triage one patient or patient scenario. The intra-rater agreement presents the agreement in triage urgency level if one triage nurse triages one case scenario at different points in time. The inter-and intra-rater agreement is dependent on the uniformity and completeness of a triage system and on how the triage nurse applies the system. Good training and instruction of the triage nurses can optimise the usage and interpretation of triage systems.

Inter- and intra-rater agreement are usually analysed using Cohen's kappa. Kappa provides a measure of agreement between observers, corrected for agreement expected by chance.[26] In case of an ordinal scale, which is the case when 5-level triage systems are studied, quadratic and linear weighted kappa analysis provide different weights per amount of disagreement.[27]

If the inter-rater agreement between multiple observers is studied, the intraclass correlation coefficient (ICC) can be used. It can easily be calculated using SPSS and is equivalent to a quadratic weighted kappa, under certain conditions.[28]

To assess validity, a 'gold standard' as a proxy for urgency has to be defined. Since it is difficult to determine the 'true urgency', different approaches are currently used to assess validity. Outcome measures such as hospitalisation, ICU admission, resource uses, total length of stay at the ED or costs of an ED consultation are used.[6,8,13]

We studied the validity of the MTS in children in a large prospective observational study by comparing the MTS urgency level with a predefined, independently assessed reference standard for urgency.[16] We defined the highest urgency level for patients with deviated vital signs according to the PRISM (Paediatric Risk of Mortality)[29], patients with a potentially life threatening diagnosis were defined as level 2, patients were allocated to level 3 or 4 depending on if they were hospitalised after ED consultation and the amount of diagnostics and therapeutic interventions performed at the ED. Patients allocated to level 5 did not meet the criteria for level 1 or 2, were not hospitalised, and no diagnostics or therapeutic interventions were performed during their ED visit. A detailed description of the reference standard was published before.[16] It is important to triage a patient and to assess the reference standard independently, in order not to overestimate validity.[25]

Assessing urgency per case by experts is another way to assess validity. However, these judgements are quite dependent on the used protocols in the hospital and the personal experience of the expert.

Validity can be expressed in sensitivity and specificity of a triage system. Sensitivity presents the ability for a triage system to identify high urgent patients. Specificity presents the ability for a triage system to identify patients with low urgent problems. The 'Likelihood Ratio for a positive test results' (LR+) represents the ratio between the chance on a high urgency test result in patients with a true high urgency and the chance of a high urgency test results in patients with a true low urgency.[25,30]

Validity is analysed in some studies by assessing agreement between the triage system urgency and a reference urgency, using kappa statistics.[6,13] Van der Wulp et al suggested a triage weighted kappa in which under-triage (when the triage urgency is lower than the reference urgency) is weighted as more severe than over-triage (when the triage urgency is higher than the reference standard urgency).[31] Lee at al proposed a weighted scheme (error weights) for a 3-level triage system, in which under-triage was weighted twice as over-triage. They calculated sensitivity, specificity, positive and negative predictive value incorporating these error weights.[32]

Reliability and validity of triage systems in paediatric emergency care

Table 1 and 2 provide an overview of studies on reliability and validity of triage systems when applied to children.

The ESI has a moderate (actual simultaneous triage) to good (written case scenarios) reliability when applied to triage children. ESI urgency levels are correlated to resource use, length of stay at the ED.[6] The paedCTAS has a moderate inter-rater agreement using actual simultaneous triage.[9,10]

Several validity studies of triage systems in children show a correlation of urgency levels with admission. A large study on the validity of the paedCTAS showed that 90% of the patients admitted to the PICU, were triaged as urgency level 1 or 2.

Three patients out of the total 58,529 were 'incorrectly' triaged as level 4 or 5[11]. Patients triaged as level 3–5 were admitted in 6% (out of 400 patients) using the ESI[6], and in 7% (out of 510 patients) and 6% (out of 53,846 patients) using the paedCTAS.[8,11] Patients triaged as level 1 or 2 were admitted in 36% (out of 110 patients) using the ESI[6], and in 30% (out of 27 patients)[8] and 41% (out of 4683 patients) using the paedCTAS.[11] Percentage admission per urgency level is comparable between triage systems.

Table 1 | Studies on reliability of the ESI, CTAS, MTS and ATS in paediatric emergency care.

Country	N scenarios, raters (response rate)*	Triage system/population	Study design	Results (95% CI)‡
Australia[34]	14 scenarios, 178 nurses**	ATS, children	7 paper, 7 computer based scenarios	K 0.40 (paper) K 0.58 (computer)
Australia[35]	8 scenarios, 97 nurses (44%)	ATS, children	Written case scenarios	K 0.21
USA[6]	20 scenarios†	ESI version 3, children	Written case scenarios	Kw 0.84–1.00
USA[6]	272 patients	ESI version 3, children	Simultaneous triage	Kw 0.59 (0.55–0.63)
Canada[9]	54 scenarios, 18 nurses (62%)	PaedCTAS children	Written case scenarios	Kw 0.51 (0.50–0.52)
Canada[10]	499 patients	PaedCTAS children	Simultaneous triage	Lineair Kw 0.55 (0.48–0.61) Quadratic Kw 0.61 (0.42–0.80)
The Netherlands[15]	50 scenarios, 48 nurses (87%)	MTS adults and children	Written case scenarios	Kw 0.62
The Netherlands	20 scenarios, 43 nurses (100%) 198 patients	MTS in children	Written case scenarios Simultaneous triage	Quadratic Kw 0.83 (0.74–0.91) Quadratic Kw 0.65 (0.56–0.72)

* For studies using the written case scenario method; ** Compliance rate not described in paper † N raters and compliance rate not described in paper; ‡ K kappa, K_W Weighted kappa, ATS = Australasian Triage Scale; ESI = Emergency Severity Index, MTS = Manchester Triage System, PaedCTAS = Paediatric Canadian Triage and Acuity Scale; Kappa/weighted kappa: poor if K = 0.20, Fair if 0.21 = K = 0.40, moderate if 0.41 = K = 0.60, good if 0.61 = K = 0.80 very good if K>0.80. (95% confidence interval)

Table 2 | Studies on validity of the ESI, CTAS, MTS in paediatric emergency care

Country	N, patients	Triage system	Design	Outcome measure	Conclusion
Canada[8]	807/560	PaedCTAS	Before and after design, prospective study	Admission rate, medical interventions, and PRISA score, comparison with previous used triage tool (4 level)	Previous triage tool had better ability to predict admission than paediatric CTAS
Canada[11]	58,529	PaedCTAS	Retrospective	Admission, ICU admission Length of stay (LOS)	Good correlation between urgency and admission, ICU admission and LOS
Canada[33]	1,618	PaedCTAS	Retrospective	Costs of resource utilization	PaedCTAS urgency level correlates well with resource utilization
USA[6]	510	ESI (version 3) Children	Prospective triage, retrospective chart review	Admission rate, medical interventions, PRISA score, comparison with used triage tool	ESI score predicts resource use, length of stay, and admission to hospital
The Netherlands[14]	1,065	MTS	Retrospective	Reference standard for urgency *	Sensitivity 63% Specificity 78%
The Netherlands[16]	17,600	MTS	Prospective	Reference standard for urgency *	Sensitivity 63% Specificity 79%

ESI = Emergency Severity Index, MTS = Manchester Triage System, PaedCTAS = Paediatric Canadian Triage and Acuity Scale, * Reference standard based on vital signs, diagnosis, resource use, admission rate, and follow-up, LOS = Length of stay

Furthermore, paedCTAS urgency levels are related to resource use and length of stay, although length of stay was shorter for level 1 patients compared to level 2 patients (191 minutes versus 250 minutes).[11,33] The ATS showed a poor to moderate reliability.[34,35] We did not find studies on the validity of the ATS for children.

The inter-rater agreement of the MTS in adults and children was studied in the Netherlands and showed a good to excellent reliability.[15,17] For children the inter-rater agreement of the MTS is good (simultaneous triage of actual patients) to excellent (written case scenarios). Validity, expressed in agreement between the MTS and reference standard for urgency, shows 34% correct triage, 54% were over-triaged and 12% under-triaged. Sensitivity was 63% (95% CI 59–66) and specificity 79% (95% CI 79–80).[16]

DISCUSSION

Several triage systems are extensively used to triage children at the emergency department. Several studies are performed to assess the reliability and validity of these systems in children. The aim of triage is to identify high urgent patients. Triage systems that show a large proportion of under-triage or perform a low sensitivity (real high urgent patients are triaged as low urgent) are therefore unsafe.

Since it will be difficult for a triage system to reach 100% sensitivity and specificity, a good balance between over-and under-triage is important. A high sensitivity may result in a low specificity resulting in many patients with real low urgent problems who will be treated as high urgent. This may result in long waiting times for real high urgent patients.

Since outcome measures used for validity studies are different, a comparison between triage systems cannot be made on how they predict 'true' urgency. However, from the available studies and the design of the triage systems, some points can be made. The ESI performs a moderate to good inter-rater agreement.[6] Inter-rater agreement for the paedCTAS is moderate when written case scenarios are used. When the paedCTAS is studied using real life scenarios, results are similar to the inter-rater agreement of the ESI. Reliability is good for the MTS[15,17] and poor to moderate for the ATS (table 1).

Validity is confirmed for the MTS and paedCTAS. Validity of the paediatric fever criteria of the ESI was not studied. Since patients presenting with fever are 15% of the paediatric population[16], it is important to study these fever criteria as well (table 2). The MTS is both detailed and objective and discriminators are organized in flowcharts of presenting problems. The system contains several specific flowcharts for children.[5]

Methodology

From a methodological view triage can be seen as a diagnostic test; predicting 'true' urgency. In that way sensitivity and specificity must be used as measures of performance.[30] A disadvantage of this method is that urgency levels following from a 5 level triage system should be dichotomised. When one chooses to combine the two highest levels of a triage system as 'high urgency' and the three lowest as 'low urgency', a distinction between the two highest levels and between the three lowest levels is not made anymore. However, the aim of triage is to identify true high urgent patients. A misclassification in the two highest urgency levels (level 1 or level 2) is clinically less important than a misclassification from level 2 to level 3, 4 or even 5. By dichotomising the 5 urgency levels and calculating sensitivity and specificity, weights are incorporated. Moreover sensitivity and specificity are very commonly used in diagnostic research and therefore easily interpretable by most users.[30]

Implementation

Implementation includes application of the system to all patients and compliance to the advice for urgency by the ED nurses. The implementation of the triage system in practise is important for the triage process. Patients who enter the emergency department should be triaged as soon as possible. If children are sitting in a waiting room without being triaged, potentially dangerous delay in treatment can occur for potentially serious diseases.

Especially in a crowded emergency department it is important that there is a triage nurse whose primarily role is triage. She will perform a rapid assessment (30–60 seconds) and long conversations with patients should be avoided.[5] The founders of the ESI and the MTS claim that a complete assessment does not need to be done at the initial triage station, although sufficient information should be gained to be able to determine the correct triage category.[4,5] Vital signs should be completed on all paediatric patients at some time during their emergency visit.[3]

The triage nurse will take care that that all patients entering are directly triaged (within 10 minutes of arrival)[3] while other nurses take care of further observation and treatment of patients.

As for implementation of clinical prediction rules, certain criteria should be met for successful implementation. At first predictions of the triage system should be better than that of the users. Secondly, users should feel that the system is valid (face validity). Since wide validation of triage system is often lacking, this is a point for improvement. Thirdly the system should be user friendly. The best predictors of a rule to be used in practice are the

familiarity acquired during training, the confidence in the usefulness of the rule, and the userfriendliness of the rule.[36,37]

Computerized triage showed a better agreement in correct triage outcome, compared to triage without the support of a computerized application.[38] Application of the paedCTAS using a computerized application (Staturg) resulted in a better reliability of the system.[9] Therefore, a computerized application of a triage system should be used.[39] Especially the MTS and the CTAS are complex systems for which several questions should be answered before a triage advice is suggested.

CONCLUSION

Several systems are available for triage in paediatric emergency care. The MTS, ESI and CTAS contain parts specific for children. Evaluation of a triage system concerns research of reliability and validity. The MTS and paedC-TAS both seem valid to triage children in paediatric emergency care. Available studies show that reliability of the MTS is good, is moderate to good for the ESI, moderate for the paedCTAS and poor to moderate for the ATS. More research is needed on the reliability and validity of triage systems when applied to children especially if they are used to identify low urgent patient for referral to another caregiver.

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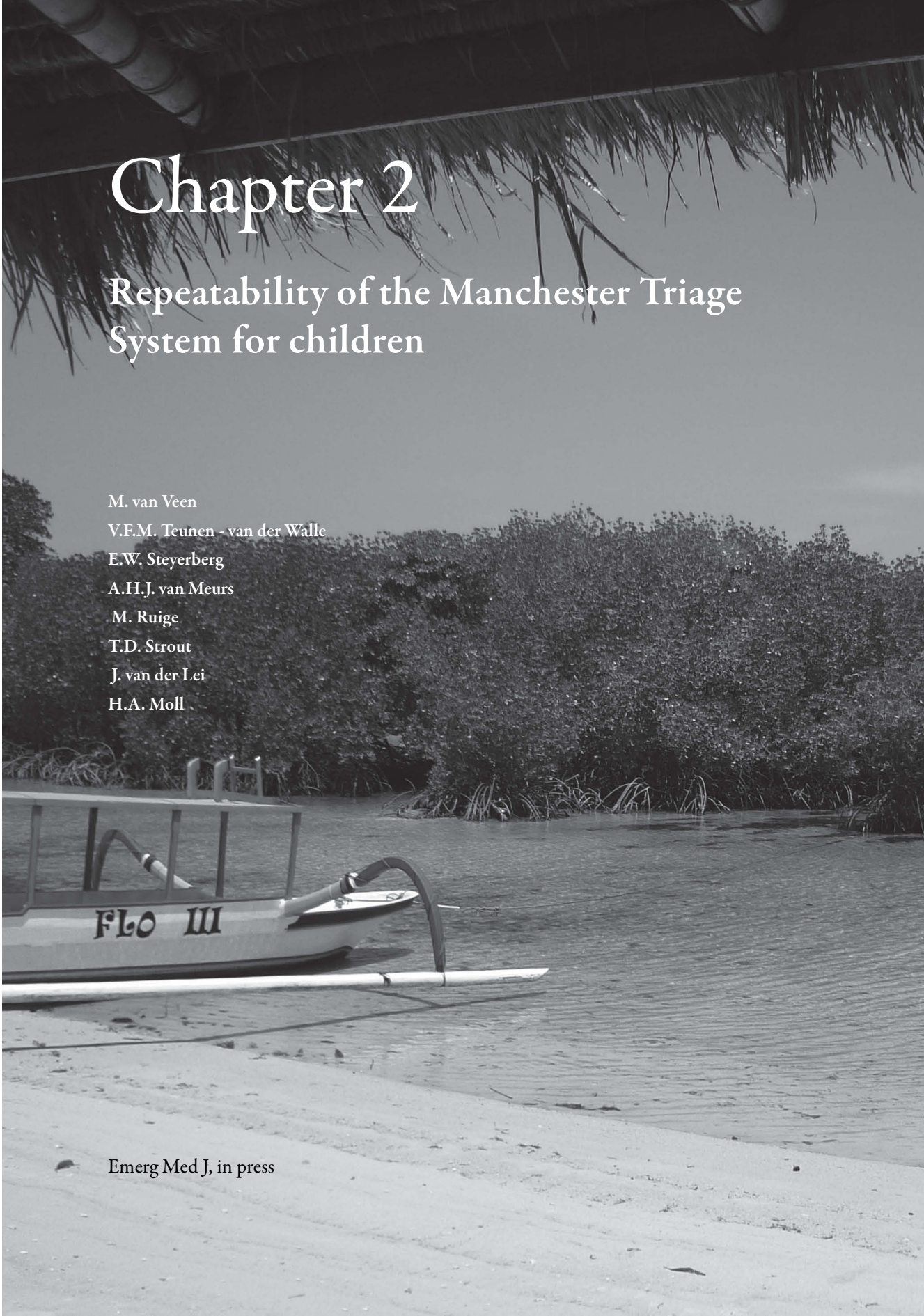
Chapter 2

Repeatability of the Manchester Triage System for children

M. van Veen
V.F.M. Teunen - van der Walle
E.W. Steyerberg
A.H.J. van Meurs
M. Ruige
T.D. Strout
J. van der Lei
H.A. Moll



Emerg Med J, in press

ABSTRACT

Objective We aimed to assess the repeatability of the Manchester Triage System (MTS) in children.

Methods All emergency department (ED) nurses (n=43) from a general teaching hospital and a university children's hospital in the Netherlands triaged 20 written case scenarios using the Manchester Triage system. Secondly, at two EDs real-life simultaneous triage of patients (<16 years) was performed by ED nurses and two research nurses. The written case scenarios and the patients included in the real-life simultaneous triage study were representative of children attending the ED, in age, problem and urgency level. We assessed inter-rater agreement using quadratic weighted kappa values.

Results The weighted kappa between the nurses, triaging the case scenarios was 0.83 (95% C.I.:0.74–0.91). In total, 88% (N=198) of the eligible ED patients were triaged simultaneously, with a weighted kappa of 0.65 (95% C.I.: 0.56–0.72).

Conclusions The MTS showed good to very good repeatability in paediatric emergency care.

INTRODUCTION

As triage aims to see patients first who benefit most from immediate care, it is essential that triage is both objective and reproducible. Different triage systems are extensively used in emergency departments across the world. The Manchester Triage System (MTS) was described and published in 1997 and is nowadays adopted around the world.[1,2] Little research on repeatability and validity of triage systems in paediatric emergency care, has been conducted to date.[3-9] As triage systems are widely used and it is not yet clear if one system is preferred over the others, research on their repeatability and validity is important and must be performed.

The MTS was developed by expert opinion.[1] The Dutch Institute of Healthcare recommended using the MTS in the Netherlands.[10] It consists of 52 flowcharts all representing a presenting problem, of which 49 are suitable for children. Following flowchart selection, general (life threat, haemorrhage, pain, conscious level, temperature and acuteness) and specific discriminators are considered. For example, a patient with an affirmative response to the discriminator "Increased work of breathing?" is triaged into urgency level two. Patients are allocated into one of five urgency levels. The MTS prescribes maximum waiting time for each urgency category (0, 10, 60, 120 and 240 minutes).

In adults, the MTS was shown to be sensitive for those with chest pain (sensitivity 87%, 95% CI: 78–92 and specificity 72%, 95% CI: 61–82 to identify high risk cardiac chest pain)[11] and for those with a critical illness.[12] The Manchester pain scale, a part of the MTS, showed a strong concurrent validity when compared to the Oucher pain scale.[13] The inter-rater agreement of the MTS in all ages, demonstrated a quadratic weighted kappa of 0.62 (95% CI 0.60 to 0.65) when studied using written case scenarios.[14] In a large prospective observational study the MTS demonstrated moderate validity when used in paediatric emergency care. It errs on the safe side, with much more over-triage than under-triage compared with an independent reference standard for urgency.[8,9] The inter-rater agreement of the MTS for children in particular has not yet been evaluated.

The aim of this study was to evaluate repeatability of the MTS in paediatric emergency care, using both written case scenarios and simultaneous triages by ED nurses.

METHODS

Study Design

To study repeatability we performed two studies on inter-rater agreement. First, 20 written case scenarios were triaged by 43 ED nurses, from two different hospitals, using the MTS. (Part 1) Second, 198 patients presenting to the two study EDs were each triaged simultaneously using the MTS, by one out of 25 ED nurses and one out of two research nurses. (Part 2) Table 1 reviews our study design. The requirement for informed consent was waived by the institutional review board.

Table 1 | Study design

Part	Patients / scenarios	Nurses	Setting	Outcome
1	20 written case scenarios	43 nurses	ED general teaching hospital* ED university hospital**	Repeatability
2	198 real life simultaneous triage assessments	First triage: triage nurse† Second triage: research nurse†	ED general teaching hospital* ED university hospital**	Repeatability

* Erasmus University Medical Center- Sophia Children's hospital, Rotterdam, The Netherlands
** Haga Hospital- Juliana Children's hospital, The Hague, The Netherlands
† During the selected shifts, one out of 25 nurses performed triage and one out of two research nurses performed the second triage assessment. ED = Emergency Department.

Patients

The ED of the Erasmus University Medical Center-Sophia Children's Hospital, Rotterdam is a paediatric-specific ED and is visited by nearly 9,000 patients per year. The MTS was implemented in 2005. The ED of the Haga Hospital-Juliana Children's Hospital, The Hague is a general paediatric-adult ED in a large teaching hospital with approximately 30,000 patients visits yearly, including 15,000 paediatric visits. For this site, the MTS was implemented in 2003. Participating ED nurses were experienced in both paediatric nursing and ED nursing, with a median of 10 years of ED nursing experience (IQR:7–14 years) and a minimum of two years. Both studies were performed between November 2006 and February 2007.

Manchester Triage System

Children under 16 years of age visiting the ED were triaged using a computerised version of the MTS. Registered nurses selected an MTS flowchart that suits the problem the patient

presents with. Selection of the appropriate discriminator leads to allocation of an urgency level. The chosen flowchart and discriminator were documented by the software application during triage. We used the official, translated version of the MTS advocated by the Dutch Association of ED Nurses.[1,15] Triage difficulties identified by the nurse participants could be reported and were discussed at ED meetings.

Part 1: Written Case Scenarios

Twenty written case scenarios were obtained and translated from Baumann et al.[3] Case scenarios are based on children presenting to the emergency department. Age, gender and presenting symptoms of the case scenarios were comparable to the total population presenting at the two EDs (table 2).

Table 2 | Patient characteristics of the total population presenting to the emergency departments in 2006 and the patients selected for the real life simultaneous triage (Part 2) and the written case scenarios (Part 1)

Variable	Total population[9] n=13,554	Real life simultaneous triage (Part 2) n=198	Written case scenarios (Part 1) n=20
ED			
General hospital	6,923 (51)*	139 (70)	N.A.
University hospital	6,631 (49)**	59 (30)	
Age†	3.4 (1.2-8.0)	2.5 (0.8-6.1)	6.0 (1.3, 7.5)
Sex, male %	7,813 (58)	104 (52)	12 (86)†
MTS urgency level			
Immediate	205 (1.5)	0	2 (10)
Very urgent	2,872 (21)	58 (29)	9 (45)
Urgent	4,462 (33)	58 (29)	2 (10)
Standard	5,895 (43)	81 (41)	5 (25)
Non urgent	120 (1)	1 (1)	2 (10)
Patient problems			
Trauma	3,591 (26)	49 (25)	6 (30)
Fever of unknown origin	1,306 (10)	35 (18)	3 (15)
Gastro-intestinal	2,166 (16)	22 (11)	2 (10)
Respiratory tract	2,356 (17)	35 (18)	3 (10)
Other	4,135 (30)	57 (29)	6 (20)

Numbers represent median with interquartile range or N (%); * Inclusion period: 7 months, ** Inclusion period: 13 months, † Sex is unknown in four cases.

The high urgency patients were overrepresented; the cases contained more boys and were somewhat older.

44 nurses received a written description of the cases and triaged the cases using the digital MTS application. Each case provided the patient's age, gender, problem of encounter and a short description of the history and vital signs (table 3).

Table 3 | Example written case scenario (English translation)

'An 8-year-old female presents to triage with her mom. The child has a sore throat, vomiting, and a fever all day. Mom states her child has been having difficulty swallowing all day. The child is making grunting noises and her skin is warm and flushed. T 38.7 °C, HR 122/min, Resp Rate 22/min, BP 110/53, SpO2 99% on room air.

Part 2: Real-time Simultaneous Triage

Patients attending the ED were triaged by one of 25 ED nurses. One of the two research nurses was present during the triage assessment, but did not interfere. After the assessment, both nurses triaged the patient. Patients were included during 12 work shifts ranging in duration from seven to ten hours. The research nurses selected the shift on basis of their own availability and were not aware of the working schedule of the triage nurses. They triaged all consecutive patients presenting at the ED.

Data on patient characteristics were gathered prospectively by the ED nurse in the triage application.

Primary Data Analysis

The characteristics of included patients were compared to characteristics of the total group of patients presenting at the same two ED's during respectively 7 and 13 months in 2006/2007[9] (table 3). The agreement between the nurses in MTS urgency level, flowchart and discriminator was determined for all twenty cases. First, we considered the urgency, flowchart or discriminator with the highest percentage agreement between nurses per case and secondly, we calculated the median and interquartile range of the percentage agreement of all cases. We determined the quadratic weighted kappa (K_w) by calculating the intraclass correlation coefficient (ICC) for agreement in urgency level. The ICC is equivalent to the quadratic weighted kappa.[16] The quadratic weighted kappa uses increasing weights for more severe disagreement.[17] We used the two way mixed model, type consistency function to calculate the ICC, for two as well as for multiple raters. (SPSS 14.0.1, Chicago, IL) The

simple kappa was calculated for agreement in the chosen MTS flowchart and discriminator using Stata v 8.2 (College Station, TX).
Kappa values can be interpreted as poor if K< 0.20, fair if > 0.21 < K and < 0.40, moderate if >0.41 < K and < 0.60, good if > 0.61 < K and <0.80 and very good if K>0.80.[17]

RESULTS

Part 1: Inter-rater Agreement: Written Case scenarios
All ED nurses (N=44) working at the two EDs, triaged each scenario. The results from one nurse were excluded due to a procedural error of the computer application. As a result, data from 43 nurses were included, 24 from the university hospital and 19 from the general hospital. The median agreement in urgency level was 81% (IQR: 60%, 90%) with a K_w of 0.83 (95% C.I.:0.74–0.91). For traumatic cases the K_w was 0.91, 95% C.I.:0.80–0.98 was and for non-traumatic cases 0.77, 95% C.I.:0.63–0.90

Part 2: Real-time simultaneous triage
During six shifts in December 2006 and six shifts in February 2007 (between 10 am and 6 pm or between 1 pm and 11 pm), 198 patients were triaged simultaneously (88% of eligible patients). 139 were included at the general hospital and 59 at the university hospital. No patients refused to participate. One research nurse was available per shift, and consequently some patients were missed because they entered the ED at the same time as other patients. The characteristics of the selected patients were comparable to the characteristics of the total ED population, except that the selected patient cohort contained slightly more patients with fever without a focus then the general patient population (table 3).
The agreement in MTS urgency level between the triage nurse and the research nurse was 66% with a K_w of 0.65 (95% CI: 0.56–0.72). In most cases of disagreement in urgency level, the disagreement was one level (28%, N=56) (table 4).

Table 4 | Real life simultaneous triage (Part 2): agreement in MTS urgency level between the triage nurse and the research nurse.

		Research nurse					Total
		Emergent	Very urgent	Urgent	Standard	Non urgent	
Triage nurse	Emergent	0	0	0	0	0	0
	Very urgent	1	48	7	2	0	58
	Urgent	0	12	28	18	0	58
	Standard	1	8	16	55	1	81
	Non urgent	0	0	0	1	0	1
Total		2	68	51	76	1	198

The used MTS flowchart and discriminator to triage patients and decide on urgency were available in 190 versus 181 patients, respectively.

The agreement in MTS flowchart and discriminator was 64% and 28% respectively, with simple kappa scores of 0.60 (95% C.I.:0.55–0.64) and 0.26 (95% C.I.:0.23–0.29). Pain score was documented at triage in 60% of the cases, with nurses agreeing on pain score in 24% of cases, (K_w=0.44,95% C.I.:0.28–0.58). Disagreement in urgency level between triage nurse and research nurse was strongly related to disagreement in discriminator and not related to disagreement in flowchart. (agreement/disagreement in urgency versus agreement/disagreement in discriminator OR=(52/3)/(69/57),=14, 95% C.I.4.2–48, agreement/disagreement in urgency versus agreement/disagreement in flowchart, OR= (83/39)/(43/25)=1.2, 95% C.I.:0.7–2.3).

Nurses agreed in 66% in both patients with a traumatic problem (N=56, K_w 0.45, 95% C.I.:0.22–0.64) and patients with a non-traumatic presenting problem (N=142, K_w=0.60,95% C.I.:0.48–0.69). Disagreement did not depend on the patient's age. (Median age 2.47 and 2.69 years, Mann Whitney test, p=0.55)

DISCUSSION

This study showed adequate repeatability of the MTS when applied to paediatric emergency care. The MTS demonstrated good to very good inter-rater agreement when studied using written case scenarios and real-time simultaneous triage.

Compared to the inter-rater agreement of other triage systems studied in children using written case scenarios, the inter-rater agreement found for the MTS in our study is high (table 5).

Table 5 | Inter-rater agreement of triage systems for children.

Triage system	Method	N	Measure	Value (95% C.I.)
ESI version 3[3]	Written case scenarios	20 scenarios	Quadratic weighted kappa	0.84–1.00
ESI version 3[3]	Simultaneous triage	272 patients	Quadratic weighted kappa	0.59 (0.55–0.63)
3-level triage system[18]	Written case scenarios	12 scenarios	Kappa	0.29
Paediatric CTAS[4]	Written case scenarios	55 scenarios	Weighted kappa*	0.51 (0.50–0.52)
Paediatric CTAS[7]	Simultaneous triage	499 patients	Linear weighted kappa	0.55 (0.48–0.61)
			Quadratic weighted kappa	0.61 (0.42–0.80)
4-level triage scale[5]	Written case scenarios	55 scenarios	Weighted kappa*	0.45 (0.45–0.46)
Soterion Rapid Triage System[19]	Simultaneous triage	117 patients	Weighted kappa*	0.90 (0.83–0.96)

* Unknown whether linear or quadratic weighted kappa was used

The agreement found at simultaneous triage of the MTS is somewhat higher compared to simultaneous triage using the ESI[3] and the paedCTAS, in children[7] and lower compared to the Soterion Rapid Triage System.[19] However, the studies on the ESI and paedCTAS studies performed the triage assessment twice, which may explain a lower agreement.

In adults, the inter-rater agreement (weighted kappa) of 5-level triage systems studied by simultaneous triage ranged from 0.66–0.87.[19-22] Two studies used written case scenarios and demonstrated a weighted kappa of 0.80 and 0.71.[22,23]

In several studies weighted kappa values were calculated to determine inter-rater agreement. However, from these papers it is often not clear if linear or quadratic weighted kappa values were calculated (table 5). A quadratic weighted kappa gives a somewhat higher weight if raters disagree with only one level compared to the lineair weighted kappa. In our study we determined quadratic weighted kappa values.[16]

We argue that the inter-rater agreement of triage systems depends roughly on three criteria. First, nurses must be experienced with the signs and symptoms of patients presenting at the ED. Second, the nurses must be well trained in the particular triage system in order to use the correct definitions belonging to the discriminators. The nurses working in the studied hospitals all met these criteria.

Third, the triage system must be unambiguous and should contain discriminators numerous enough to match the diversity of patients visiting the ED. For example, one written case scenario had a very low agreement in urgency level, since nurses had chosen fourteen different discriminators to triage the case. It presented a 2-month-old boy with a short period of apnoea. The fact that this presentation (incident or Apparent Life-Threatening Event, ALTE) is not exactly covered in the MTS, probably explains the low agreement for this case. Agreement could potentially be improved with ongoing training for ED nurses. After finishing the study, investigators discussed the disconcordant cases with the ED nurses in order to improve the triage process.

Our results showed that the agreement on flowchart level (representing the patient's presenting problem) is moderate (K 0.60, 95% C.I.:0.55–0.64) and on discriminator level fair. (K 0.26, 95% C.I.:0.23–0.29) The low agreement at discriminator level did not result in a low agreement in urgency level. Since more MTS discriminators can lead to one urgency level, the low agreement in MTS discriminator has little influence on the urgency level. This provides evidence supporting a high internal consistency for the MTS.

In the case scenarios study (part 1), nurses performed a somewhat higher agreement in traumatic cases compared to non-traumatic cases. However, 0.91 and 0.77 represent a very good and good inter-rater agreement. The difference between good and very good agreement is not considered as clinical important.

To appreciate the results, some limitations should be considered.

The set of written case scenarios was obtained from another study group so we had no influence on the selection of cases. That's why selection bias does not seem likely. To check if the cases were representative of our population we compared patient characteristics of the cases with our population (table 2). The cases were comparable with our population.

The triage of written case scenarios is not an exact substitute for evaluation of the actual triage process. The nuance of the nurse's interpretation of each patient's signs and symptoms is an important part of the triage process, and this essence is not captured using the written case scenarios method. We attempted to address this shortcoming of the paper scenarios

with the addition of real-time simultaneous triages. This method still demonstrated a good inter-rater agreement.

The written case scenario method is often used to assess the inter-rater agreement of triage systems. A recent study showed moderated to high agreement between simultaneous triage and paper case scenarios.[24]

During the real-time simultaneous triage (part 2) we did not perform the triage assessment twice. The research nurse was present during the assessment of the triage nurse. Subsequently, both nurses triaged the patient blinded using the MTS in a separate room and did not discuss the patients' signs and symptoms with each other.

A double independent triage assessment might better evaluate the actual triage process. However, such a method was not possible because of the possible impact on patient management and waiting times. Using a double assessment method, the nurse's translation from the patient's signs and symptoms to a triage decision, would be incorporated.

CONCLUSION

The MTS has a good to very good inter-rater agreement when applied to paediatric emergency patients. Good repeatability is an essential requirement for valid triage.

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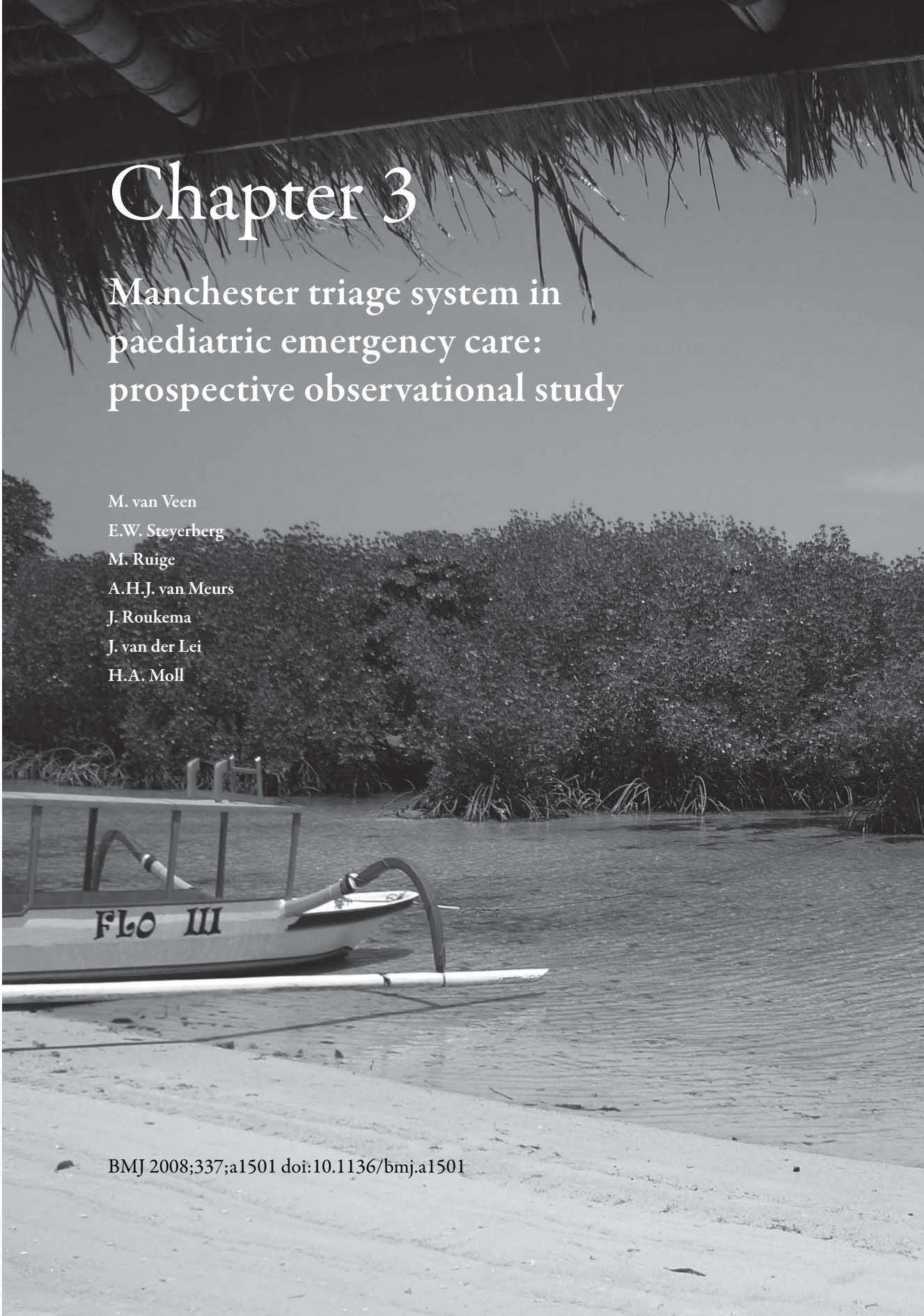
Chapter 3

Manchester triage system in paediatric emergency care: prospective observational study

M. van Veen
E.W. Steyerberg
M. Ruige
A.H.J. van Meurs
J. Roukema
J. van der Lei
H.A. Moll



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ABSTRACT

Objective To validate use of the Manchester triage system in paediatric emergency care.

Design Prospective observational study.

Setting Emergency departments of a university hospital and a teaching hospital in the Netherlands, 2006-7.

Participants 17 600 children (aged <16) visiting an emergency department over 13 months (university hospital) and seven months (teaching hospital).

Intervention Nurses triaged 16 735/17 600 patients (95%) using a computerised Manchester triage system, which calculated urgency levels from the selection of discriminators embedded in flowcharts for presenting problems. Nurses over-ruled the urgency level in 1714 (10%) children, who were excluded from analysis. Complete data for the reference standard were unavailable in 1467 (9%) children leaving 13 554 patients for analysis.

Main outcome measures Urgency according to the Manchester triage system compared with a predefined and independently assessed reference standard for five urgency levels. This reference standard was based on a combination of vital signs at presentation, potentially life threatening conditions, diagnostic resources, therapeutic interventions, and follow-up. Sensitivity, specificity, and likelihood ratios for high urgency (immediate and very urgent) and 95% confidence intervals for subgroups based on age, use of flowcharts, and discriminators.

Results The Manchester urgency level agreed with the reference standard in 4582 of 13554 (34%) children; 7311 (54%) were over-triaged and 1661 (12%) under-triaged. The likelihood ratio was 3.0 (95% confidence interval 2.8 to 3.2) for high urgency and 0.5 (0.4 to 0.5) for low urgency; though the likelihood ratios were lower for those presenting with a medical problem(2.3 (2.2 to 2.5) v 12.0 (7.8 to 18.0) for trauma) and in younger children (2.4 (1.9 to 2.9) at 0–3 months v 5.4 (4.5 to 6.5) at 8–16 years).

Conclusions The Manchester triage system has moderate validity in paediatric emergency care. It errs on the safe side, with much more over-triage than under-triage compared with an independent reference standard for urgency. Triage of patients with a medical problem or in younger children is particularly difficult.

INTRODUCTION

Emergency departments need systems to prioritise patients.[1] Triage should identify those who need immediate attention and those who can safely wait for a longer time or who might not need emergency care. Furthermore, category of urgency related to actual waiting time is used as a quality measure for emergency departments.[2]

As "subjective" triage by nurses without using a system has low sensitivity and specificity, it is important to develop and evaluate triage systems.[3] The Manchester triage system is a five category triage system based on expert opinion.[4] The validity of this system has been studied in specific subgroups of adults and was shown to be sensitive in identifying seriously ill patients ("immediate" or "very urgent") and for the detection of high risk chest pain.[5,6] Several studies have evaluated inter-rater agreement of triage systems in paediatric emergency care,[7-12] and some have evaluated trends in resource use and admission.[7,13,14] One small retrospective study validated the Manchester system in children.[15]

We prospectively validated the Manchester triage system for children in paediatric emergency care. We conducted a large prospective study to allow for sufficient statistical power and detailed evaluation of specific categories of patients.

METHODS

Study design

In this prospective observational study we measured validity by comparing the assigned urgency categories of the Manchester triage system with a predefined independent reference classification of urgency.

Study population

The study included children aged under 16 attending the emergency departments of two large inner city hospitals. The emergency department of the Erasmus MC-Sophia Children's hospital (Rotterdam) is a university paediatric emergency department visited by about 9000 patients per year; the Manchester triage system has been in use here since August 2005. We included in our study children who attended from January 2006 to January 2007.

The emergency department of the Haga Hospital-Juliana Children's Hospital (The Hague) is a mixed paediatric-adult emergency department of a large teaching hospital visited by nearly

30 000 patients per year, of whom about half are children. The Manchester triage system was implemented at this site in 2003; we included children attending from January to July 2006. Both hospitals are in the southwest of the Netherlands, which has a population of about four million people and an annual birth rate of 47 000.[16]

Manchester triage system

Emergency department nurses performed a short assessment and triaged patients using the Manchester triage system. The system is an algorithm based on flowcharts and consists of 52 flowchart diagrams (49 suitable for children) that are specific for the patient's presenting problem. The flowcharts show six key discriminators (life threat, pain, haemorrhage, acuteness of onset, level of consciousness, and temperature) as well as specific discriminators 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). The presence of key discriminators in different flowcharts will lead to the same level of urgency. Pain is scored on a scale from 0–10 and could assign patients to a higher urgency level. If the nurse does not agree with the assigned urgency category, the system can be overruled. We used a computerised version that uses the official Dutch translation of the flowcharts and discriminators of the first edition (1996).[4,17]

Data collection

Patients' characteristics, selected flowcharts, discriminators, and urgency category were recorded in the computerised triage system. Nurses or physicians recorded data concerning vital signs, diagnosis, diagnostic and therapeutic interventions, admission to hospital, and follow-up on structured electronic or paper emergency department forms. Trained medical students gathered and entered the data on a separate database, independent of the triage outcome, using SSPS data entry version 4. The database was checked for consistency and outliers. Data on laboratory tests were obtained from the hospital information system.

Reference standard

Before the study we defined a reference standard based on literature and expert opinion.[15] It consists of a combination of vital signs, diagnosis, diagnostic and therapeutic interventions, and admission to hospital and follow-up. Paediatricians and a paediatric surgeon developed the standard in a meeting before the study started.

Patients were considered to be category 1 (immediate) if they had abnormal vital signs according to the paediatric risk of mortality score (PRISM).[18] Deviations in heart rate, respiratory rate, and blood pressure predict mortality in children in intensive care.[18] Hyperthermia (temperature >41°C) indicates a higher risk for severe bacterial infection.[19] Temperature, respiratory rate or pulse oximetry, and mental status are routinely recorded and if deviations from normal occur they are related to resource use and admission.[20,21] Nurses fully examined all children; vital signs were measured at the discretion of the nurse or physician. For those presenting with a medical (non-trauma) problem, temperature was measured in 84%, heart rate in 44%, and respiratory rate in 30%. If vital signs were not recorded, they were assumed to be normal.

Patients were considered to be category 2 (very urgent) if their vital signs were within normal range and the presumed diagnosis at the end of their consultation in the emergency department was a potentially life threatening condition (as defined in appendix 1). Most of these conditions are associated with a high morbidity and mortality and are discussed in the advanced paediatric life support workbook as emergencies.[22,23] The expert panel classified aorta dissections and high energy traumas as potentially life threatening conditions. In a systematic review, McGovern et al suggested that patients with an apparently life threatening event (ALTE) should be monitored for 24 hours.[24]

Patients were allocated to category 3 or 4 (urgent or standard) depending on the performed diagnostics, administered treatment, and the scheduled follow-up.

Patients were considered to be category 5 (non-urgent) if they did not require any of the resources. Previous studies on other triage systems for children 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).[7,13]

A classification matrix of the reference classification and detailed definitions of the reference standard urgencies are shown in appendices 1 and 2. We defined the reference standard for each patient independent of urgency according to the Manchester system and based on a computerised application of the classification matrix.

>1 category over-triaged | Correct triage | >1 category under-triaged
1 category over-triaged | 1 category under-triaged

Manchester triage system	Reference standard: Immediate	Very urgent	Urgent	Standard	Non-urgent	Total
Immediate	70	22	80	26	7	205
Very urgent	233	119	1079	942	524	2897
Urgent	79	83	1729	2278	731	4900
Standard	48	53	1096	2621	1622	5440
Non-urgent	0	0	7	62	43	112
Total	430	277	3991	5929	2927	13 554

Figure 1| Manchester triage system compared with reference standard.

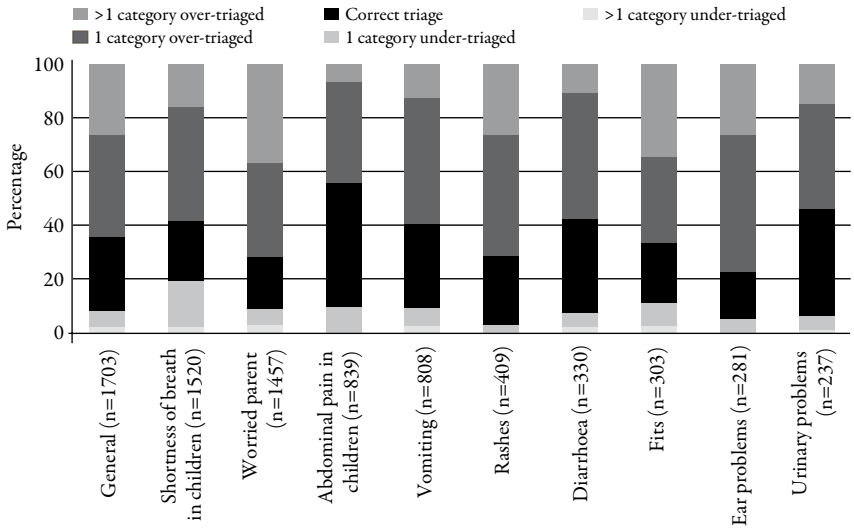

Figure 2 | Ten commonly used medical flowcharts and validity.

Sample size

In our pilot study 1% of the patients were classified as immediate.[15] To have at least 100 patients available for assessment of validity in this category[25], we set the sample size at a minimum of 10 000 patients.

Data analysis

We validated the Manchester triage system by comparing the assigned urgency category with the category assigned with the reference standard. We defined over-triage and under-triage as the proportions of patients who had a higher or lower urgency category with the Manchester system, respectively, than with the reference standard.[15]

We calculated sensitivity, specificity, and likelihood ratios for classification as high urgency and low urgency (likelihood ratio+=sensitivity/(1-specificity) and likelihood ratio-=(1-sensitivity)/specificity).[26] Patients categorised as immediate and very urgent were considered as high urgency and those classified as urgent, standard, or non-urgent as low urgency. The validity for subgroups was determined according to age and flowchart. Age was divided into subgroups (< 3 months, 3 months-11 months, 1-3 years, 4-7 years, ≥ 8 years). We distinguished patients with trauma and medical flowcharts. The trauma flowcharts included limb problems, head injury, major trauma, falls, wounds, injury to the trunk, and assault; all other flowcharts were considered to be medical ones. Commonly used medical flowcharts were considered. We calculated the percentage over-triage and under-triage for patients triaged with commonly used discriminators (fever and recent problem). Secondly, we assessed validity for patients with fever divided into age groups. Analyses were performed using SPSS software (version 14.0.1, SPSS, IL). Sensitivity, specificity, and likelihood ratios with 95% confidence intervals were calculated with the VassarStats website (http://statline.cbs.nl/statweb).[16]

RESULTS

Nurses applied the Manchester triage system in 16 735 of 17 600 children (95%) who attended the emergency department. The distribution of the reference standard did not differ between those who were or were not triaged (p=0.06). Nurses over-ruled the urgency category in 1714 (10%); 735 of whom (43%) had originally been triaged with the Manchester triage system as very urgent compared with 21% of the patients triaged with the Manchester system overall. Of these children in whom the classification of very urgent was over-ruled, 720 (98%) were downgraded by at least one category.

In the 384 and 509 patients triaged into the urgent and standard categories of the Manchester triage system, 73 (19%) and 22 (4.4%), respectively, were downgraded by at least one category. Fever discriminators (27%) and the discriminator of recent problem (22%) were often used if the urgency category was overruled.

In 1467 (9%) children, complete data were unavailable for the reference standard, leaving 13 554 for analysis. Distribution of the urgency category among children in whom the reference standard was missing was comparable with that in those without missing data (P=0.14). Median age was 3.4 years (interquartile range 1.2–8.0), 6631 (49%) children attended the university hospital, 5740 (42%) were female, and 6965 (51%) were not referred by a general practitioner or medical specialist.

Classification of urgency according to the Manchester triage system and the reference standard agreed in 4582 (34%) children. More children were classified as very urgent with the Manchester system than with the reference standard (2897 (21%) v 277 (2%)). Considerably fewer children were classified as non-urgent with the Manchester system than with the reference standard (112 (1%) v 2927 (22%)) (figure 1).

Validity

The Manchester urgency level agreed with the reference standard in 34% (n=4582). Some 5001 (37%) children were over-triaged by one category and 2310 (17%) by more than one category. With the Manchester system 1474 (11%) were under-triaged by one category and 187 (1%) by more than one category.

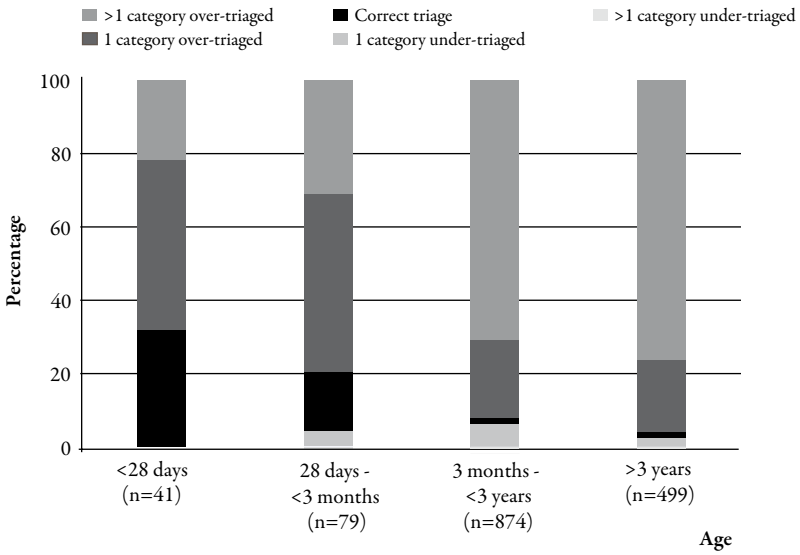

Figure 3 | Patients triaged with discriminator fever: relation of age to validity.

Agreement with the reference standard was particularly low for the very urgent category, with only 119 of 2897 (4%) classified correctly; 2545 (88%) were over-triaged and 233 (8%) patients were under-triaged (figure 1).

Overall, the Manchester system had a sensitivity of 63% (95% confidence interval 59% to 66%) and a specificity of 79% (79% to 80%) for identifying high urgency patients. The likelihood ratio was 3.0 (95% confidence interval 2.8 to 3.2) for a high urgency result and 0.5 (0.4 to 0.5) for a low urgency result. The Manchester system was less sensitive for very young patients (0–3 months) (sensitivity 50%), resulting in a likelihood ratio+ of 2.4, while specificity was better for older children (> 4 years), resulting in higher likelihood ratios. The validity of the Manchester system was lower for children presenting with a medical problem, of whom 61% were over-triaged and 10% under-triaged compared with 32% and 19%, respectively, for patients presenting with trauma. The likelihood ratio (+) was also lower (table 1).

The validity of the Manchester system in children triaged with medical flowcharts differed considerably between the top 10 medical flowcharts, with poor validity for the worried parent flowchart (19% correct triage; likelihood ratio+ 0.9, likelihood ratio- 1.0) (figure 2 and table 1).

Commonly used general discriminators were recent problem (20%), pain discriminators (17%), fever discriminators (15%), recent injury (9%); commonly used specific discriminators were increased work of breathing (4%) and persistent vomiting (4%). Patients triaged with a fever discriminator showed a low validity, especially with increasing age (figure 3).

Table 1 | Sensitivity, specificity, and likelihood ratios with 95% confidence intervals for different subgroups on age, presenting problem, and medical Manchester triage system flowcharts .

Subgroup	No. of patients	High urgency %*		Sensitivity†	Specificity†	LR+	LR-
		Manchester	Reference				
Overall	13 554	23.0	5.2	63 (59 to 66)	79 (79 to 80)	3.0 (2.8 to 3.2)	0.47 (0.43 to 0.52)
Age:							
0-2 months	1033	25.0	14	50 (42 to 58)	79 (76 to 82)	2.4 (1.9 to 2.9)	0.63 (0.54 to 0.74)
3-11 months	1965	33.0	6.6	65 (56 to 73)	69 (67 to 72)	2.1 (1.9 to 2.5)	0.50 (0.39 to 0.63)
1-3 years	4427	27.0	5.7	67 (61 to 73)	75 (74 to 77)	2.7 (2.5 to 3.0)	0.43 (0.36 to 0.52)
4-7 years	2760	20.0	3.0	66 (55 to 76)	81 (80 to 83)	3.6 (3.0 to 4.2)	0.41 (0.31 to 0.56)
8-16 years	3369	13.0	2.8	64 (53 to 73)	88 (87 to 89)	5.4 (4.5 to 6.5)	0.41 (0.31 to 0.54)
Presenting problem‡:							
Medical	9774	30.0	7.0	64 (60 to 67)	72 (71 to 73)	2.3 (2.2 to 2.5)	0.50 (0.45 to 0.55)
Trauma	3332	4.9	0.6	55 (32 to 76)	95 (95 to 96)	12.0 (7.8 to 18.0)	0.47 (0.29 to 0.77)
Medical flowcharts‡:							
General	1703	34.0	7.9	63 (55 to 71)	68 (66 to 71)	2.0 (1.7 to 2.3)	0.53 (0.43 to 0.67)
Shortness of breath in children	1520	50.0	12	78 (72 to 84)	54 (51 to 56)	1.7 (1.5 to 1.9)	0.40 (0.30 to 0.53)
Worried parent	1457	45.0	6.0	42 (32 to 54)	55 (52 to 58)	0.9 (0.7 to 1.2)	1.0 (0.87 to 1.2)
Abdominal pain in children	839	5.6	0.6	40 (7 to 83)	95 (93 to 96)	7.4 (2.4 to 22)	0.63 (0.31 to 1.3)
Vomiting	808	4.2	5.2	14 (6 to 29)	96 (95 to 97)	3.9 (1.7 to 8.9)	0.89 (0.79 to 1.0)
Rashes	409	23.0	1.5	83 (36 to 99)	78 (74 to 82)	3.8 (2.6 to 5.7)	0.21 (0.036 to 1.3)
Diarrhoea	330	6.1	5.5	44 (22 to 69)	96 (93 to 98)	11.6 (5.4 to 25)	0.58 (0.38 to 0.87)
Fits	303	60.0	17	83 (70 to 91)	45 (39 to 51)	1.5 (1.3 to 1.8)	0.38 (0.21 to 0.69)
Ear problems	281	17.0	1.1	33 (2 to 87)	83 (78 to 87)	2.0 (0.4 to 10.0)	0.80 (0.36 to 1.8)
Urinary problems	237	28.0	2.1	80 (30 to 90)	73 (67 to 79)	3.0 (1.8 to 4.9)	0.27 (0.047 to 1.6)

LR+=likelihood ratio for high urgency triage test result, LR-=likelihood ratio for low urgency triage test result. *Immediate and very urgent category.
†Sensitivity=high urgency (immediate or very urgent) according to Manchester system/high urgency according to reference standard. Specificity=low urgency (urgent, standard, or non-urgent) according to Manchester system/low urgency according to reference standard.
‡Flowcharts available for 13 106 (97%). Selection of the 10 most used medical flowcharts accounts for 80% (7887/9774) of patients' medical flowcharts.

DISCUSSION

Principal findings and interpretation

The Manchester triage system has an overall moderate validity compared with an independent reference standard. The agreement with the reference standard was 34%, with over-triage in 54% and under-triage in 12% (mostly by one category). The sensitivity for high urgency was 63%, implying that 37% of the patients who actually needed to be seen within 10 minutes were not categorised as that urgent. The specificity was 79%, implying that 21% low urgency patients were categorised too high. In particular, patients in the very urgent category were over-triaged.

The validity was lower in children presenting with medical problems compared with those presenting with trauma. Any modifications should therefore be particularly targeted for medical problems. Specific discriminators can be considered for their role in the triage system. For example, children aged <3 months with fever are at greater risk for a serious bacterial infection, whereas children aged ≥3 months with fever might be allocated to a lower urgency category.[27] Such a modification was incorporated in the emergency severity index (ESI) (version 4), a commonly used triage system in Europe and the United States.[28] A modification of the paediatric CTAS, a Canadian triage system, in which febrile children aged 6-36 months with no signs of toxicity could be triaged to a lower urgency level (from level 3 to 4), has been shown to be safe.[29]

The validity of triage systems depends on the extent to which the system predicts urgency and on the accuracy of the nurse who applies the system (interrater agreement). We previously found a good inter-rater agreement of the Manchester system in children at our two emergency departments, both for written case scenarios (weighted κ 0.83, 95% confidence interval 0.74 to 0.91) and for simultaneous triage of actual patients (0.65, 0.56 to 0.72).[30] We can therefore assume that the validity of the Manchester system compared with the reference standard is mostly due to the predictive value of the system to assess urgency.

Strengths and limitations of the study

In the Manchester triage system, conditions such as shock, inadequate breathing, compromised airway, and unresponsiveness are used to identify children who need to be seen immediately. For the reference standard we classified children as immediate if blood pressure, heart rate, and respiratory rate were abnormal, if they had a decreased consciousness, or if hyperpyrexia or hypothermia was present. As abnormal vital signs predict mortality in children in critical care units[18] and the measurement of vital signsis part of triage assessment,

they should be used to identify patients who need immediate attention. Our reference standard was based on literature and expert opinion, which admittedly reflects a low grade of evidence.[31] The goal of seeing patients in the order of their category of urgency is to decrease morbidity and mortality.[32] Mortality, however, is rare in children presenting at the emergency department and thus cannot be evaluated. Also, differences in morbidity are hard to relate to shorter or longer waiting times.

Furthermore, the reference standard is based on a combination of patients' characteristics collected at the time of presentation and at the end of the consultation in the emergency department. Characteristics gathered at the end of the consultation might be less suitable to define urgency because of possible changes in the patient's condition overtime. Assessment of true acuity requires more information than is available at the time of triage.

Our reference standard can therefore be seen only as an approximation of an ideal standard as it was previously used to study the Manchester triage system in paediatric emergency care and had the advantage of classifying patients across five urgency categories.[15,31,33,34]

Another limitation of the study is that nurses overruled the Manchester system urgency category in 10% of the patients. Originally, these patients were often allocated to the very urgent category, which showed a low validity. Inclusion of the 10% over-ruled patients would probably have lowered the validity of the Manchester system.

Furthermore, data for the reference standard were missing in 9% of the patients. Selection bias is not likely as the distribution of the Manchester system categories for patients with missing data was similar to that of the patients without missing data.

Finally, the study was performed in a large urban mixed paediatric-adult emergency department and a large university paediatric emergency department with 90% basic paediatric care. Although these two centres might have a relatively larger number of immediate cases, they are likely to be representative of large emergency departments.

Strengths and weaknesses in relation to other studies

In an earlier retrospective evaluation of the Manchester triage system in paediatric emergency care, we found 40% correctly triaged, 15% under-triaged, and 45% over-triaged.[15] In the present prospectivestudy we found a lower percentage of correct agreement, but the percentage under-triaged patients was also lower. This can be explained by a difference in fractions of immediate cases.[15] The sensitivity and specificity for high urgency is highly comparable between these two studies.

Table 2 | Studies on validity of triage systems in emergency care, published 1997-2008.

Study	Sample size	Patients/ triage system	Study design	Outcome measure	Conclusion
Manchester triage system: adult and paediatric population					
Cooke et al[5] 1999, UK	91	Adults admitted to critical care area	Retrospective	Admission to critical care unit	Sensitive tool for those who need subsequent admission to critical care
Speake et al[6] 2003, UK	167	Adults with chest pain	Prospective	Chest pain assessment protocol	Sensitivity 87%, specificity 72%
Roukema et al[15] 2006, Netherlands	1065	Children	Retrospective	Reference standard based on vital signs, diagnosis, resource use, admission rate, and follow-up	Sensitivity 63%, specificity 78%
Current study	13 554	Children	Prospective	Reference standard based on vital signs, diagnosis, resource use, admission rate, and follow-up	Sensitivity 63%, specificity 79%
Other triage systems studied in paediatric population					
Maningas et al[14] 2006, US	7077	Soterion rapid triage system, 5 level	Retrospective	Admission rate, length of stay, hospital charges, current procedural terminology	High validity in paediatric patients, <2% of patientsadmitted ofurgency levels 4 and 5
Gouin et al[13] 2005, Canada	807/560	Paediatric CTAS, 5 level	Before and after prospective study	Admission rate, medical interventions, and PRISA score, comparison with previous used triage tool (4 level)	Previous triage tool had better ability to predict admission than paediatric CTAS
Baumann et al[7] 2005, US	510	ESI (version 3)	Prospective triage, retrospective chart review	Admission rate, resource use, emergency department length of stay	ESI score predicts resource use, length of stay, and admission to hospital in children

CTAS=Canadian emergency department triage and acuity scale; ESI=emergency severity index.

Other triage systems studied in paediatric emergency care show a high validity (Soterion rapid triage system)[14], predicted admission (paediatric Canadian emergency department triage and acuity scale)[13], and predicted resource use and length of stay (emergency severity index).[7] Although all of these studies used outcome measures to correlate with urgency or to identify the high urgency patients (intensive care admission), they did not define a "reference standard" for urgency (table 2).

The use of an independent reference standard for each patient will allow for further development and evaluation of modifications to the Manchester triage system. When applying the Manchester triage system in paediatric emergency care, users should be aware of its moderate validity. We need to consider and study modifications for specific flowcharts, discriminators, and age groups for which the triage system has a low validity.

CONCLUSION

The Manchester triage system shows a moderate validity in paediatric emergency care but errs on the safe side as the percentage over-triage is much larger than under-triage compared with a reference standard for urgency. Triage of patients with a medical problem or younger patients is particularly difficult.

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APPENDIX 1 Reference classification parameters

Table A | Vital signs: normal values according to PRISM III[18]

Age	Respiratory rate /min	Systolic BP (mmHg)	Heart rate/min
<1 month	15-90	55-160	80-215
1-11 months		65-160	60-215
1-11 year	10-70	75-200	45-185
>12 year		85-200	40-145

heart rhythm: arrhythmia; respiration pattern: inspiratory stridor, respiratory insufficiency;
temperature: ≤33°C or ≥41°C;
oxygen saturation: absolute percentage, cut-off = < 90%;
level of consciousness: decreased, convulsive at arrival, coma.

Presence of a possible life- threatening condition (PLC)

Meningitis, sepsis, high-energy trauma, substantial external blood loss or trauma (sharp/blunt) leading to substantial blood loss, aorta dissection, >10% dehydration, (near)drowning, electric trauma, apparently life-threatening event (ALTE), possible dangerous intoxication, >10% burns, facial burns or possible inhalation trauma, other (specified).

Diagnostic work-up

- Simple laboratory tests (CBC, electrolytes, liver enzymes, renal function, urine/stool cultures, nasal swabs)
- Imaging (radiograph, ultrasound imaging)
- Extensive laboratory tests (blood culture, CSF puncture or combination of two or more laboratory test groups as stated above) or CT/MRI

Therapy

- Rx: simple advice, or medication on prescription
- Rx at the ED: oral medication at the emergency department (i.e. ORS, prednisone, antibiotics) or small surgical intervention (suture, debridement, bandage)
- Intervention: Intravenous medication or intervention at the emergency department (including fluids, aerosols) or surgical intervention (including casting, gastrolavage, inguinal hernia reposition, luxation reposition)
- Other (specified)

Follow-up

- General practitioner / telephone contact
- Outpatient / emergency department
- Hospital admission

APPENDIX 2 | Reference classification matrix and definitions of reference urgency categories.

Table B | Reference classification matrix

			Diagnostics			Therapy			Follow-up		
	Vital	**PLC**	**Simple**	**Imaging**	**Extensive**	**Rx**	**Rx at ED**	**Intervention**	**Tel./GP**	**Outpatient**	**Hospitalisation**
1. Immediate	**1**	n/a		n/a			n/a			n/a	
2. Very urgent	0	**1**		n/a			n/a			n/a	
3. Urgent	0	0		n/a		0	0	**1**		n/a	
	0	0		n/a		0	**1**	0	n/a	0	**1**
	0	0	**1**	0	0		n/a		n/a	0	**1**
	0	0	0	**1**	0		n/a		n/a	0	**1**
	0	0	0	0	**1**		n/a		n/a	0	**1**
	0	0	0	**1**	0	**1**	0	0	n/a	**1**	0
	0	0	0	0	**1**	**1**	0	0	n/a	**1**	0
	0	0	0	**1**	0	0	**1**	0		n/a	
	0	0	0	0	**1**	0	**1**	0		n/a	
	0	0	0/**1**	**1**	**1**		n/a			n/a	
4. Standard	**All other combinations**										
5. Non-urgent	0	0	0	0	0	0/**1**	0	0	0	0	0

1= present / 0= absent
PLC = possible life-threatening condition
n.a. = not applicable
Rx = medication on prescription

Category 1. Immediate:
Vital parameters: abnormal

Category 2. Very urgent:
Possible life-threatening condition: present

Category 3. Urgent:
One of the following combinations:

- intervention at the emergency department, diagnostic work-up and follow-up not of application
- extended laboratory diagnostics AND X-ray/ultrasound imaging, intervention
- extended laboratory diagnostics or X-ray/ultrasound imaging AND oral medication or small surgical intervention at the emergency department. Extended laboratory diagnostics or X-ray/ultrasound imaging AND medication on prescription, AND out-patient/emergency department follow-up within 24 hours
- hospital admission AND some diagnostic work-up, Rx at emergency department, or intervention

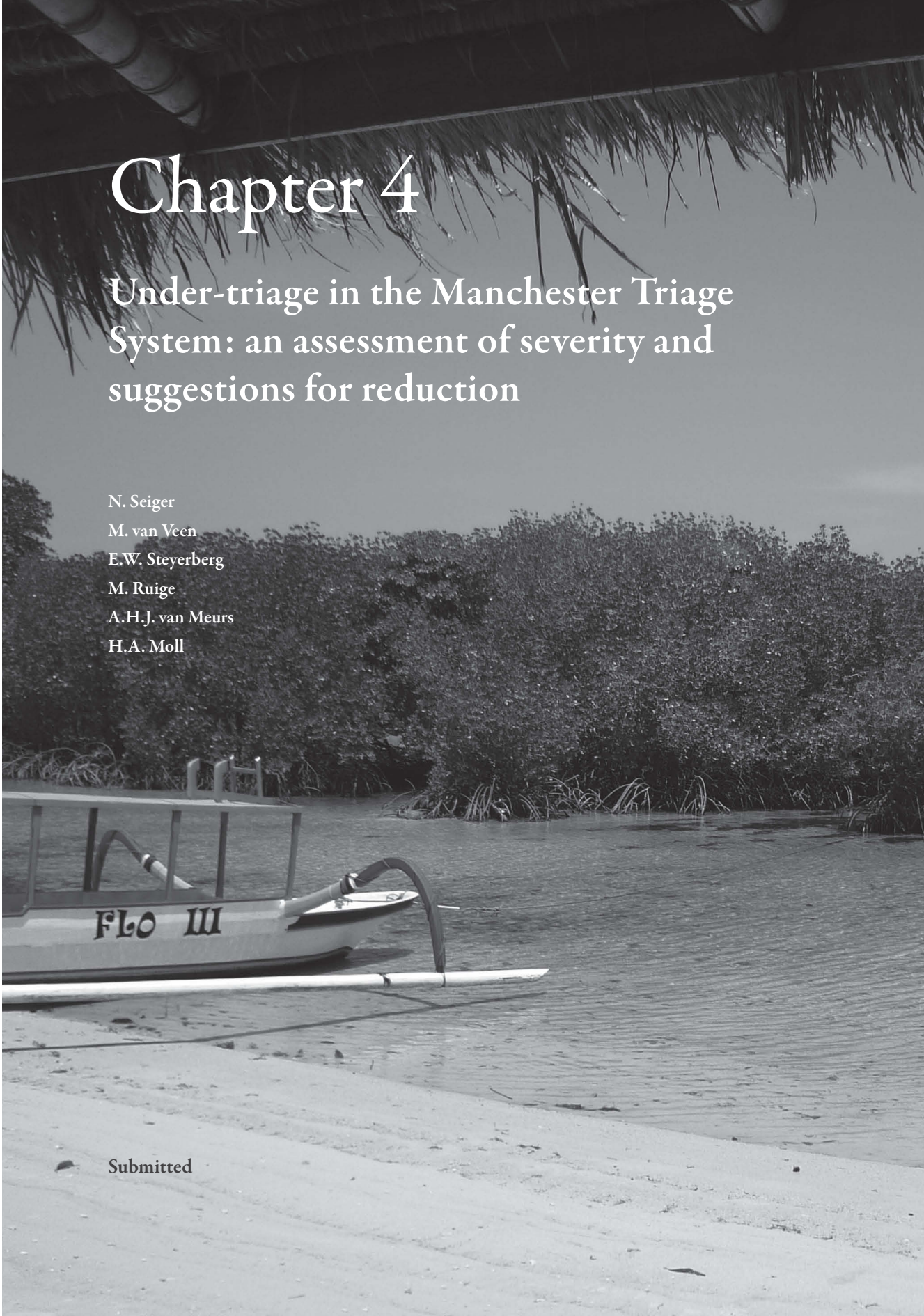
Category 4. Standard:
All patients that were not classified as urgent or non-urgent.

Category 5. Non-urgent:
Diagnostic work-up: none
Therapy: none/medication on prescription
Follow-up: none

Chapter 4

Under-triage in the Manchester Triage System: an assessment of severity and suggestions for reduction

N. Seiger
M. van Veen
E.W. Steyerberg
M. Ruige
A.H.J. van Meurs
H.A. Moll



Submitted

ABSTRACT

Background The Manchester Triage System (MTS) determines an inappropriately low level of urgency (under-triage) to a minority of children. The aim of the study was to assess the clinical severity of under-triage and to determine predictors for under-triage in paediatric patients.

Methods Patients presenting at the ED were triaged using the MTS. Under-triage was defined as patients classified as high urgent (level 1 or 2) by the MTS and low urgent (level 3-5) by a fixed reference standard, based on abnormal vital signs (level 1), potentially life-threatening conditions (level 2) and a combination of diagnostic and therapeutic interventions and hospitalisation/follow up for the three lowest urgency levels. The clinical severity of under-triage was assessed by three experienced paediatricians for cases presented in a standardised format. We used logistic regression analysis to assess predictors for under-triage.

Results In total, 152/13,554 (1.1%) were under-triaged, of whom 70% could have been considered clinically severe (107/152). The reference standard was determined by abnormal vital signs, in 83 patients (78%).

Younger children (especially those below 3 months of age), and children assigned to the MTS flowchart 'unwell child' were more likely to be under-triaged than children assigned to other flowcharts, both in univariate and adjusted analyses.

Conclusion Under-triage occurs infrequently, but might have serious clinical consequences. The MTS may potentially be improved by adding abnormal vital signs as a discriminator for very young children and in the MTS flowchart 'unwell child'.

BACKGROUND

The Manchester Triage system (MTS) is commonly used in emergency departments (ED) to determine the clinical priority of patients.[1] The MTS is a consensus based system, which consists of 52 flowcharts containing discriminators. The selection of the discriminator leads to one of five urgency levels.[1]

Earlier performed studies on the validity of the MTS calculated the sensitivity of detecting high urgent cases or patients with specific conditions.[2-4]

In a previous performed study we defined validity as sensitivity and specificity of the MTS in comparison to a reference standard for urgency.[5] This study showed that the MTS errs on the safe side. The sensitivity was 63% and specificity 79%. Over- and under-triage are inevitable. More importantly, however, are the consequences of errors in triage and how these could be avoided in clinical practice.[6]

Under-triage is considered more severe for the individual patient than over-triage,[7,8] since under-triage might increase morbidity and even mortality. We therefore focus here on under-triaged patients. This study aims to assess clinical severity of under-triage by experts and to determine predictors for under-triage in paediatric patients at the ED.

METHODS

Study design

We compared the MTS urgency classification (first edition) with an independent reference standard.[5]

Under-triage was defined when patients were triaged as low urgent according to the MTS and set as high urgent according to the reference standard urgency.

Experienced paediatricians discussed the possible impact of treatment delay in under-triaged cases to determine the clinical severity. The expert opinion was accomplished by standardized questionnaires. Subsequently, a logistic regression analysis was performed to determine predictors of under-triage. This study is part of an ongoing study.[5,9] The same dataset was used before to assess the validity of the MTS in children.[5] The study was approved by the institutional medical ethical committee; the requirement for informed consent was waived.

Patients

Patients, age range 0-16 years, who visited the ED of the Haga Hospital-Juliana Children's Hospital in The Hague between 1-1-2006 until 1-8-2006 and the Erasmus MC Sophia Children's hospital in Rotterdam between 1-1-2006 until 1-2-2007, were included. Nurses triaged the patients according to the MTS. The MTS applies five levels of urgency determined by standard discriminators in problem-specific flowcharts.[1] The clinical priority is categorized into five levels of urgency. The assigned urgency level decides the maximum possible waiting time for a patient to be seen by a physician, and the order in which the physician evaluates the patient. Urgency level "Immediate" (red) demands immediate medical evaluation, "very urgent" (orange) needs evaluation within 10 minutes, "urgent" (yellow) within 60 minutes, "standard" (green) within 120 minutes and "non-urgent" (blue) can wait for up to 240 minutes prior to clinical assessment.

The reference standard (see appendix, chapter 3) based on literature was used as an approximation of the patient's true urgency. The reference urgency levels were defined by abnormal vital signs (level 1), potential life-threatening conditions (level 2) and a combination of diagnostic and therapeutic interventions and hospitalisation/follow up (level 3, 4 and 5). [5,10]

Under-triage

We defined under-triage as patients who were triaged as urgent, standard or non-urgent (level 3, 4 or 5) according to the MTS and set as immediate or high urgent (level 1 or 2) according to the reference standard. We included under-triaged patients with at least a difference of two urgency levels between the MTS level of urgency and the reference standard urgency level.

The patients were assigned to reference level 1 if they had abnormal vital signs according to the paediatric risk of mortality score (PRISM)[5,11] and to level 2 if they had normal vital signs, but the presumed diagnosis at the end of the ED consultation was potentially life-threatening.[5] In the event of similar under-triaged cases, one case was randomly selected as a representative case for the expert meeting.

Expert meeting

Three paediatricians evaluated the cases based on the anonymous ED forms at a meeting. The ED forms included information of the assigned MTS and reference urgency levels, the presenting symptom(s), history, physical examination, working diagnosis, therapy, diagnostics and follow-up.

First, the experts scored the expected clinical severity of under-triage on a scale from zero to ten. Zero represented 'the absolute minimum severity' and ten 'the maximum severity of under-triage'. Secondly, the experts evaluated the clinical severity of under-triage by using an eight-item questionnaire. The experts were asked to decide what the maximum waiting time for the discussed case might be. The maximum waiting time is the time the patient could wait safely before being seen by a physician. The assigned maximum waiting time can be seen as an indicator for patient's true urgency and varied from zero to 240 minutes.
Subsequently the experts assessed the risk of more interventions or diagnostics, a longer duration of hospitalization, complications, long-term morbidity and mortality for the cases. The answers for the questionnaire provided to ascertain their opinions was purely in a 'yes and no' format. The experts were paediatricians with a minimum of fifteen years of clinical experience with expertise in emergency medicine, working in large inner-city teaching or university hospitals.

Data analysis

Assumptions were made that the experts would have scored similar cases in an equal manner. Therefore, the results of the discussed case were multiplied to the number of similar cases.
Under-triage was defined as severe if the severity score was high (≥7) or if the probability for one of the possible consequences of under-triage was high (≥67%).
We performed a univariate and multivariable logistic regression analysis to determine predictors for under-triage.
Age, gender and the assigned MTS flowchart, specific for the patient's presenting problem were considered as possible predictors of under-triage. Since the relation between age and risk of under-triage was non-linear, age was categorized as younger than 3 months, 3 months to 11 months, 1 to 4 years, 4 to 8 years and older than 8 years. SPSS version 15.0 was used for statistical analysis.

RESULTS

Under-triage

Complete data of MTS triage and reference standard were available for 13,554 patients.[5] 243 (1.8%) of patients triaged by the MTS as 'urgent' 'standard' or 'non-urgent' (N=10,445) were assigned to the reference urgency levels 'very urgent' or immediate'.

In 160/243 (66%) of under-triaged cases the difference between the MTS urgency and reference standard urgency was two or more urgency levels. In 8 cases the medical records were missing. In total 152 cases remained for analysis (figure 1).

With regards to cases featuring similar medical problems, one was randomly selected for evaluation in the expert meeting. This provided 23 cases for discussion by the panel of experts.

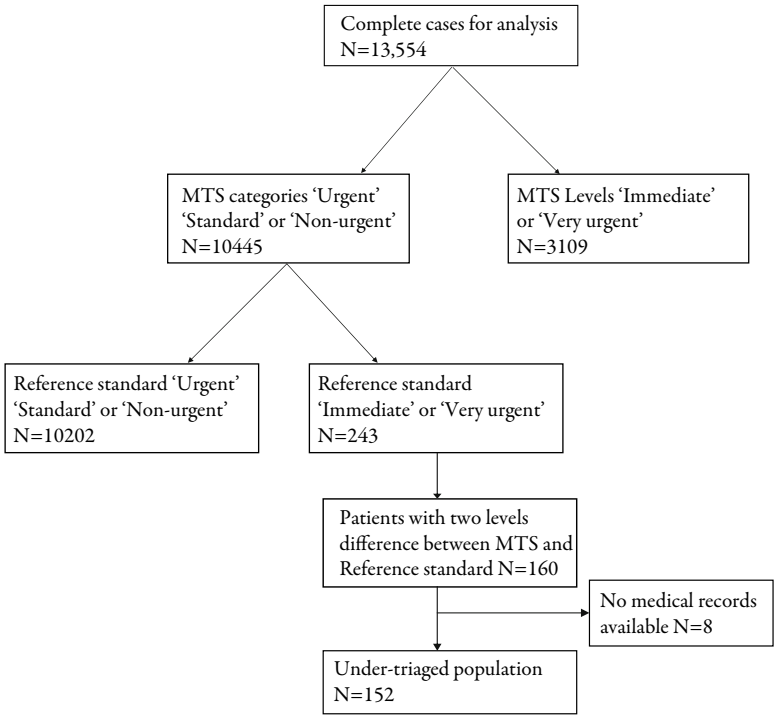


Figure 1 | Population

Clinical severity

The items discussed by the experts are showed in table 1.

In 70% (107/152) of the under-triaged patients, under-triage was considered severe and 78% (83/107) had a high urgency for the reference standard due to abnormal vital signs (heart rate, blood pressure, pulse oximetry, respiratory rate).

According to the experts, 65% (99/152) of the under-triaged patients could potentially experience at least one consequence of under-triage. In 58% (89/152) the consequences of under-triage might include more interventions and in 50% (77/152) more diagnostic

Table 1 | The clinical severity of undertriaged patients discussed by experts.

Under-triaged patients			Items discussed by expert panel							
Vital sign or life-threatening condition*	Under-triaged Patients	EP**	More interventions	More diagnostics	Longer hospitalization	Complications	Severity†	Maximum waiting time‡	Morbidity	Mortality
Alte	37 (24%)	3	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0-8)	120 (10-240)	0 (0%)	0 (0%)
Sepsis	4 (3%)	2	2 (50%)	2 (50%)	0 (0%)	2 (50%)	5 (1-9)	65 (10-120)	2 (50%)	0 (0%)
Near drowning	4 (3%)	2	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0-0)	120 (120-120)	0 (0%)	0 (0%)
Intoxication	1(1%)	1	0 (0%)	0 (0%)	0 (0%)	1 (100%)	10 (10-10)	0 (0-0)	1 (100%)	0 (0%)
Abnormal Heart rate	34 (22%)	6	26 (76%)	20 (58%)	8 (25%)	23 (67%)	7 (6-10)	10 (10-10)	11 (33%)	8 (25%)
Abnormal Blood pressure	7 (5%)	2	0 (0%)	0 (0%)	5 (71%)	5 (71%)	10 (3-10)	5 (5-10)	5 (71%)	0 (0%)
Pulse oximetry deviated	18 (12%)	2	18 (100%)	11 (61%)	0 (0%)	7 (39%)	8 (8-8)	10 (10-30)	7 (39%)	0 (0%)
Abnormal Respiratory rate	21 (14%)	3	21 (100%)	21 (100%)	7 (33%)	7 (33%)	4 (4-8)	10 (5-10)	0 (0%)	7 (33%)
Hyperpyrexia	3 (2%)	1	0 (0%)	0 (0%)	0 (0%)	3 (100%)	7 (7-7)	30 (30-30)	0 (0%)	0 (0%)
Unresponsiveness	23 (15%)	1	23 (100%)	23 (100%)	0 (0%)	23 (100%)	9 (9-9)	10 (10-10)	0 (0%)	0 (0%)
Total	152 (100%)	23	90 (58%)	77 (50%)	20 (13%)	71 (46%)	7 (4-9)	10 (10-60)	26 (17%)	15 (10%)

* Patients characteristic, which determines the reference standard;

** Number of cases as discussed by expert panel (EP);

† Clinical severity: median of the marks experts scored on a scale from 1-10, 10 is considered as highest severity (25^{th}-75^{th} percentiles);

‡ Median waiting time in minutes before the physician should see the patient and the subsequent priority level, on scale 0-240 minutes (25^{th}-75^{th} percentiles).

investigations. In 46% (70/152), complications were considered likely to occur and it was predicted that in 13% (20/152), under-triage could lead to an increased duration of hospitalization. Substantial risks of morbidity or mortality due to under-triage were estimated as 7% (26/152) and 10% (15/152) respectively by the experts.

Apparent life-threatening event (ALTE) was present in 37 of the under-triaged cases. All were considered as absolute non severe according to the experts. (Severity score 1 and no consequences due to under-triage).

Determinants of under-triage

Patients assigned to the flowchart 'unwell child' were more often under-triaged compared to patients assigned to the 'general' flowchart. ($OR_{unwell\ child}$ 5.6, 95% CI 2.6-12). (Table 2)

Table 2 | Predictors for under-triage

Predictors	Low urgent patients* (N=10,445)	Under-triage N=152	OR, (95% C.I) univariate	Adjusted OR (95% C.I) **
Gender				
Male	5,982	79	0.8 (0.6-1.1)	-
Female	4,463	73	Reference	-
Age				
<3 months	773	42	7.2 (4.3-12.1)	3.3 (1.9-5.8)
3-11 months	1,321	27	2.6 (1.5-4.6)	1.3 (0.7-2.4)
1-4 years	3,220	46	1.8 (1.1-3.0)	1.3 (0.8-2.2)
4-8 years	2,208	14	0.8 (0.4-1.6)	0.8 (0.4-1.5)
8-16 years	2,923	23	Reference	Reference
Flowchart used				
Diarrhoea and vomiting	1,084	20	0.7 (0.4-1.2)	0.7 (0.4-1.2)
General	1,122	31	Reference	Reference
Headache	158	5	1.2 (0.4-3.0)	1.7 (0.6-4.6)
Shortness of breath	792	30	1.4 (0.8-2.3)	1.5 (0.9-2.5)
Unwell child	73	10	5.6 (2.6-11.9)	5.9 (2.7-12.8)
Worried parent	805	37	1.7 (1.0-2.8)	1.5 (0.9-2.5)
Other	6,411	19	-	-

* According to the MTS;

** Adjusted for age and flowchart, respectively

Younger patients (under 4 years, and especially under 3 months of age) had a higher risk of under-triage than children aged 8-16 years ($OR_{<3\ months}$ 7.2, 95% CI 4.3-12, $OR_{3\text{-}11\ months}$ 2.6, 95% CI 1.5-4.6, $OR_{1\text{-}4\ years}$ 1.8, 95% CI 1.1-3.0).
Younger patients (0-3 months) and patients assigned to the 'unwell' flowchart also had a higher risk of under-triage when adjusted in multivariable analyses ($aOR_{0\text{-}3\ months}$ 3.3, 95% CI 1.9-5.8 adjusted for flowchart, $aOR_{unwell\ child}$ 5.9, 95% CI 2.7-13 adjusted for age).

DISCUSSION

Our study aimed to assess the clinical severity of treatment delay as a result of under-triage using the Manchester triage system, compared to a reference standard.
70% (107/152) of the under-triaged patients highlighted by this study could be considered as clinically severe, and 65% (99/152) might experience at least one consequence due directly to under-triage.
78% (83/107) of the clinically severe under-triaged patients had abnormal vital signs. In the MTS vital signs are not measured; instead, abnormal vital signs were identified using the discriminators shock, inadequate breathing, compromised airway, and unresponsiveness. Not all patients with abnormal vital signs were assigned to one of these discriminators and therefore not always recognized as patients with high urgency.[5] Cooke et al demonstrated misclassification in the MTS due to abnormal vital signs in adults.[3] In this study, three patients with chest pain could have been assigned to the correct urgency level if pulse oximetry had been part of the triage assessment.
73% (37/51) of patients diagnosed with a potential life-threatening event (ALTE) were under-triaged according to our reference standard. The experts considered these cases as not severe. Thus, in these cases the experts agreed with the MTS urgency level and not with the reference standard. Therefore ALTE should not be considered a level 2 condition in the reference standard.
Although under-triage was infrequent in children assessed with the MTS, some specific predictors for under-triage were distinguished. Patients younger than 3 months (26.3% under-triaged cases) and patients assigned to the flowcharts 'unwell child' (6.3% of the under-triaged cases) were more likely to be under-triaged. Together these subgroups contained 31% (47/152) of all under-triaged patients.

In a triage system, a certain percentage of under-triage is considered inevitable, because patients presenting with the same symptoms could have different priorities. As a result, it is difficult to find discriminators, which embrace all presenting signs and symptoms. Modification of a triage system should decrease under-triage, while the number of over-triaged cases is reduced or remained constant.

Measuring vital signs in every patient increases the sensitivity of the MTS, but will increase the workload substantially. Therefore, only measuring vital signs in children younger than three months and in children assigned to the flowcharts 'unwell child' could be considered. Then 19% (20/107) of the clinically severe under-triaged could be prevented, while in 9% (1,157/13,554) vital signs should be measured.

Limitations

The value of expert opinion has been criticized. Nonetheless, expert opinion is the best available method to evaluate the consequences of under-triage for individual cases. Standardized questionnaires were used to improve validity of the judgment of the cases. The experts were all experienced paediatricians in emergency medicine.

We did not check all cases for errors on the assigned MTS. Earlier performed studies demonstrated adequate reliability and accuracy of the MTS as a predictive tool.[9, 12-14]

Under-triage is a term used for patients who are assigned to a low urgency level, while the "true" urgency is high. To determine patient's true urgency a reference standard based on patient's characteristics during ED consultation was determined as best proxy for true urgency.[9] The items on which the reference standard was based were extracted from the literature, but the final combinations of these items were defined by expert opinion, which is a low grade of evidence-based medicine. Despite these limitations, a reference standard is in our opinion a reasonable best approach to assess the urgency with which particular patients should be seen and assessed.[15]

CONCLUSION

Serious under-triage occurs in very small numbers of cases (approximately 1%), but could potentially have serious consequences. To reduce significant under-triage, some adjustments to the MTS are recommended. Adding abnormal vital signs as a discriminator in severity to the MTS, when applied to patients younger than three months, and for those assigned to the flowchart 'unwell child' could reduce the numbers considered under-triaged.

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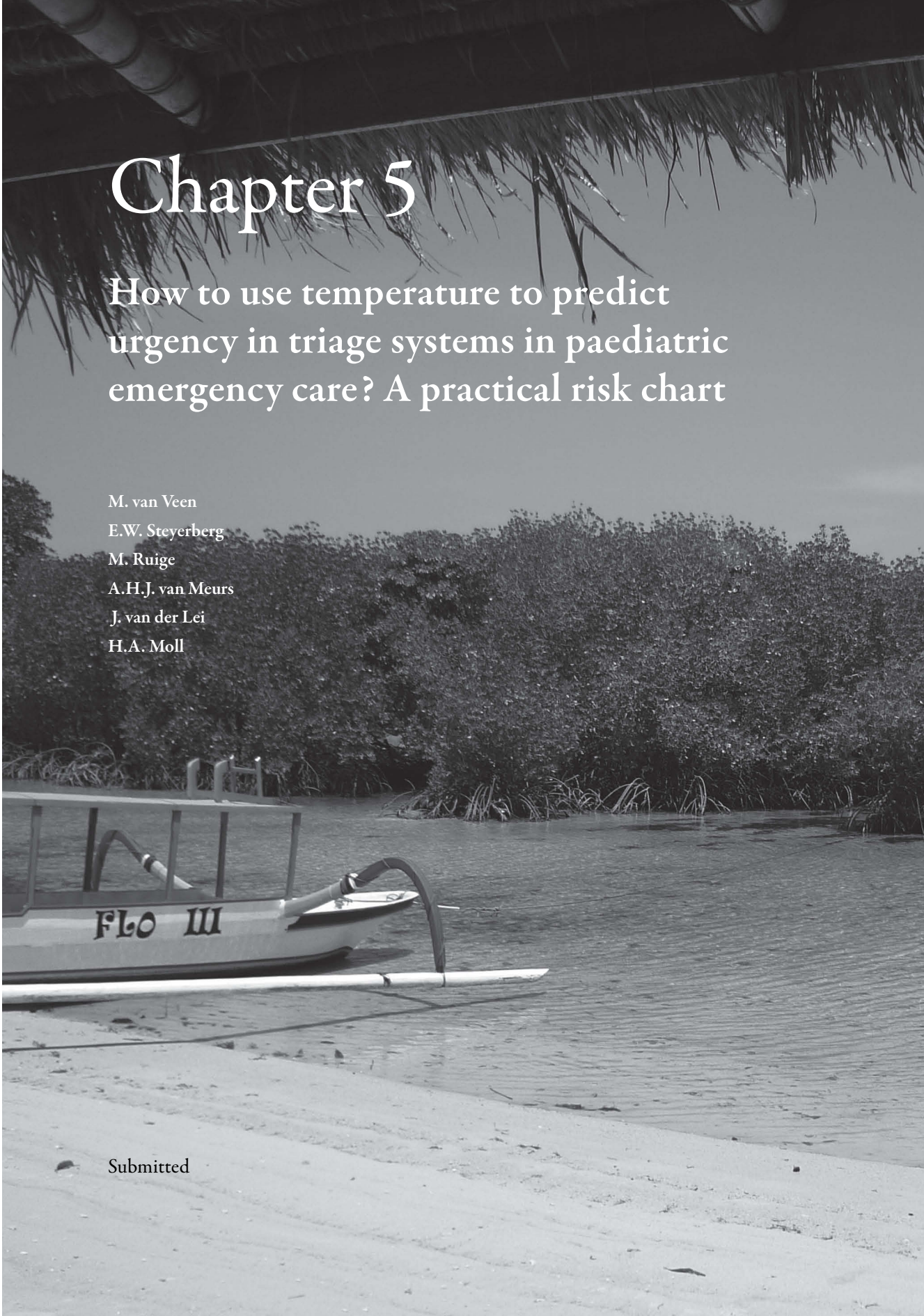
Chapter 5

How to use temperature to predict urgency in triage systems in paediatric emergency care? A practical risk chart

M. van Veen
E.W. Steyerberg
M. Ruige
A.H.J. van Meurs
J. van der Lei
H.A. Moll



Submitted

ABSTRACT

Objective To explore how to use temperature as a discriminator to predict urgency in triage systems for children.

Methods Observational study. Patients aged 0–15 years presenting with a non-traumatic problem, at two emergency departments in the Netherlands in 2006/2007 were included. Missing values on temperature were imputed. As a proxy outcome measure for urgency, we defined patients with deviated vital signs and patients with a potentially life threatening condition as high urgent and others as low urgent. Univariable and multivariable logistic regression analysis was used with the easily accessible characteristics age and presenting problem combined with temperature as discriminators. Model performance was quantified by the area under receiver operating characteristic curve (AUC). The model was validated in a new dataset (patients included 2007/2008). Finally, a risk score was developed to predict urgency.

Results In 2006/2007 12,562 patients were included and in 2007/2008 9,281 patients. In 1,407 (11%) and 331 (4%) patients, respectively, the outcome measure was missing, leaving 11,155 and 8,950 patients for analysis. Temperature separately had a moderate discriminative ability to predict urgency (AUC 0.58, 95% Confidence Interval (CI) 0.56–0.60), but its combination with presenting problem and age led to a better performance.(AUC 0.75, 95% CI 0.73-0.76) Presenting problem and age without temperature results in an AUC of 0.73 (95% C.I. 0.71–0.74).

Temperature influences urgency especially in patients presenting with upper respiratory tract and urinary tract problems.

Conclusions Body temperature combined with age and presenting problem is an important discriminator in triage systems. These discriminators modify the triage level for children visiting an ED for fever or infectious disease and can be implemented in triage systems.

INTRODUCTION

The aim of triage is to identify patients who benefit most from immediate medical care. Benefit is high in patients who have conditions in which delayed treatment is likely to harm the patient. Triage focuses on the patient's condition at presentation instead of the diagnosis since the diagnosis does not necessarily determine the patient's acuity.[1] To identify patients with a condition, which needs immediate action, easily and quickly available signs and symptoms must by incorporated in triage systems to predict these potentially harmful conditions.

In feverish children the condition varies from mild symptoms, not needing immediate care to serious signs and symptoms due to an underlying condition, such as a meningitis or sepsis in which immediate care is necessary.[2]

Body temperature is used in all commonly used triage systems to estimate urgency for children. Although, studies in patients with fever show that the risk of a serious bacterial infection depends, among other predictors, on age and presenting problem, these criteria are not always taken into account in triage systems.

The Manchester Triage System (MTS) and Emergency Severity Index (ESI) are both widely used 5-level triage systems.[1,3] According to the MTS all patients with fever are triaged as level 2, independent on age.[4] The ESI attributes children with fever aged less than 28 days to level 2. Both systems do not take presenting problem into account, although the ESI takes 'no obvious source of fever' into account to differentiate between level 3 or 4.[5] Table 1 provides an overview of triage criteria for children with fever of different systems.

A large study on the validity of the MTS in children shows that validity of the system for children with fever is low, especially for older children.[9]

Our study aimed to explore how to use temperature as a discriminator to predict urgency in triage systems for children.

Table 1 | Specific criteria for children with fever, in commonly used triage systems

Manchester Triage System*[1]

Urgency level 2 (10 min)†: hot child or fever (temperature >38.5°C) **and** presenting problem is one out of the following: Back pain, Crying baby, Dental problems, Diabetes problems, Ear problems, Fits, General, Headache, Haematological disease, Irritable child, Limping child, Local infection and abscesses, Neck pain, Rashes, Sore throat, Testiculair pain, Unwell child, Urinary problems, Worried parent.

Or very hot (temperature >41°C) **and** presenting problem sexually acquired infection.

Urgency level 3 (60 min): fever (temperature >38.5°C) **and** presenting problem is a sexually acquired infection.

Urgency level 4 (120 min): if the child is warm (temperature 37.5–38.5°C) **and** presenting problem is one out of the following: Crying baby, Dental problems, Diabetes, Ear problems, Fits, General, Haematological disease, Headache, Irritable child, Local infection and abscesses, Limping child, Pregnancy, Rashes, Sexually acquired infections, Sore throat, Unwell child and Worried parent.

Emergency Severity Index*[3]

Urgency level 2: temperature >38.0°C **and** <28 days old

(child with fever aged 28 days – 3 months must be assigned to **level 2 or 3**, depending on the hospital's institutional protocol)

Urgency level 3: temperature >39.0°C **and** age 3–36 months **and** under immunized **or** no obvious source of fever

Canadian Paediatric Triage and Acuity Scale*[6,7]

Urgency level 2 (15 min): a temperature of <36°C or >38°C **and** age <3months **and** a history of abnormal behavior or abnormal examination **or** age >3 months **and** toxic appearance **or** immune-suppressed and asplenic children with minimal elevations of temperature and minimal findings.

Urgency level 3 (30 min): temperature >38.5°C **and** age 3–36 months, children aged >3 years with fever who look unwell

Urgency level 4 (60 min): Children over 3 years of age and looking well with normal vital signs

Australasian Triage Scale*[8]

Urgency level 2 (10 min): fever with signs of lethargy (any age) **or** suspected meningococcaemia

† Maximum time to medical care, time frames are not available for the ESI

* Selection of urgency level is hierarchical; urgency level 2 can only be chosen if the criteria for level 1 are negative, etc.

METHODS

Study design

We studied the discriminative value of temperature separately, and compared these with the discriminative value of temperature combined with age and presenting problem to predict urgency, using logistic regression analysis. As outcome measure for urgency we used a reference standard based on vital signs at presentation and presence of a potentially threatening diagnosis. We used the data from an ongoing study aiming to assess the validity of the MTS in paediatric emergency care.[9,10] The institutional medical ethical committee approved the study; the requirement for informed consent was waived.

Study setting and population

The Erasmus MC-Sophia Children's hospital is a university hospital and has a specific paediatric emergency department (ED). It is visited by nearly 9,000 patients per year. The Haga Hospital-Juliana Children's hospital is a large general paediatric-adult teaching hospital with nearly 30,000 ED visits yearly, of which 18,000 concern children. Children under 16 years of age attending the ED of two large inner-city hospitals in the Netherlands were enrolled in the study. Patients with a traumatic presenting problem and patients with temperature under 36.0°C or above 41°C were excluded. For derivation, patients were included between January 1st 2006 and January 31st 2007 (university) and between January 1st and July 31st 2006 (general hospital). For validation, patients were included between May 1st 2007 and April 2008 30th (university hospital) and August 1st and December 31st 2007 (general hospital).

Determinants

Patients were triaged by trained ED nurses using the MTS. Nurses triaged patients using a software application, which provided the flowcharts and discriminators of the MTS. Presenting problem was categorized into eight problems based on the MTS flowchart as selected during triage: rash, dyspnea, upper respiratory tract, gastro-intestinal, neurological, urinary tract, fever of unknown origin and other.[1] (Appendix)

Patients, of whom the MTS flowchart was unknown, were categorized according to their reason of encounter, which was entered in the database by the ED nurse at presentation.

Temperature was measured rectally, for children aged less than 1 year in the general hospital, and all children in the university hospital, or by using tympanic infrared thermometers for children age above 1 year in the general hospital.

Data concerning vital signs and working diagnosis were recorded on structured electronic or paper ED forms by the nurse or physician.

Outcome measure: reference standard for urgency

A reference standard for urgency was defined based on literature and combined by expert opinion. We used this standard to validate the MTS in children and a detailed description was published previously.[9] (see: http://www.bmj.com/cgi/data/337/sep22_1/a1501/DC1/1)

Patients were defined as high urgent when their heart rate, respiratory rate, systolic blood pressure, oxygen saturation or level of consciousness, as measured at presentation, were deviated according to the PRISM (Paediatric Risk of Mortality Score)[11] or if they had a potentially life threatening condition at the end of the ED consultation. Deviations in heart rate, respiratory rate and blood pressure predict mortality in children at the intensive care unit.[11] Hyperthermia (temperature >41°C) indicates a higher risk for severe bacterial infection.[12] Patients were considered as having a potentially life threatening condition when their presumed diagnosis was set as: meningitis, sepsis, ≥10% dehydration, high-energy trauma, substantial external blood loss or trauma (sharp/blunt) leading to substantial blood loss, aorta dissection, (near)drowning, electric trauma, possible dangerous intoxication, ≥10% burns, facial burns or possible inhalation trauma. These conditions are associated with a high morbidity and mortality and are discussed in the Advanced Paediatric Life Support workbook as an emergency.[13] An apparently life-threatening event (ALTE) was set as a high urgency condition as well, since these patients should be monitored.[14] If patients had normal vital signs and no potentially life threatening diagnosis, they were defined as low urgent. Data were gathered independent of the triage outcome.

Data analysis

Since missing temperature values were related to the reference standard's urgency, age and presenting problem (Missing At Random on determinants (x) and outcome (y)), we used multiple imputation to impute missing values on temperature.[15-17] Imputation of missing values is replacing the missing by a value that is drawn from an estimate of the distribution of the variable.[18] Multiple imputation methods are shown to be valid to deal with missing values.[16,17]

We used the variables age, presenting problems, hospitalization and the reference standard for urgency to impute missing values on temperature. We compared the results to a complete case analysis.

We used Restricted Cubic Spline (RCS) functions aiming to model non-linear relationships between urgency and temperature and age. RCS are splines containing X^3 terms which are restricted to be linear in the tails.[19] Temperature as modeled by the RCS is graphically shown in figure 1 and 2. Interaction terms were added and tested for statistical significant model improvement ($p<0.05$).

The effect of temperature, presenting problem and age was evaluated using univariable and multivariable logistic regression modeling. In an Receiver Operator Curve (ROC) the sensitivity is plotted against the 1 – specificity for all cut off points. (Curve not shown) The area under the curve (AUC) is a measure of the discriminative ability of the model.[20] AUC of the receiver operator curves and Nagelkerke's R^2 were calculated to quantify model performance for the derivation set, when the model was applied to the validation set and when the model was fitted for the combined dataset (table 2).

Table 2 | Discrimination of uni- and multivariable logistic regression models

Dataset	**Derivation**		**Validation***		**Combined****	
	n=11,155		**n=8,950**		**n=20,105**	
Predictor	**AUC†**	**R^2 (%)‡**	**AUC†**	**R^2 (%)‡**	**AUC†**	**R^2 (%)‡**
Univariable						
Temperature	0.58	1.8	0.59	2.1	0.58	1.7
Age	0.64	3.7	0.55	0.52	0.60	1.9
Problem	0.68	7.3	0.73	12	0.70	9.3
Multivariable						
Temperature and age	0.67	5.9	0.60	2.2	0.63	3.7
Temperature, problem and problem*temperature§	0.70	9.3	0.74	13	0.72	11
Age and problem	0.72	11	0.72	9.9	0.73	11
Temperature, age, problem and problem*temperature§	0.75	13	0.73	11	0.75	13

*Model is applied to validation dataset
**Model was fitted again for the combined dataset
† Area Under the Curve of Receiver Operator Curve (ROC), indicates discrimination
‡ Nagelkerke's R^2, indicates explained variation
§ interaction term problem*temperature was added to the model

We calculated risk of high urgency per subgroup based on age, temperature and presenting problem, using the final model and presented these as a score chart (figure 3). Statistical

analysis were performed using SPSS version 15.0 (Chicago, IL) and R package version 2.7.0., using the Design and Hmisc library and the AregImpute function. (www.r-project.org)

RESULTS

In total 17,600 patients visited the ED. Patients with a traumatic presenting problem (n=4,752, 27.0%), patients with temperature < 36.0°C (n=259, 1.5%) and patients with hyperthermia (temperature >= 41°C, N=27, 0.15%) were excluded. 12,562 patients were eligible. In 1,407 (11.2%) patients the reference standard for urgency was missing, leaving 11,155 patients for analysis. The MTS urgency distribution did not differ in patients in whom the reference standard was missing compared to patients in whom the reference standard was available (Chi-square test, p=0.17).

In the validation dataset (2007/2008), 13,642 patients presented at the ED, 3,912 (29%) presented with a traumatic presenting problem, 208 (2.1%) patients had a temperature under 36°C or above 41°C and were excluded. 9,281 patients were eligible. The reference standard for urgency was missing in 331 patients (3.6%) leaving 8,950 patients for analysis.

Temperature was measured in 9,350 out of 11,155 (83%) (derivation set) and 7,062 out of 8,950 (79%) patients (validation set), respectively. Patients in which temperature was missing were older compared to patients in which temperature was known.(2.1 years, IQR 0.72–5.3 versus 3.6 years, IQR 1.3–8.4) Temperature was more often measured in patients with dyspnea (88%), gastro-intestinal problems (89%) and fever without other specific symptoms (96%). In patients with 'other' problems, temperature was measured in 66%. Urgency as defined by the reference standard was somewhat higher for patients in which temperature was measured. (High urgency 7.2% versus 5.1%) Therefore, missing values on temperature were imputed.

General characteristics of patients presented in 2007/2008 (validation set) were comparable to patients presenting in 2006/2007 (derivation set) and are presented in table 3.

Model performance

The interaction term Problem*Temperature was added to the model with temperature, age and presenting problem and resulted in an improvement of the discriminative ability, suggesting a different effect of temperature for different presenting problems. (Wald test, p<0.001) (AUC 0.72, R^2 11% to AUC 0.75, R^2 13%)

When the model was validated in a new population, discrimination of the final model remained similar (AUC 0.73 versus 0.75, R^2 13 versus 11%) (table 3).

A univariate model with temperature has a moderate discriminative ability to predict urgency. (AUC 0.58, 95%CI 0.56–0.60) The combined model with presenting problem and age (final model) has a higher discriminative ability. (AUC 0.75, 95% CI 0.73–0.76) Presenting problem and age without temperature results in an AUC of 0.73. (95% C.I. 0.71–0.74) Calibration of the model with temperature, age and problem as predictors in the validation set was adequate.

Table 3 | Patient characteristics

Dataset		**Derivation, n=11,155**	**Validation, n=8,950**
		n, (%)	**n, (%)**
Hospital	ED* of general hospital	6,153 (55.2)	4,558 (50.9)
	ED* of university hospital	5,002 (44.8)	4,392 (49.1)
Gender		4,788 (42.9) female	3,821 (42.8) female
Age		2.4, 0.8–6.0†	2.3, 0.7–5.6†
Temperature in °C		37.6, 37.0–38.6†	37.5, 36.9–38.4†
Presenting problem‡			
Rash		496 (4.5)	350 (3.9)
Dyspnea		1,770 (15.9)	1,767 (19.8)
Upper respiratory tract		691 (6.2)	486 (5.4)
Gastro-intestinal		2,519 (22.6)	1899 (21.3)
Neurological		565 (5.1)	516 (5.8)
Urinary tract		272 (2.4)	306 (3.4)
Fever of unknown origin		1,399 (12.6)	933 (10.4)
Other		3,433 (30.8)	2,674 (29.9)
Admission		2,211 (19.8)	1660 (18.5)
Reference standard		735 (6.6) high urgency	634 (7.1) high urgency
		10,420 (93.4) low urgency	8,316 (92.9) low urgency

* ED emergency department
† Median, Interquartile range
‡ Development set 0.1%, n=10 is missing, validation set 0.2%,n=19 is missing

Temperature as discriminator in triage systems to predict urgency

Figure 1 shows the univariate relation between temperature (curve 1), presenting problem (curve 2) and age (curve 3) and the probability of high urgency according to the final model. The probability of a high urgency increases with increasing body temperature. The curve becomes steeper above 37.5 °C. Age is negatively related to the probability of high urgency, as patients less than one year of age have a higher probability of a high urgency. Patients older than 10 years also demonstrated a higher probability of a high urgency although this effect was less strong. The probability of high urgency is high for neurological problems and dyspnea and low for rash and urinary tract problems (figure 1).

The relation between probability of high urgency and temperature, for different age groups and presenting problems, according to the final model is shown in figure 2.

Odds ratios are presented for the 75th percentile versus the 25th percentile of temperature (38.6 versus 37.0 °C) since the relation between temperature and urgency is non-linear. When corrected for age, the odds ratio (95% C.I.) of the 75th versus the 25th percentile of body temperature is 2.0 (0.9–4.4) for patients with rash, 1.5 (1.2–1.7) for patients with dyspnea, 3.3 (1.9–5.9) for patients with upper respiratory tract problems, 1.7 (1.4–2.2) for patients with gastro-intestinal problems, 0.9 (0.7–1.1) for patients with neurological problems, 3.4 (1.4–8.3) for patients with urinary tract problems, 1.2 (0.9–1.6) for patients with fever of unknown origin and 1.5 (1.3–1.8) for patients with other problems.

Risk of high urgency for the different levels of body temperature, age groups, and presenting problems were calculated, based on the final model (risk on high urgency >5%, >10%, >15% or >20%, figure 3).

When the analyses were performed using a complete case analysis for the combined two datasets (n=16,365), the AUC of the different models and the odds ratios for temperature to predict high urgency, were comparable with the results from the imputed dataset. (Data not shown) Only the odds ratio for temperature for patients with rash was somewhat higher. (OR 2.4, 95% CI 1.0-5.5 versus 2.0, 0.9-4.4)

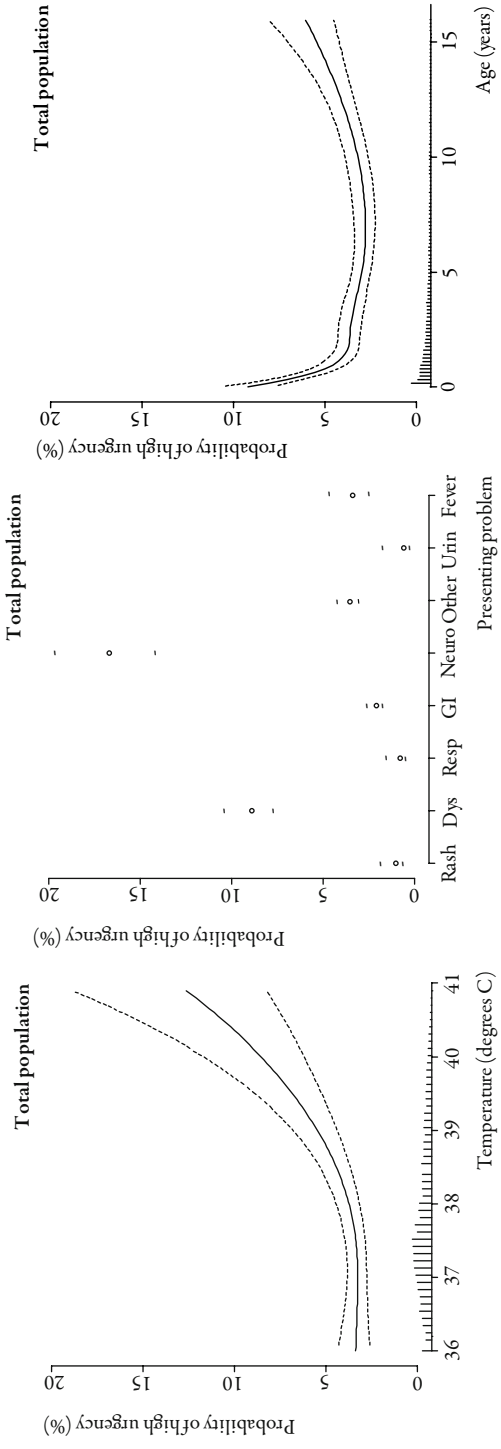


Figure 1 | Probability of high urgency for body temperature, presenting problem and age, based on the final model (n=20,105).

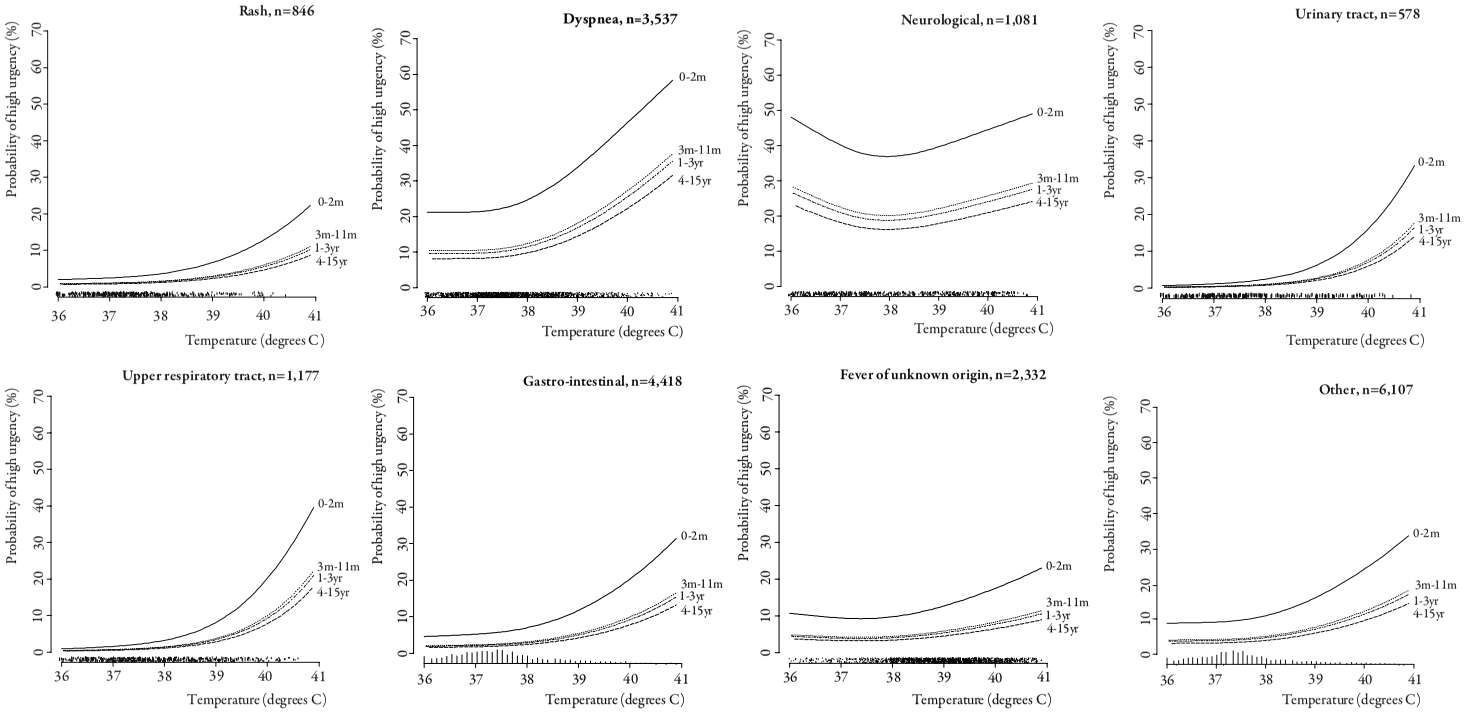


Figure 2 | Probability of high urgency for different temperature values for different age groups and presenting problems, based on the final model (n=20,105) (m=month, yr=years, stripes on the x-axis present frequency distribution of patients).

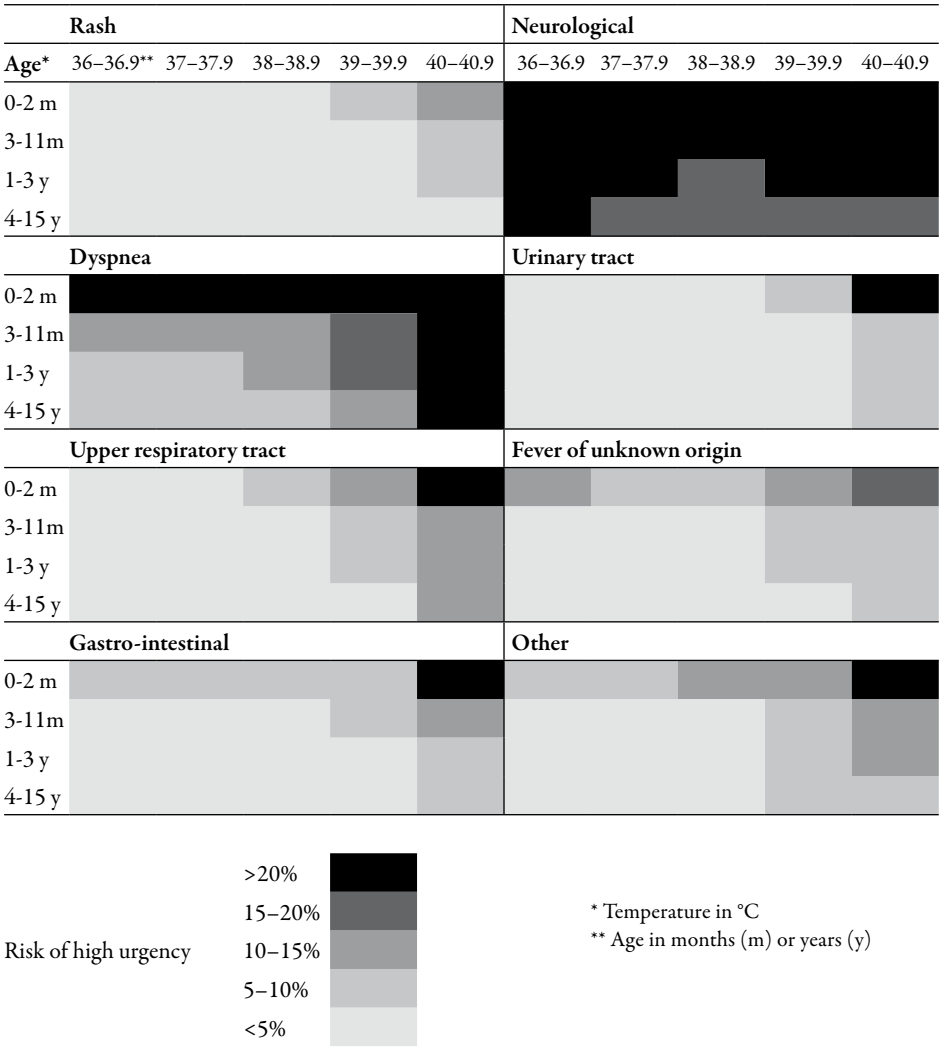


Figure 3 | The light gray/gray/black scales provide an advice on the use of height of temperature, age subgroups and presenting problems as discriminators in triage systems for children for different risks of high urgency, based on the final model.

DISCUSSION

This study shows that body temperature combined with age and presenting problem as discriminators in triage systems can better predict urgency in children compared to

temperature separately. Age and presenting problem are important discriminators by themselves.

Based on our findings we argue that young patients with fever should have a higher urgency when presenting with upper respiratory tract problems and urinary tract problems. The height of temperature has no effect in patients with neurological problems (high urgency regardless of temperature) or skin problems (low urgency also in patients with fever) and in young patients (under 3 months) with dyspnea (all high urgent).

In figure 3 we propose different cut off levels for the risk of high urgency. A low cut off will place many patients in a high urgency resulting in an increased sensitivity and a decreased specificity. Although theoretically this may result in a safer triage system, the excess of patients in the high urgency level will limit the capacity of EDs to see these patients within a reasonable time frame. Conversely, an excessively high cut off level will result in an unsafe triage system. Further research should evaluate which cut off level is optimal for different presenting problems and settings.

Fever is a common problem in paediatric emergency care and therefore an important issue in the triage of children.[9] The commonly used triage systems all use fever as a specific discriminator to determine urgency, but in a different way[1,3,4,7,8,21] (table 1). The MTS consists of 49 flowcharts for different presenting problems, which are suitable for children. The system does not contain a specific flowchart for patients with fever. Fever is incorporated as discriminator in 20 out of 49 flowcharts for children, and when selected it leads to urgency level 2 (maximum waiting time of 10 minutes) if patients are not vitally threatened, independent of other signs and symptoms or patient characteristics. The MTS does take the height of temperature (>38.5 or above 41°C) into account, but age is not a discriminator itself. In all MTS flowcharts, the discriminator fever results into the same urgency level. The ESI uses vital signs, pain level, and the number of resources that are needed during consultation at the ED as estimated by the ED nurses, to determine the urgency level.[22] In the fourth version of the ESI, a specific flowchart for children with fever was added. It uses age, the height of fever, whether there is an obvious source of fever and if the child is immunized to determine urgency.[3] The Canadian Triage and Acuity Scale (CTAS) is a five level triage system, commonly used in the US and Canada.[23] It contains specific flowcharts per reason of encounter containing groups of discriminators (signs and symptoms). Selection of one of these discriminators determines the urgency category. A specific flowchart for children with fever determines urgency based on vital signs, age, unwell appearance and whether the patient is immune compromised or not.[5]

Overall, these triage systems all use fever as discriminator for high urgency. The ESI and CTAS take age into account; young age leads to a higher urgency level. For the MTS, for some flowcharts, fever is not incorporated as discriminator. (Such as in the flowcharts 'Diarrhea and Vomiting' and 'Shortness of Breath in Children')

None of the systems applied the discriminator fever different for the different presenting problems.

Limited research has been performed on the reliability and validity of triage systems in paediatric emergency care.[9,23-29] Modifications of triage systems are usually consensus based, warranted by health professionals and supported by published literature.[3] We found one empirical study evaluating the effect of temperature combined with age to predict urgency. Using the Canadian paedCTAS, children with fever could be safely assigned to a lower urgency category (urgency category 4 instead of urgency category 3) if they were older than six months of age **and** if they had no signs of toxicity. These patients had lower admission rates than patients remaining in category 3, and none of them died or required ICU admission.[30] The modification to allocate older patients with fever to a lower urgency level agrees with our finding that young age is associated with high urgency in children with fever.

Limitations

In the general hospital, body temperature was measured using ear thermometry for children aged above one year. Ear thermometry measures a somewhat lower temperature than rectal thermometry.[31] Measuring temperature with ear thermometry instead of rectal thermometry could have resulted in measurement of a somewhat lower temperature for patients above one year with a temperature under 39°C. However, since 65% of the paediatricians use ear thermometry, results are probably comparable to practice in other EDs.[32]

Secondly, we used a proxy for high urgency as outcome measure. Patients with deviated vital signs or presence of a potential life threatening condition were defined as high urgent[9] This is a surrogate outcome measure because real gold standards such as morbidity and mortality are hard to use. As was discussed with experts it contains objective criteria to identify patients who should have a high urgency.

We used deviated heart rate and respiratory rate as criteria to define a high urgency. These will be elevated by the effect of fever itself. To overcome this problem we used vital signs limits as were defined in the PRISM, and which are related to mortality. In the PRISM high cut off levels are used (for example a maximum respiratory rate above 70 per minute and a maximum heart rate of 185 per minute for children aged 1–11 years). Only due to fever, the

heart rate is elevated by 10 beats per minute per degree Celsius body temperature. Therefore a heart rate above 185 can not only be explained by fever.[33]

Our study focuses on three major discriminators (age, fever and presenting problem) and its predictive value for urgency. We are aware that the predictive value of the discriminators age, fever and presenting problem might be limited in children with underlying medical conditions. The urgency category can not only be identified by these discriminators in these patients. However, in most triage systems, comorbidity is used as a separate discriminator for high urgency.

We excluded patients with a temperature above 41°C. For the predefined reference standard of urgency, temperature above 41°C was used as one of the criteria for high urgency.[9] Including these patients would relate temperature directly to the outcome measure, the reference standard for urgency.

The reference standard was missing (not recorded or untraceable paper ED forms) in 11% in the derivation and 4% in the validation set. These patients were excluded. Since the number of missing values is small and the MTS urgency distribution was not different between the missing data and the available data, selection bias is not likely.

Body temperature was not measured in 17 of the patients in the derivation set and 21% of the patients in the validation set.

Temperature is more often measured in younger patients and patients with dyspnea, gastro-intestinal problems and patients with fever without specific other symptoms, and less often in patients with 'other' problems. In these patient groups measurement of temperature is more indicated, since feverish illnesses are more prevalent.

To minimize the risk of selection bias missing values were statistically imputed. Imputation has been advocated to deal with missing values if missing is related to the outcome variable and predictors (MAR on x and y). It gives a good prediction of the model's regression coefficients and standard errors when the proportion missing data is 20%.[15-17]

The measured effects were comparable to those using a complete case analysis. Except for the effect of temperature for patients presenting with a rash, it was somewhat higher using complete case analysis.

CONCLUSION

Body temperature combined with age and presenting problem is an important discriminator in triage systems. These discriminators modify the triage level for children visiting an ED for fever or infectious disease and can be implemented in triage systems.

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APPENDIX MANCHESTER TRIAGE SYSTEM FLOWCHARTS CATEGORIZED INTO PRESENTING PROBLEMS.

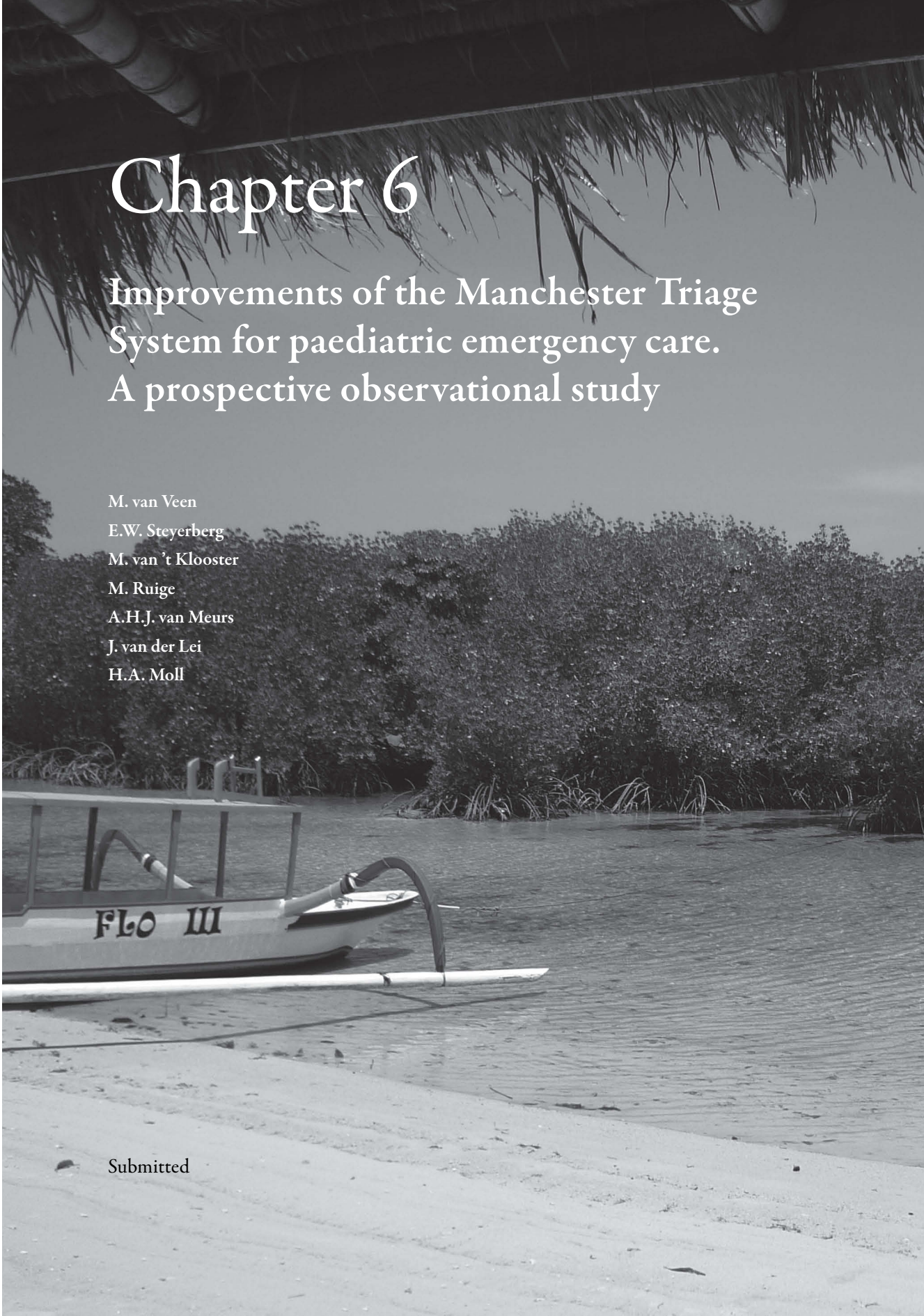
Presenting problem	MTS flowchart
Rash	Rashes
Dyspnea	Asthma, Shortness of breath in children
Upper respiratory tract	Sore throat, Nasal problems, Ear problems
Gastro-intestinal	Vomiting, Diarrhea, Abdominal pain in children, GI bleeding
Neurological	Fits, Unwell child, Irritable child
Urinary tract	Urinary problems
Fever of unknown origin	Worried parent or General and discriminator 'Hot child' or 'Hot'
Traumatic or extremities *	Limb problems, Limping child, Head injury,
Other	Other flowcharts

* 'Traumatic or extremity problems' were excluded.

Chapter 6

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

M. van Veen
E.W. Steyerberg
M. van 't Klooster
M. Ruige
A.H.J. van Meurs
J. van der Lei
H.A. Moll



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]

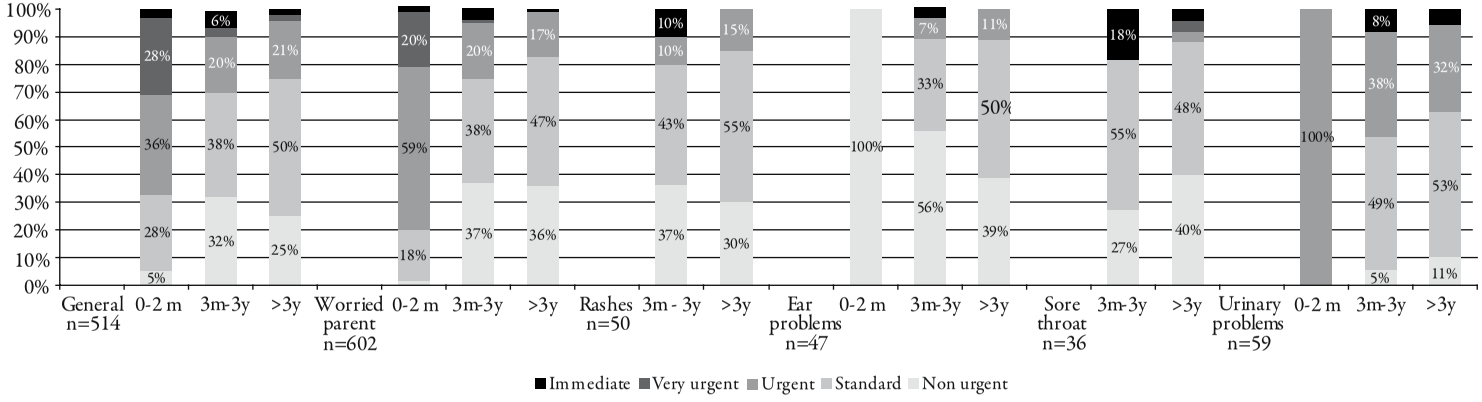


Figure 1 | Reference standard urgency distribution for MTS flowcharts and age subgroups, for patients in which a fever discriminator was selected.

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 which performance was low, 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

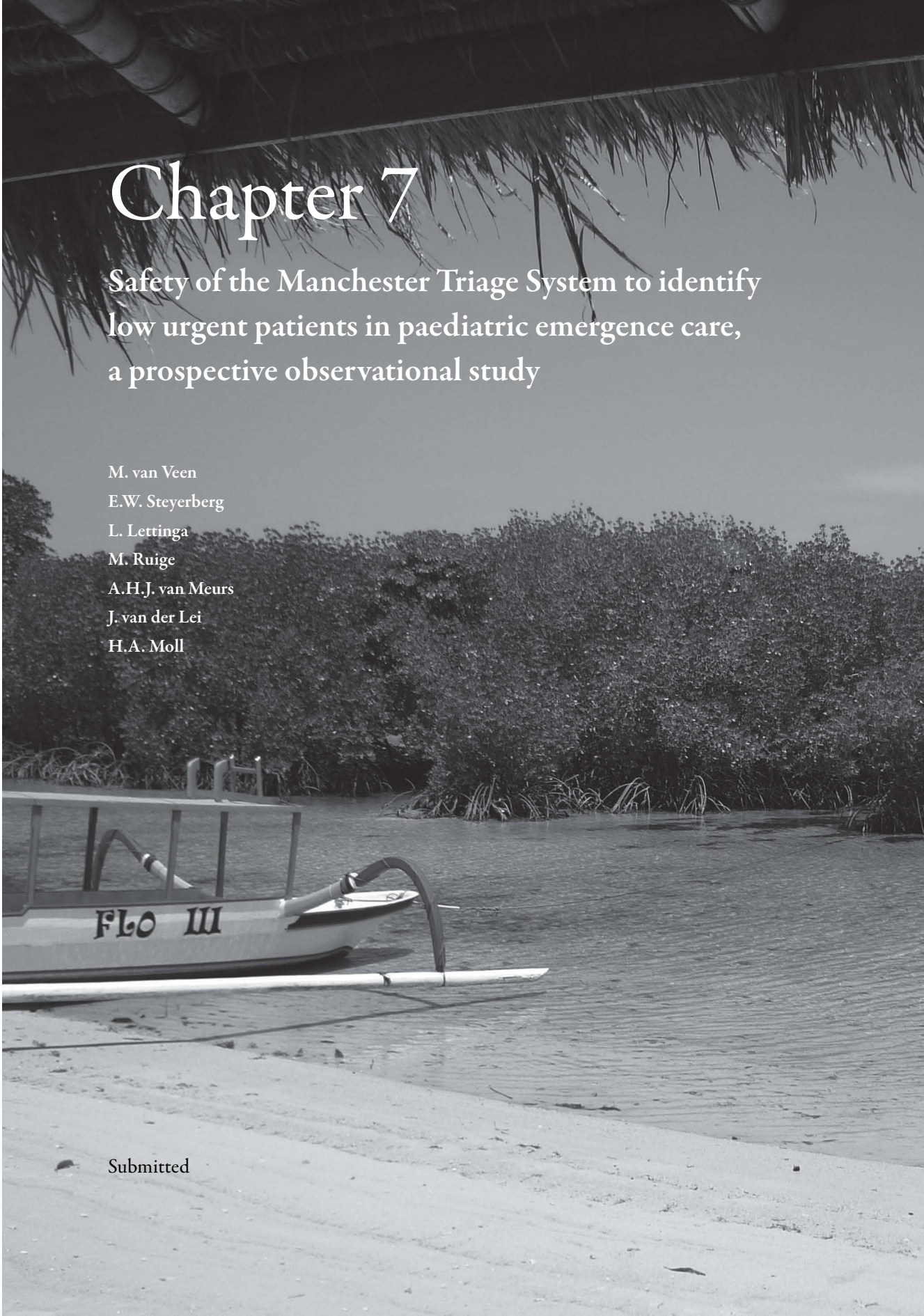
		Original MTS		Modification		
General discriminator	MTS Flowchart	MTS Discriminator	Urgency	Age group**	Urgency	Cut off level†
Fever*	General & Urinary Problems	Hot child	Very urgent	0–2 m	Very urgent	80%
				> 3 m	Urgent	80%
	Worried parent			0–2 m	Very urgent	80%
				3 m–3 y	Urgent	80%
				4–15 y	Standard	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

Chapter 7

Safety of the Manchester Triage System to identify low urgent patients in paediatric emergence care, a prospective observational study

M. van Veen
E.W. Steyerberg
L. Lettinga
M. Ruige
A.H.J. van Meurs
J. van der Lei
H.A. Moll



Submitted

ABSTRACT

Background Triage systems at emergency departments (ED) are used to identify low urgency patients and refer them to another caregiver. The aim of the study was to assess the safety of the Manchester Triage System (MTS) to identify low urgent patients in paediatric emergency care.

Methods Patients aged 0–15 years visiting the ED of a paediatric university hospital or a large teaching hospital in the Netherlands, were triaged with the MTS. Hospitalization and determinants for hospitalization were assessed for low urgent, self-referred patients (MTS level 4 or 5) using logistic regression analysis. Secondly, discharged patients received a telephonic follow-up 2–4 days after consultation.

Results Among 5,425 patients, 191 (3.5%) were hospitalized. Children under one year old (10%, n=84/848) and children presenting with dyspnea (8%, n=40/310), gastrointestinal problems (8%, n=72/848) and patients with fever without other specific signs (6%, n=5/83) were more likely to be hospitalized. These characteristics remained statistically significant in a multivariable analysis, with odds ratios of 3.0 (95% confidence interval 2.2 to 4.1) for age under one year and 2.5 (1.5 to 4.1) for dyspnea, 3.5 (2.5 to 4.9) for gastrointestinal problems and 2.8 (1.1 to 7.2) for patients with fever without other specific symptoms.

In patients over one year of age without dyspnea, gastrointestinal problems or fever, only 54 of 3,738 (1%) were hospitalized following ED consultation.

3,975 / 5,234 (76%) could be contacted for follow-up after discharge. Six (0.15%) patients were hospitalized after ED discharge.

Conclusion In the MTS low urgency categories, children younger than one year of age or with dyspnea, gastrointestinal problems or fever without other specific symptoms have an increased risk for hospitalization. Therefore, referral from ED to another caregiver may be safe except for these patient groups.

INTRODUCTION

Emergency departments (EDs) are increasingly visited by patients with non-urgent problems. In European countries with a general practitioner (GP) referral system, the number of self-referred patients is high.[1] In the US, especially children use the ED as a regular source of care.[2] This contributes to high costs, increased use of diagnostics, longer waiting times, full waiting rooms, and more work pressure for hospital personnel.[3-5]

Triage aims to identify high urgent patients in an easy and fast way and to prioritize these patients to be seen by a physician. Secondly, triage systems can be used to identify patients with low urgency problems, which can safely wait for a longer time or can be sent to another caregiver such as a GP.[6]

The Manchester Triage System (MTS) is a 5-level triage system. The system provides a specific advice for patients who can be allocated to a primary emergency service instead of being treated at the ED. In general, patients triaged as 'Standard' (level 4) or 'Non-urgent' (level 5), with non-traumatic problems can be referred to primary care. This guideline was developed by expert opinion and the authors state that utility in these processes must be proved rather than assumed.[6]

Referring patients to a GP can be a solution for the increasing overcrowding of EDs by patients who present on their own initiative and have a low prevalence of high urgent problems.[7] Moreover, more diagnostic tests or prescriptions for medication are performed when low urgent patients are seen by an emergency physician compared to a GP.[3] Safety to identify low urgency patients in paediatric emergency care has not been studied before. The aim of this study was to assess the safety of the MTS to identify low urgent patients in paediatric emergency care which can be safely referred to another caregiver.

METHODS

Study design

We performed a prospective observational study. We assessed determinants for hospitalization in low urgent triaged children who visit the ED on their own initiative. Secondly, discharged patients received a routinely performed telephonic follow-up two to four days after their ED consultation. This study is part of an ongoing study on the validity of the MTS in children.[8,9] The study was approved by the institutional Medical Ethics Committee.

Patients

All children between 0 to 16 years who visited the ED of the Haga Hospital-Juliana Children's Hospital in The Hague between August 2007 and May 2008 and the Erasmus MC-Sophia Children's Hospital in Rotterdam between May 2007 and August 2008 were triaged using the MTS.[10]

The ED of the Haga Hospital-Juliana Children's hospital is a mixed paediatric-adult emergency department of a large teaching hospital visited by nearly 30,000 patients per year of which about 15,000 are children. The Erasmus MC-Sophia Children's Hospital is a university hospital with a specific paediatric ED visited by nearly 9,000 patients per year. Both hospitals are situated in the southwest of the Netherlands, which has a population of approximately four million people and an annual birth rate of 47,000 children.[11]

Manchester Triage System

Emergency department nurses performed a short assessment and triaged patients using the MTS.[6,10] The system is a flowchart-based algorithm and consists of 52 flowchart diagrams (49 suitable for children), which are specific for the patient's presenting problem. The flowcharts contain six key discriminators (life threat, pain, hemorrhage, acuteness of onset, consciousness level, and temperature) as well as specific discriminators relevant to the presenting problem. Selection of a discriminator leads to one out of five urgency categories.

We used a modified version of the MTS with specific modifications for children The modifications were developed for patient groups based on an earlier study in which the validity of the MTS was evaluated.[8,12] For the detailed modifications we refer to our previous paper.[12]

The modified MTS was used in 87% to triage patients. The modification led to a shift of patients to lower urgency categories. Patients are more often triaged into the 'Standard' and 'Non-urgent' categories (48%, n=5,347/11,210), compared to the original MTS (41%, n=5,552/13,554). Modifications were shown to improve validity of the MTS in paediatric emergency care compared to a predefined reference standard for urgency.[8,12]

Data collection

Nurses recorded patient characteristics on electronic forms when patients presented at the ED. Triage data and hospitalization were registered using the triage software package. Data on hospitalization were extracted from medical files.

Telephonic follow-up

A nurse and medical students performed follow-up with a standardized telephonic questionnaire. Patients attending without being referred by a GP and who were triaged as 'Standard' (level 4) or 'Non urgent' (level 5), received a telephonic follow up 2-4 days after their ED visit.

We tried to reach parents daily until 96 hours after their ED visit. Language barriers were overcome by inviting an interpreter using a telephonic conference call. When patients could not be reached by telephone, we sent a short written questionnaire. The questionnaire data was registered using SPSS Data Entry Builder/Station (version 4.0).

Data analysis

We categorized the chosen MTS flowchart into eight different present problems categories; skin problems (flowchart Rashes), dyspnea (flowchart Asthma, Shortness of breath in children), upper respiratory tract infection (flowchart Sore throat, Nasal problems, Ear problems), gastro-intestinal problems (flowchart Vomiting, Diarrhoea, Abdominal pain in children, Gastrointestinal bleeding), head injury (flowchart Head injury), extremity problems or wounds (flowcharts Limb problems, Wounds and Limping child) and other. If the MTS 'General' flowchart or the MTS 'Worried parent' flowchart was selected, we used the presenting problem as registered by the nurse and categorized these into one of the categories or to 'fever without other specific symptoms'.[6]

To predict hospitalization using univariate and multivariate logistic regression analysis, we considered age, gender, MTS urgency level and presenting problem as candidate predictors for hospitalization, because they are easily obtainable signs in the triage assessment. Since the relation between age and hospitalization may not be linear, we used a restricted cubic spline (RCS) function to model the relation between age and hospitalization.[13] Restricted cubic splines contain cubic (X^3) terms which are restricted to be linear in the tails.[14] In order to calculate clinical interpretable odds ratios, age was divided in categories (<3 months, 3–11 months, 1–2 years, 2–3 years, 4–7 years, 8–15 years) and odds ratios were shown compared to patients aged 8–15 years.

Presenting problem was shown with odds ratios for the different categories compared to the category 'Extremity problems or wounds'.

Secondly, selection of the presenting problem categories and age group with the highest odds ratios leads to the final model. Odds ratios were shown for the selected presenting problems categories and age group compared to the all other categories. SPSS 15.0 (Chicago, IL) and

R package version 2.9.1 using the Design library (www.r-project.org) were used for statistical analysis.

RESULTS

A total of 5,425 children attended the ED on their own initiative during the inclusion period and were triage as low urgent. Of these patients, 191 (3.5%) were hospitalized (figure 1).

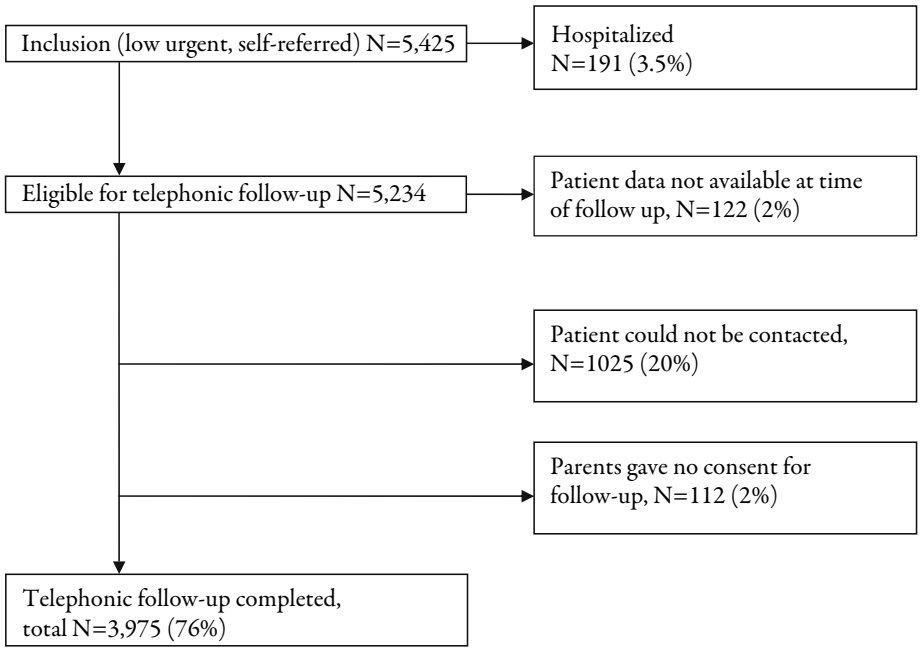


Figure 1 | Flow of patients attending during the study period

Hospitalization

The hospitalized patients had a median age of 1.5 years (Interquartile Range (IQR) 0.4–4.4 years), 45% (n=86) were female, 91% (n=173) was triaged as 'Standard' and 9% (n=17) as 'Non urgent'.

One patient (1%) was admitted to the intensive care unit. It concerned a 12-year-old girl with a history of a catecholaminergic polymorphic ventriculair tachycardia, who presented with a syncope and an irregular cardiac rhythm with a hemodynamically stable condition.
Details of hospitalization could be retrieved for 172 patients (90%). The median length of admission was 2 days (IQR 1–3 days). 45% (n= 78) had a length of stay shorter than 24 hours, 20% (n=34) between 24 and 48 hours and 35% (n=60) longer than 48 hours. The main reasons for admission were at risk of dehydration in 6% (n=31), head injury in 12% (n=20) and Acute Life Threatening Event (ALTE) in 9% (n=15).
Interventions were needed in 63% (n=109) and only observation in 37% (n=63). The interventions included oral medication (n=34) intravenous therapy (n= 24), urgent surgery (n=2) and non urgent surgery (n=28), oxygen (n=1), rehydrated by nasogastric tube with oral rehydration solution (ORS) (n=14), and inhaled medication (n=5).
An urgent intervention (defined as IV therapy, oxygen or urgent surgery) was required or the length of stay was longer than 24 hours in 56% (n=97).

Determinants of hospitalization

Gender and urgency were not associated with hospitalization (OR_{female} 0.98, 95% CI 0.73–1.31, p_{Wald} 0.89, $OR_{urgency\ 4}$, 0.96 95% CI 0.57–1.61, p_{Wald} 0.87).
Patients with gastrointestinal problems (8%, n=72/848), with dyspnea (8%, n=24/310) and fever without specific other symptoms (6%, n=5/83) were often hospitalized. Hospitalization was more likely for young patients (0–2 months 14%, n=33/235, 3–11 months, 8%, n=51/613) (table 1).
Figure 2 shows the multivariate regression model with age and presenting problems as discriminators and hospitalisation as outcome. When adjusted for age, adjusted odds ratios were 6.4 (95% C.I. 3.8–11) for patients with gastro-intestinal problems, 4.7 (95% CI 2.5–9.1) for patients with dyspnea and 5.1 (95% CI1.8–14) for patients with fever without other specific signs compared to patients with extremity problems or wounds. When adjusted for presenting problems odds ratios were 6.6 (95% CI 3.7–12) and 3.2 (95% CI 1.9–5.4) for children aged under 3 months and aged between 3–11 months, respectively, compared to children aged 8–15 years (table 1).

Table 1 | Determinants for hospitalization in low urgent, self-referred patients n=5,407* / 5,425

Variable		N	Hospitalization	OR, univariate	Adjusted OR**
Gender	Male	2,991	102 (3)	1.0†	NA
	Female	2,416	84 (3)	0.98 (0.73–1.3)	NA
MTS Urgency	Standard	4,959	170 (3)	0.96 (0.57–1.6)	NA
	Non urgent	448	16 (4)	1.0†	NA
Presenting problem	Extremity problems or wounds	2,168 (40)	20 (1)	1.0†	1.0†‡
	Gastro-intestinal	848 (16)	72 (8)	10 (6.0–16)	6.4 (3.8–11)
	Head injury	255 (5)	8 (3)	3.5 (1.5–8.0)	2.7 (1.2–6.3)
	Skin	219 (4)	6 (3)	3.0 (1.2–7.6)	1.6 (0.6–4.2)
	Dyspnea	310 (6)	24 (8)	9.0 (4.9–16)	4.7 (2.5–9.1)
	Upper respiratory tract infection	314 (6)	7 (2)	2.4 (1.0–5.8)	1.9 (0.80–4.6)
	Fever without other specific symptoms	83 (1)	5 (6)	7.0 (2.5–19)	5.1 (1.8–14)
	Other	1,211 (22)	44 (4)	4.0 (2.4–6.9)	2.5 (1.4–4.5)
Age	0–2 months	235 (4)	33 (14)	12 (6.8–20)	6.6 (3.7–12)
	3 –11 months	613 (11)	51 (8)	6.5 (4.0–11)	3.2 (1.9–5.4)
	1–2 years	696 (13)	18 (3)	1.9 (1.0–3.5)	1.2 (0.63–2.2)
	2–3 years	608 (11)	21 (3)	2.5 (1.4–4.6)	1.8 (1.0–3.3)
	4–7 years	1,441 (27)	38 (3)	1.9 (1.2–3.2)	1.5 (0.87–2.5)
	8–15 years	1,814 (33)	25 (1)	1.0†	1.0†

*Complete cases on gender, urgency, problem and age
**Odds ratio adjusted for age and presenting problem, respectively
† Reference category
‡ Wald, p<0.001

These characteristics remained statistically significant in a final multivariable analysis with adjusted odds ratios of 3.0 (95% CI 2.2 to 4.1) for age under one year and 2.5 (95% CI 1.5 to 4.1) for dyspnea, 3.5 (95% CI 2.5 to 4.9) for gastrointestinal problems and 2.8 (95% CI 1.1 to 7.2) for patients with fever without other specific symptoms compared to all other patients. In patients over 1 year old without dyspnea or gastrointestinal problems or fever without specific signs, only 54 of 3,738 (1%) were hospitalized after ED consultation. Details of these hospitalizations were available in 52 out of 54. In 19 out of 52 (36%), an

urgent intervention was required (IV therapy, oxygen or urgent surgery) or the length of stay was longer than 24 hours.

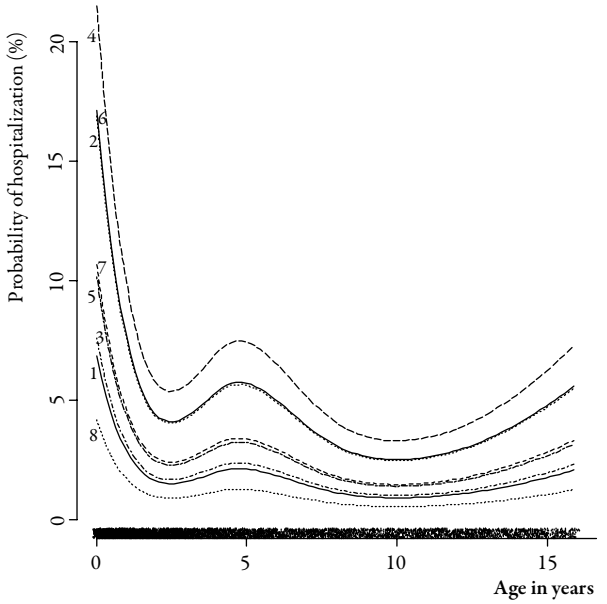


Figure 2 | Probability of hospitalization for patients presenting with skin problems (1), Dyspnea (2), Upper respiratory tract infections (3), Gastrointestinal problems (4), Other (5), Fever without other specific symptoms (6), Head injury (7), Wounds or extremity problems (8) depending on age. The scatter diagram on the x-axis represents the data density of age.

Follow up after ED discharge

Compliance of telephonic follow up was 76% (figure 1).

Patients who could not be reached or who did not want to participate did not differ in median age (No follow-up 4.2, IQR 1.9–8.7 4.4, follow-up performed 4.4, IQR 1.7–9.1, Mann-Whitney U, p=0.75) but differed in presenting problem. (Chi square, p<0.001).

Patients who could not be contacted had more often gastrointestinal (17%, n=218/1,247 versus 14%, n=558/3,974) and fever without other specific complaints (3.8%, n=48 versus 0.7%, n=29) and less often 'other' problems. (19%, n=233 versus 23%, n=934).

301/3,975 patients (8%) had an unscheduled follow-up visit, of which 65% at primary care and 34% in emergency care. Six patients out of 3,975 were subsequently admitted. (0.15%) Details of these six hospitalisations after ED discharge are provided in table 2.

Table 2 | Patients hospitalized after ED discharge (6 out of 3,975 low urgent patients)

1. ♀ 11 months, admitted because of vomiting, diarrhea and dehydration (4%), rehydration with ORS by nasogastric tube, discharge after 5 days, follow-up visit scheduled
2. ♂ 10 months, upper respiratory tract infection with otitis, not drinking, not able to swallow antibiotics*
3. ♂ 5 years old, heavy abdominal pain after fall on abdomen, observation, discharged after 1 day, follow-up visit scheduled
4. ♀ 5 months, suspicion of dehydration, follow-up visit was planned (one day), but patient presented by own initiative on the same day again and was admitted because of rehydration with ORS, discharge after 1 day, follow-up visit scheduled
5. ♂ 2 years old, admitted because of pneumonia and unable to take oral antibiotics, antibiotics by nasogastric tube, discharge after 2 days, follow-up visit scheduled
6. ♀ 6 years old, fever and rash, some petechiae, antibiotics IV, observation during admittance, discharge after 3 days, no scheduled follow-up

*Details of hospitalization were unknown for this patient

DISCUSSION

Self-referred patients triaged as low urgent are rarely hospitalized except for children younger than one year of age (10%, n=84/848) or presenting with dypsnea (8%, n=40/310), gastrointestinal problems (8%, n=72/848) or fever without other specific symptoms (6%, n=5/83).

Follow-up after ED discharge showed only 0.15% (n=6/3,975) hospitalizations. Referring low urgent children to another caregiver may be safely implemented excluding these specific patient groups.

One low urgent patient was admitted at the intensive care unit. This patient presented with an arrhythmia. The MTS does not contain a specific discriminator for patients with arrhythmia.[15] We argue that these children should be considered as high urgent.

The MTS is a common used triage system in and outside Europe.[6] The system showed a good reproducibility in children and a moderate reproducibility when studied in children and adults.[9,16] Our earlier study showed a moderate validity in paediatric emergency care. The system errs on the safe side, with much more over-triage than under-triage compared with an independent reference standard for urgency. Validity was low in young children, in patients with non-traumatic problems and in older children with fever.[8] We developed and implemented modifications to improve validity. It resulted in an improved validity of the MTS, in which especially the specificity improved (79%, 95% CI 79-80% to 87%, 95% CI 86–87%) and more patients were triaged as low urgent.[8,12] The consensus based advice of the MTS working group to refer low urgent patients to the GP could be translated to an evidence based guideline for selected children based on our study.

A study on the Canadian Triage and Acuity Scale (CTAS) showed that low urgent (level 4 or 5) children were hospitalized in 214/2,035 (10%).[17] The authors concluded that the system is therefore not valid to identify low urgent patients in order to send them away from the ED. We found a considerably lower hospitalization proportion of one percent (n=54 of 3,738) for self-referred, low urgent patients with selected problems.

Several solutions are developed to decrease the workload for EDs and were shown to be safe. In the US, out-of-hours call centers function as gatekeepers and screen patients who want to attend the ED, in order to decrease the amount of non urgent patients at the ED, or low urgent patients are seen at a fast track area.[18-20] In the UK, general practitioners are situated at the ED to see low urgent patients.[21,22]

In a randomized controlled trial performed in the US, criteria were defined to identify adults with non-acute conditions. They were randomly assigned to be seen at the ED or to be referred to next day primary care. Patients who were referred to primary care did not demonstrate disadvantages in health status or numbers of physician visits. No patients were hospitalized or died. However, the sample size was too low to detect hospitalization or mortality. (n=72 for usual care and n=68 for next day primary care).[23]

When the MTS is used to refer low urgent patients to the GP, considering our results, we are mostly concerned about the 1% (n=54/3,738) hospitalizations, especially for the 0.51% (n=19/3,738) with interventions or a length of stay of more than 24 hours.

The 1% hospitalization is relatively low when compared to the higher MTS urgency categories. Proportion hospitalization for self-referred patients was 44% (n=28/64) for MTS 1, 31% (n=171/558) for MTS 2 and 10% (n=178/1,836) for MTS 3, respectively. (Based on the data of our previous validation study of the modified MTS).[12]

When low urgent patients are referred to a GP, the 1% hospitalized patients in this study, will probably be referred back to the ED after GP consultation. This might result in a delay in treatment.

However, hospitalization in our selected low risk population is less frequent compared to hospitalization of patients visiting the GP post. A study on characteristics of GP post visits for all ages showed that 7.5% (n=853/11,375) of patients consulting the GP cooperative were referred to the ED and 48% (n=316/664) of the refereed patients were hospitalized. So for patients contacting the GP post, 3.6% (7.5% x 48%) were hospitalized.[27]

Screening patients using a triage system before they enter the ED resulted in a shift of 10-53% of patients from secondary to primary care.[24-26] Patients were seen at integrated GP posts, in which the GP is situated next to the ED. Hospitalizations in all adults and children decreased with 34% and fewer patients were referred to the GP or outpatient clinic follow-up, compared to before the introduction of the integrated GP post. However, this study did not evaluate the effect on unscheduled follow-up visits or hospitalizations after discharge to identify adverse effects, neither was a specific focus on children.[26]

Limitations

In this study we focused on safety of referring low urgent children to primary care. We studied the patient group, which may be referred but which is seen at the ED. We showed that referral might be safe for a selected group. In order to evaluate the actual effect of referral, patients should be referred and the effects on safety should be evaluated.

Telephonic follow-up was performed to trace adverse events due to ED discharge.

76% (n=3,975/5,234) could be contacted for a telephonic questionnaire. Patients were not contacted because the phone number was incorrect or patients were not at home during the several days we tried to call. It is possible that the selection of contacted patient might have influenced the results. Relatively fewer patients with gastro-intestinal problems could be contacted. Since two out of the six hospitalizations after discharge were because of gastrointestinal problems, this selection could have led to a slight underestimation of the percentage unscheduled hospitalizations.

On the other hand, by using a telephonic questionnaire method in stead of using the hospital information system to track revisits, we gathered all revisits, also those to other EDs and general practitioner. Compared to one other study with a telephonic follow up (response 46%) our response rate was high.[19]

CONCLUSION

In the MTS low urgency categories, children younger than one year of age or with dypsnea, gastrointestinal problems or fever without other specific symptoms have an increased risk for hospitalization. Therefore, referral form ED to another caregiver may be safe except for these patient groups.

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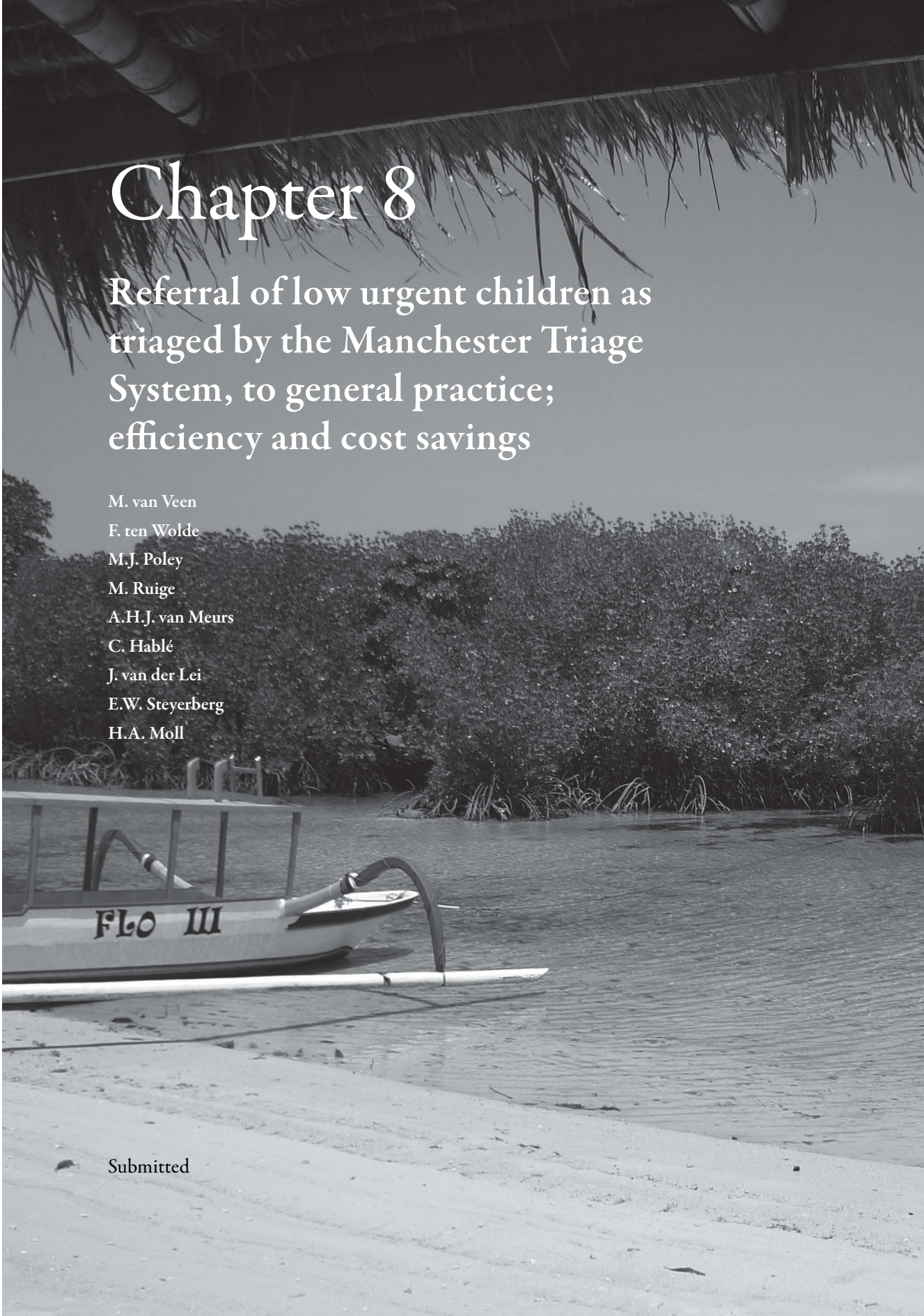
Chapter 8

Referral of low urgent children as triaged by the Manchester Triage System, to general practice; efficiency and cost savings

M. van Veen
F. ten Wolde
M.J. Poley
M. Ruige
A.H.J. van Meurs
C. Hablé
J. van der Lei
E.W. Steyerberg
H.A. Moll



Submitted

ABSTRACT

Aim To evaluate costs and compliance of referral of low urgent children who present at the emergency department (ED), to the general practitioner cooperative (GPC).

Methods Prospective observational before-after study. During six months in 2008 the triage nurse discussed referral to the GPC with parents, when self-referred children with a non-traumatic problem, aged 3 months – 16 years presented at the ED and were triaged as low urgent according to Manchester Triage System. A telephonic follow up was performed 2–4 days after referral. Real costs were compared between ED consultation (pre-intervention period) and GPC referral (post-intervention period). Compliance of referral was studied during four days a week.

Results 140 patients were referred to the GPC. 101/140 patients (72%) were reached during follow up. After discharge seven patients (7%) had an unscheduled revisit. No patients were subsequently hospitalized. Satisfaction was graded as 6.6 (95% CI 6.2–7.1) on a 0–10 scale. 275 patients were included to study compliance. Data on 28/275 patients (10%) were missing. 95/247 (38%) patients were referred to the GP. 46/247 parents (19%) refused referral. For 106/247 patients (43%) referral was not initiated by the nurse mainly because of co-morbidity or the nurse expected she could not convince the parents. Mean costs per patient were €106 for the pre-intervention period and €101 for the post-intervention period.

Conclusion Patients were moderately satisfied and referral resulted in a small cost reduction. Effectiveness was not optimal. Larger cost reductions are feasible if more patients are referred and patients would be referred during daytime as well.

INTRODUCTION

A substantial part of the visitors of emergency departments (ED) are low urgent and present on their own initiative.[1-3] This may increase waiting times for all patients and has an impact on health care costs. It raises the question whether it would be more appropriate to manage these patients in other locations, freeing capacity in the ED for more seriously ill or complicated patients.

Several alternatives for the care of low urgent patients have been described, such as 'fast track units' at the ED, general practitioners (GP) who see patients at the ED and integrated GP cooperatives (GPC) functioning independently but situated next to the ED.[4-6]

Evidence is scarce about the effects on patient outcomes, resource utilization, and costs of referring paediatric patients to the GPC.[7]

The Manchester triage group, who developed the Manchester Triage System (MTS) stated that low urgent, non-traumatic patients could be referred to primary care emergency centres but effects of referral should be evaluated.[8] We recently evaluated safety of the MTS to identify low urgent children, and concluded that referral might be safe for children older than one year of age, except for patients with dyspnea, gastro-intestinal problems or fever without other specific signs.[9] The effects of actual referral of MTS low urgent patients from the ED to another caregiver have, to our knowledge not been studied.

In today's healthcare arena, healthcare professionals and institutions are increasingly pressed to show that their treatments are cost-effective and evidence based. Therefore, the aim of this study was to evaluate compliance and costs of referral of low urgent children who present to the ED, to the GPC. It was hypothesized that referral of low urgent patients is generally acceptable for parents, and associated with a reduction in cost.

METHODS

Study design

Prospective observational before-after study. We evaluated effects on costs and patient satisfaction of referring low urgent children to the GPC. Details of consultation at the ED were reported before.[9] Referral of low urgent patients was performed as part of standard ED care. Medical ethics committee approval was hence not required for this study.

Manchester triage system

The MTS is a five level triage system and consists of 52 flowcharts specific for a patient's presenting problem. Each flowchart consists of specific discriminators, eventually leading to an urgency category. We used an adapted version of the MTS, which showed to improve validity. The modifications were developed for different age groups and mainly concerned patients with fever.[10]

Setting

We conducted the study from May to December 2008 at the ED of the Haga Hospital-Juliana Children's hospital, The Hague in the Netherlands, a mixed paediatric-adult ED of a large teaching hospital visited by nearly 30,000 patients per year of which about 18,000 are children. The three participating GPCs, which together provided out-of-hours primary care to approximately 115,000 patients in 2008, are situated 3, 6 and 12 km from the hospital ED.

Study protocol

During the post-intervention period, referral to the GPC was discussed with the parents of patients when presenting at the ED between 17.00 until 22.00 on weekdays and from 08.00 until 22.00 in the weekends and when they met the following inclusion criteria: self-referred (not referred by physician, other health professional or ambulance), age between 3 months and 16 years, presentation with a non-traumatic problem, and triaged as MTS urgency level 4 or 5.

Patients were not referred to the GPC if nurses felt that a patients' underlying disease required consultation at the ED. Compliance was evaluated during an average of four days/week, when a research employee was present. (98 week – and 17 weekend days). If parents refused referral, they fill out a questionnaire about their reasons. If parents agreed with referral, an appointment was made at one of the cooperating GPCs at the same day. If ED nurses did not initiate referral, they were required to record their reasons and the patient was treated at the ED.

Follow-up

We performed a follow-up using standardized telephonic questionnaire 2–4 days after the ED visit. Parents were asked about the child's general health, development of the chief complaint, unscheduled revisits and subsequent hospitalization. Parents of referred patients to the GPC were asked if they actually went to the GPC and to grade their satisfaction with the proceedings on a scale from 1–10. If parents were not reached by phone, a written questionnaire was sent.

Data collection

Patients' characteristics and urgency were recorded in electronic medical files by ED nurses and receptionists. Consult reports of referred patients were retrieved from the GPC. Telephonic follow up calls were performed by a trained nurse researcher or medical student.

Economic evaluation

Taking a broad perspective, the economic evaluation included the costs incurred at the ED, of GP care and costs of traveling to the GPC. We compared the total mean cost per patient between the situation in which all patients were seen at the ED (pre-intervention period) and the situation in which low urgent patients were referred to the GPC (post-intervention period). We took into account that during the post-intervention period in some cases referral was either rejected by the parents or not initiated by the ED nurse. All costs were calculated for the year 2006 and reported in euros (€).

The cost price of an ED consultation comprised the cost categories as stated in table 1.

Personnel costs per minute for nurses, residents, and paediatricians were based on the Collective Employment Agreement for Hospitals. Taking into account public holidays, vacations, illness, and study leave, the number of working hours per person per year was set at 1,540 (nurses), 1,988 (residents), and 2,100 (medical specialists) respectively leading to hourly personnel costs of €38, €32 and €71, respectively, including increments for holiday allowances, social security expenses, and allowances for working irregular hours. Cost prices of laboratory tests and diagnostic radiology (ultrasound, X ray, CT/MRI) were multiplied by the mean quantity of diagnostic procedures per urgency category.

Regarding the post-intervention period, we calculated personnel costs of explaining referral to the GPC to patients by the nurse (based on the above mentioned cost price of €38 per hour), costs made by the parents to travel to the GPC (€0.16 per kilometre + €2.50 parking costs), and costs of GPC consultation. The cost price of a GPC consultation was an integral cost price, including all costs of personnel, materials and buildings.

Sensitivity analysis

We considered mean prices per patient for different scenarios; when more patients accept referral, when referral is more often initiated by the nurse and when patients are referred during daytime.

Table 1 | Mean cost price of a visit to the ED by a low-urgent patient (in euros).

Variable costs	*Personnel**	Nurse	€ 34
		Resident	€ 29
		Medical specialist (supervision)	€ 8
	Diagnostics		€ 12
Non variable costs	Triage (software and personnel costs)		€ 4
	Other personnel costs**		€11
	Materials		€ 7
Total			**€ 106**

* Costs depended of the duration of consultation (Nurse and resident) or duration of supervision (medical specialist)
**Based on 17,000 patient contacts for children <16 years

RESULTS

Safety and parental satisfaction

During the total post-intervention period 140 patients were referred to the GPC. Follow-up data were available in 101 of 140 referred patients (72%). Seven patients had an unscheduled revisit (7%, 95% CI 3–14%), five at the GP and two at the ED. Development of chief complaint was registered for 81 of 101 patients. In 68 of these 81 patients (84%), the chief complaint had improved. In 12 patients (15%) the complaint did not change and in one patient the complaint worsened. 95 patients graded their satisfaction with care provided with an average of 6.6 (95% CI 6.2–7.1) at a 0-10 scale.

Compliance

During the days for which compliance was evaluated, 311 patients attended the ED. 36 of these 311 (12%) were excluded because the MTS was overruled. 28/275 (10%) patients were not referred without documentation of the reason. Compliance analysis was done in the remaining 247 patients. 95/247 patients (38%) were referred to the GPC. 46/247 parents (19%) refused referral. The nurse did not initiate referral in 106/247 patients (43%). Detailed information on reasons for rejected referral and not initiated referral by the nurse is provided in figure 1. 46% (n=16/35) recorded that they had accepted referral if the GPC was situated next to the the ED.

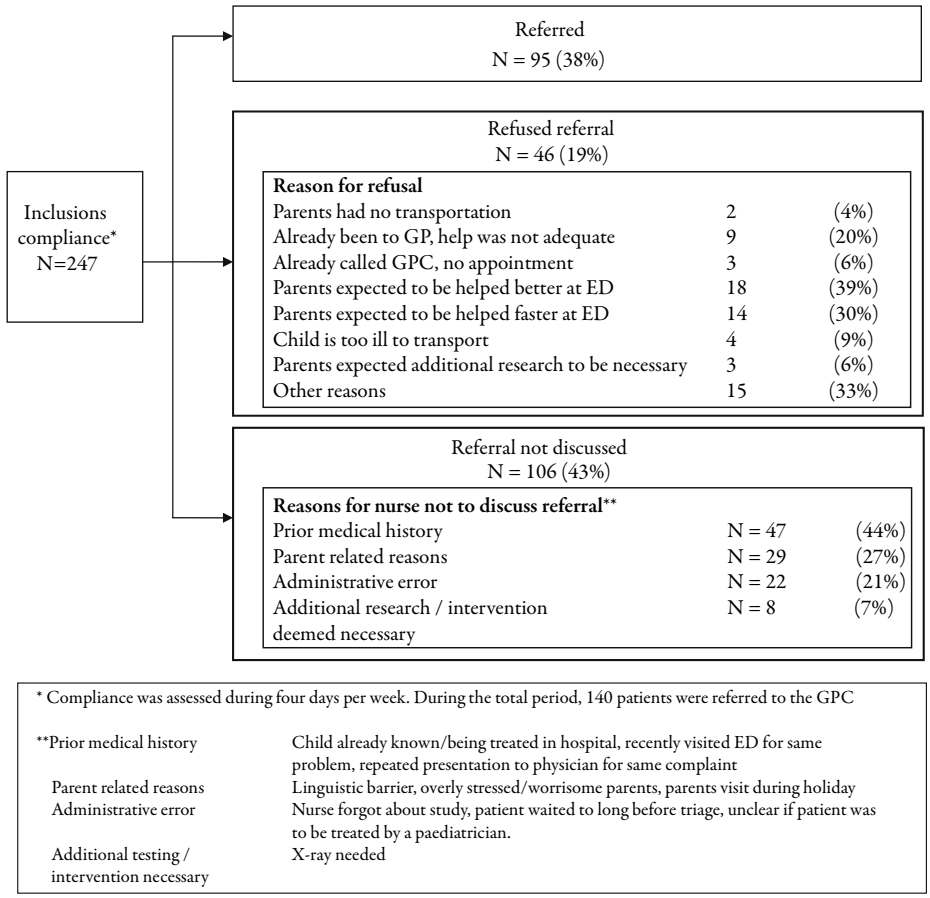


Figure 1 | Compliance: flow of included patients and reasons for rejection of referral or not initiating referral to GPC by the nurse.

GPC consultation

Of the 140 patients referred to the GPC, 101 (72%) were reached during telephonic follow-up, 13% (n=13/101) of them did not attend the GPC. None of them were hospitalised.

81 patients gave permission to use data collected from the GPC and GPC reports from 75 GP consultations could be collected. After attending the ED, patients were seen at the GPC after a median time of 77 minutes (IQR 61–130).

At the GPC, diagnostics were performed in two consultations (3%), both concerning urine analysis. In 44/75 (59%) patients the GP prescribed medication of which 8/75 (11%) concerned oral antibiotics. 68/75 patients (91%) were discharged from medical care, 6/75 (8%) got an appointment for check-up with their own GP and 1/75 patient (1%) was sent

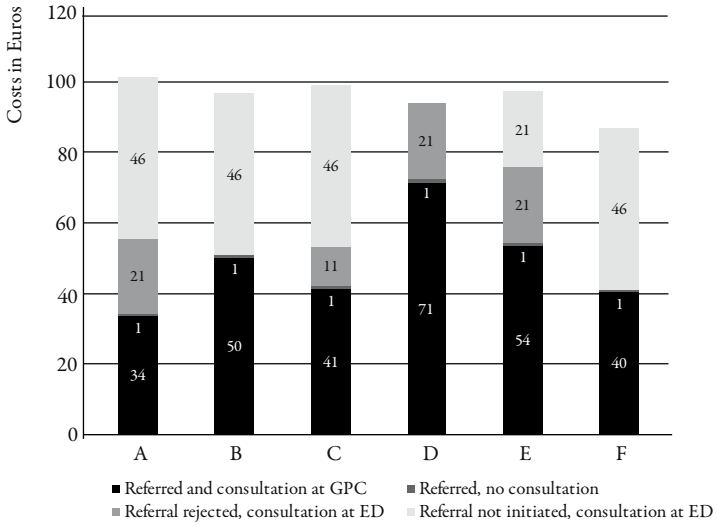
back to the ED because the GP suspected an infection with respiratory syncytial virus. The average length of a consultation at the GPC was 8 minutes (95% CI 7–9 minutes).

Economic evaluation

The mean cost price of consultation at the ED for non-referred low urgent patients was €106 (table 1). To calculate costs for referral to the GPC we used the actual situation as described above resulting in mean costs per patient during the post-intervention period of €101 (table 2). Implementation of referral to the GPC led to a cost reduction of €5 per patient (5%).

On a national level, in the Netherlands yearly 288,000 children visit the ED.(11, 12) 31% is triaged as low urgent according to the modified MTS and non-referred and 50% of them presents with a non-traumatic problem. The urgency level would be overruled in 10%. Therefore, annually 40,000 patients could be referred to the GPC. In case of 19% refusal and 43% is not referred based on the nurse's opinion, yearly costs would be (40.000 x €101= €4,040,000). When compared to the pre-intervention setting (40.000 x €106= €4,240,000), €200,000 could be saved each year.

Figure 2 shows the mean costs per patient for different scenarios. Especially the scenarios in which referral was not initiated (D) and referral of patients during daytime hours when everybody accepted referral (F), resulted in somewhat larger cost reductions (€94 and €87, respectively).



Numbers represent mean costs per patient in Euros
Scenarios:
A: Actual situation (€101)
B: No patients refused referral (€97)
C: 10% refused referral (€99)
D: All patients in whom referral was not initiated were now referred to the GPC (€94)
E: Half of the patients in whom referral was not initiated, were referred to the GPC (€97)
F: During daytimes on weekdays, patients are referred to the GP instead of GPC and no patients refused referral (€87)

Figure 2 | Sensitivity analysis for mean cost per patient based on study findings for different scenarios.

Table 2 | Determinants of costs of the pre-intervention and post-intervention period.

		Patient flow	Triage	ED consultation	Discussing referral	Travel costs	GPC consultation	Mean total costs of consultation(€)
Pre-intervention period	ED consultation	100%	€ 4	€ 102	-	-	-	€ 106
Post-intervention period	Referred, GPC consultation	34%	€ 4	-	€ 6	€ 3	€ 87	€ 100
	Referred, no GPC consultation	5%	€ 4	-	€ 6	-	-	€ 10
	Referral rejected, ED consultation	19%	€ 4	€ 102	€ 6	-	-	€ 112
	Referral not discussed, ED consultation	43%	€ 4	€ 102	-	-	-	€ 106
	Mean costs	100%						€ 101

DISCUSSION

In this study, referral of low urgent patients to the GPC resulted in a small cost reduction. Patients were moderately satisfied and 38% accepted referral to the GPC.

Main reasons for parents to refuse referral were that they expected better or faster care at the ED. Secondly, in 43% nurses did not initiate referral, mainly because of co morbidity. These findings led to the conclusion that at this stage the referral of low urgent children has a low efficiency. Other studies evaluated the process in which all low urgent patients were referred and patients were not given the possibility to refuse.[4,5] When all patients in which referral were initiated would have consulted the GPC, referral to the GPC would have been more efficient.

Conditions can be improved to refer more patients. For example the GPC may be located next to the ED, as is increasingly common in the Netherlands.[7] In our study 46% of the patients who refused referral, would have gone to the GPC if it was located next to the ED. Furthermore, in this study's main analysis, the included patients visited the ED during out-of-office hours. In the Netherlands, urgent primary care is then provided by GPCs, the costs of which (€87 per consultation) are much higher than care provided by the patient's own GP during office hours (€21 per consultation).[13] Therefore, as the sensitivity analysis showed, the scenario in which patients would be referred to their own GP during office hours (and if all patients would accept referral) would lead to further cost savings (figure 2).

When patients would initially call the GPC (rather than visit the ED), they would be triaged using the urgency classification of the Netherlands College of General Practitioners. Using this system, 50% would not be seen at the GPC but a self care advice would be provided by telephone. This scenario would lead to even more cost savings. However, safety of this guideline was only evaluated in two studies and not optimal.[14,15]

To our knowledge the effect of sending ED patients triaged as low urgent to the GPC, was not studied before. Other referral policies were evaluated. The effect of referring low urgent patients to a fast track area resulted in a cost reduction.[4,5]

To assess safety of referral of low urgent triaged patients to a GPC, we should focus on hospitalization after referral and unscheduled revisits after discharge. After referral 7/101 patients had an unscheduled revisit and none were hospitalized. In our previous follow-up study of 1,970 similar patients seen at the ED, the proportions of unscheduled revisits and hospitalizations were 11% and 0.14%, respectively.[9] It can be concluded that referral to the GPC in our study had no serious adverse effects.

We used precise methods to calculate real economic cost prices. This study did not rely on charges, which are not necessarily good surrogates for real costs. Another strength of the study was that its scope was not restricted to the ED, but included detailed cost assessment of GP care and the sacrifices made by parents (travelling costs).

Limitations

Some limitations should be considered. The studied ED is one of the EDs in the Netherlands with the largest number of children (n=15,000 yearly). However, we are aware that EDs in other European countries usually see many more patients. Furthermore, the cost calculations were done in only one ED and one GPC. It is not sure whether the results can be generalized to other settings, such as university hospitals.

This study was not sufficiently powered to detect differences in the amount of hospitalisations after discharge between the post-intervention and pre-intervention period. Future research should include costs of hospitalisation (as well as costs of follow-up visits to the ED or the GP) in the cost analysis. For a general hospital costs per inpatient day are €514[16], so differences in hospitalization rate have a large effect on the total costs.

CONCLUSION

Patients were moderately satisfied and referral resulted in a small cost reduction. Effectiveness was not optimal since a minority could be referred and many patients refused referral. Larger cost reductions are feasible if more patients are referred and patients would be referred during daytime as well.

Acknowledgements

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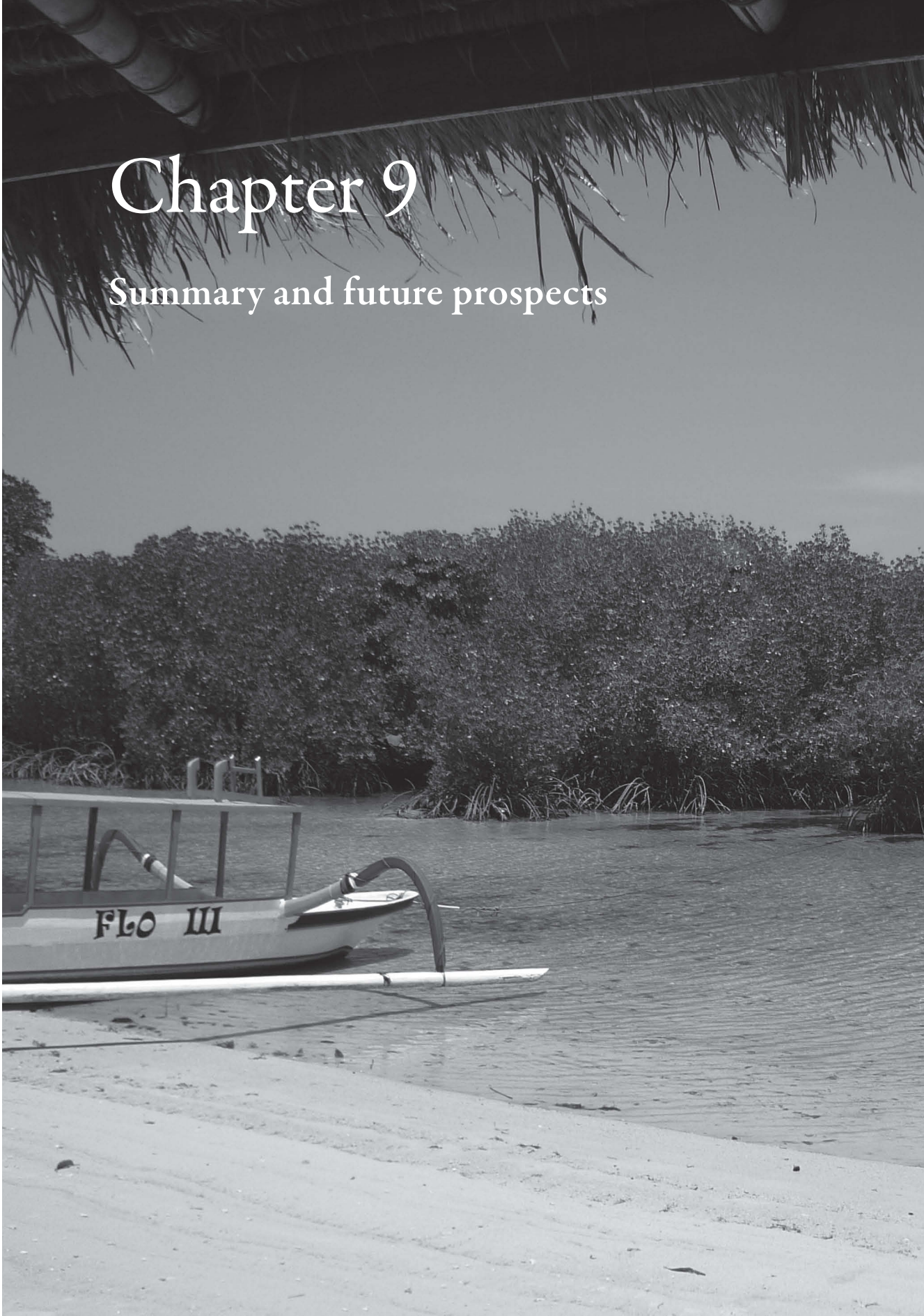
Chapter 9

Summary and future prospects



SUMMARY

In **Chapter 1** we provided an overview of the literature on the reliability and validity of triage systems in paediatric emergency care.
The Manchester Triage System (MTS), the Emergency Severity Index (ESI), the Paediatric Canadian Triage and Acuity Score (paedCTAS) and the Australasian Triage Scale (ATS) are common used triage systems and contain specific parts for children.
We concluded that the MTS and paedCTAS both seem valid to triage children in paediatric emergency care. The internal validity is moderate for the MTS and confirmed for the CTAS, but not studied for the most recent version of the ESI, which contains specific fever criteria for children. Reliability of the MTS is good, moderate to good for the ESI and moderate for the paedCTAS. More studies are necessary to evaluate if one triage system is superior over other systems when applied in emergency care.

We evaluated reliability and validity of the MTS in paediatric emergency care. The studies were performed at the Erasmus MC-Sophia Children's hospital and the Haga hospital Juliana Children's hospital. In **chapter 2** the reliability of the MTS was studied. We performed an inter-rater agreement study in which all ED nurses triaged twenty written case scenarios and actual patients were triaged simultaneously by two nurses using the MTS. The inter-rater agreement was good to very good (weighted kappa of 0.83, 95% C.I.0.74–0.91) using case scenarios and good (weighted kappa of 0.65, 95% C.I. 0.56–0.72) when actual patients were triaged.
In chapter 3 the validity of the MTS was evaluated in a large prospective observational study in 17,600 children in 2006/2007. The MTS was applied to patients attending the ED. Data was gathered to determine the urgency level according to an independent predefined reference standard for urgency. This reference standard was based on abnormal vital signs at presentation to define urgency 1, potentially life threatening condition for urgency 2, and a combination of diagnostic resources, therapeutic interventions, hospitalization and follow-up for urgency 3, 4 and 5.
Overall compliance to the MTS was 95%. The Manchester urgency level agreed with the reference standard in 4,582 of 13,554 (34%) children. In 7,311 (54%) the MTS attributed a too high urgency level (over-triage) and in 1,661 (12%) a too low urgency level.(under-triage) The sensitivity of the MTS to correctly identify high urgent patients was 63% (59 to 66) and specificity to correctly identify low urgent patients was 79% (95% CI 79 to 80).

The likelihood ratio was 3.0 (95% CI 2.8 to 3.2) for high urgency and 0.5 (0.4 to 0.5) for low urgency; though the likelihood ratios were lower for those presenting with a medical problem (2.3, 95% CI 2.2 to 2.5) versus 12.0, 95% CI 7.8 to 18.0, for trauma and in younger children (2.4, 95% CI 1.9 to 2.9) at 0–3 months v 5.4 (95% CI 4.5 to 6.5) at 8–16 years.
We concluded that the MTS has a moderate validity in paediatric emergency care. It errs on the safe side, with much more over-triage than under-triage compared with an independent reference standard. Triage of patients with a medical problem or of younger children is particularly difficult.
In **chapter 4** we evaluated patients who were severely under-triaged, compared to the reference standard for urgency. We performed a case study to determine the severity of under-triage in children. Under-triage was defined as patients triaged as low urgent (level 3-5) by the MTS and high urgent (level 1 or 2) by the reference standard, with at least two levels difference between the MTS and the reference standard urgency. Three experts in paediatric emergency care discussed cases, to determine severity. Secondly, to assess predictors of under-triage a univariate and multivariate regression analyses were performed. Under-triage could be considered as severe in 70% (N=107/152, 8 cases with missing data) of the under-triage. The reference standard was in 78% (N=83) of those patients determined by abnormal vital signs. Further, children younger than four years of age and children assigned to the MTS flowchart 'unwell child' are more likely to be under-triaged than children assigned to other flowcharts. ($OR_{<3\ months}$ 7.2, 95% CI 4.3–12.1, $OR_{3\text{-}11\ months}$ 2.6, 95% CI 1.5–4.6, $OR_{<1\text{-}4\ years}$ 1.8, 95% CI 1.1–3.0 and $OR_{unwell\ child}$ 5.6, 95% CI 2.6–11.9). Under-triage might have serious consequences in a few patients. The validity of the MTS may improve by adding abnormal vital signs as a discriminator in young children and in the MTS flowchart 'Unwell child'.
In **chapter 5** we studied the value of body temperature combined with age and presenting problem to predict high urgency, according to the reference standard for urgency.
Temperature separately had a moderate discriminative ability to predict urgency (AUC 0.58, 95% CI 0.56–0.60), but in combination with presenting problem and age the performance improved.(AUC 0.75, 95% CI 0.73–0.76) Temperature influences urgency especially in patients presenting with upper respiratory tract and urinary tract problems. We concluded that body temperature, combined with age and presenting problem is an important discriminator in triage systems. Together, these discriminators contribute to differentiate the triage decisions and can be implemented in different triage systems.

We modified the MTS for patients with fever based on age and presenting problem and for other specific patient groups, such as for patients with only a recent problem as discriminator,

and implemented the modified MTS at both EDs. In **chapter 6** we evaluated the external validity of the modified MTS in 11,481 patients by comparing the modified MTS urgency level to the reference standard urgency in both hospitals in 2007/2008. Compared to the original MTS 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, from 4.1 (95% CI 3.2 to 5.1) to 11 (95% CI 9.6 to 14).
We concluded that Modifications of the MTS for paediatric emergency care resulted in an improved specificity while sensitivity remained unchanged. Further research should focus on the improvement of sensitivity.

In the final section (**chapter 7 and 8**) we focussed on the ability of the MTS to identify low urgent patients in order to refer these patients to another healthcare professional.
In **chapter 7** we assessed hospitalization, as a proxy for safety and determinants for hospitalization for low urgent, self-referred patients (MTS level 4 or 5) presenting at the ED. Secondly, discharged patients received a telephonic follow-up 2-4 days after consultation.
Among 5,425 patients, 191 (3.5%) were hospitalized. Hospitalization was more likely for children younger than one year of age (OR 3.0, 95% CI 2.2 to 4.1) and for patients presenting with dyspnea (OR 2.5, 95% CI 1.5 to 4.1) gastrointestinal problems (OR 3.5, 95% CI 2.5 to 4.9) and for patients with fever without other specific symptoms. (OR 2.8, 95% CI 1.1 to 7.2). 3,975 / 5,234 (76%) could be contacted for follow-up after discharge. After ED discharge only six (0.15%) patients were hospitalized.
Referral of low urgent, self referred children to another healthcare professional may be safe except for children aged under one year or when presenting with dyspnea, gastrointestinal problems and for patients with fever without specific symptoms.

In **chapter 8** we evaluated compliance and effects on costs when low urgent, self referred children, who visited the ED were actually referred to the general practitioner cooperative.
During six months 140 patients were referred to the general practitioner cooperative. 101/140 patients (72%) were reached during telephonic follow up. After discharge seven patients (7%) had an unscheduled revisit. No patients were subsequently hospitalized. Patient satisfaction was graded as 6.6 (95% CI 6.2–7.1).
275 patients were included to study compliance. 95/247 (38%) patients were referred to the GP. 46/247 parents (19%) refused referral. For 106/247 patients (43%) referral was not initiated by the nurse due to co-morbidity or the nurse expected she could not convince the

parents. Data on 28/275 patients (10%) were missing. Mean costs per low urgent patient were €106, when initially seen at the ED and €101 after implementation of GP referral. Larger cost reductions are feasible if more patients are referred and patients would be referred during daytime as well.

We concluded that parents and children were moderately satisfied and referral resulted in a small cost reduction. Effectiveness was not optimal since a minority could be referred and many patients refused referral.

FUTURE PROSPECTS

Validity of triage systems

In order to evaluate the validity of a triage system a reference standard for urgency should be defined. In the past different methods were used. Trends in resource use and hospitalization in relation to the urgency classification were studied in several observational studies. In smaller studies an expert panel defined the reference urgency classification.[1]
The aim of triage is to determine the urgency of the patient. Urgency is based on presenting symptoms and partly determined by the patient's working diagnosis. However, urgency might differ between patients with the same diagnosis. For example not all patients with a serious bacterial infection will need very urgent care. Patients with pneumonia with normal vital signs will need a lower urgency level than a patient who present with a septic shock.

Triage should determine urgency at the time of triage. Especially for urgent presentations, the patient's condition may change quickly over time. That's why it is important to use a reference standard based on the patient's condition which has been measured within a short time frame from the triage moment.[2]

The reference standard we used determines urgency based on a number of items. Deviated vital signs at presentation defined an 'immediate' level. A potentially life threatening condition defined a 'very urgent' level, as stated at the end of ED consultation. The three lowest urgency levels ('urgent', 'standard' or 'non urgent') were defined based on the amount of resources used (diagnostics, treatment, hospitalization) and scheduled follow up.
Although all items of the reference standard are related to urgency we are aware that they do not precisely define urgency. By combining the items we developed a more precise measure to determine five urgency levels.

Improvements of the Manchester Triage System for children

With specific modifications, mainly for children with fever, based on the presenting problem and age we further improved specificity to identify true non-urgent patients based on the reference standard. The modifications did not improve sensitivity of the system to identify true high urgent patients, it remained 63%. Sensitivity focuses on the two highest MTS urgency levels. Our study on the validity of the original MTS showed that these two levels account for only 5.2% of the population following the reference standard for urgency. (Chapter 3)

When studying high urgent patients who were not correctly triaged (severe under-triage), we showed that especially patients with deviated vital signs were severely under-triaged. The MTS identifies 'Immediate' patients by describing conditions in which care should be delivered immediately. These conditions described the consequences of severe deviation of vital signs such as airway compromise, inadequate breathing and shock. Patients with only elevated heart rate, deviated blood pressure or irregular heart rhythm, will be triaged into a lower urgency levels based on other present discriminators.
Further modifications should be studied and focus on the inclusion of vital signs into the MTS in order to identify high urgent patients.[3]

By comparing the MTS urgency levels with the reference standard urgency we could identify discriminators, which showed to have a better validity when linked to a higher or lower urgency. Using this strategy we studied patient groups triaged with the ten most common used MTS flowcharts. These flowcharts accounted for 80% of the patients with non-traumatic problems. We were limited to study only the common used discriminators within these flowcharts such as 'Recent Problem' (20%), pain discriminators (17%), fever discriminators (15%), 'Recent Injury' (9%), 'Increased work of breathing' (4%) and 'Persistent vomiting' (4%) (Chapter 3).
With more extended data collection we may study less common used discriminators in order to identify more patient groups in which validity of the MTS is low, aiming to further improve the MTS.

In the presented study we only studied and modified discriminators which are present in the original MTS. Based on comments from users and literature specific discriminators could be added and studied. New discriminators such as seasonality, comorbidity and more specific discriminators will be likely to further improve the MTS. However, a large dataset is necessary to have sufficient power. A multicenter study could result in a larger number of included patients. Compared to EDs in the UK and US, the patient load visiting the EDs in the Netherlands is relatively low. Including EDs from the UK could increase generalizability and efficiency.

In the second version of the MTS as proposed by the Manchester Triage Group, some minor modifications, which were based on comments from users, were inserted.[4] The flowchart 'Unwell Child' was changed and contains new discriminators as 'Fails to react to parents'

and 'Signs of Meningism' which lead to 'Very Urgent' category. Before, children were triaged using the 'General flowchart', which did not contain specific discriminators for children.[5] We applied and studied the original MTS. The second version combined with the described modifications, is now used at the ED of the Haga hospital, Juliana Children's hospital and the Erasmus MC-Sophia Children's hospital. It is important to externally validate the modified second version of the MTS in a new population.

Methodology

Triage systems are based on consensus based decision rules. To validate triage systems the methodology of diagnostic research can be applied.
However, some specific factors of triage classification differ from clinical decision models, and should be considered. We used multivariate logistic regression modelling to study temperature as discriminator in triage systems. (Chapter 5) We combined the categories of the five level reference standard for urgency, into two categories. The categorization of the reference standard leads to a more simplified final result. We studied the risk of high urgency, and therefore did not further differentiate between the two highest urgency categories and the three lowest urgency categories. Further research could apply multinomial, or proportional odds regression analysis, for which ordinal variables, as the five level reference standard for urgency can be used as outcome measure.

When studying options for modifications the risk of increasing over- or under-triage should be taken into account. Sensitivity and specificity express the balance between over- and under-triage. A five level triage system is categorized into the two highest and three lowest urgency categories. Experts can decide if improving sensitivity is more important than improving specificity or the other way around. The value of over-, under- and correct triage is based on the number of categories over- or under-triage compared with the reference standard. By comparing the triage urgency level to a reference standard urgency level, weights can be assigned for the number of categories over- or under-triage for different urgency levels. In the literature some suggestions for weighting were proposed.[6,7] Under-triage is weighted as more severe than over-triage. They can be used to further study validity of triage systems.

The aim of triage is to see patients first who will be harmed if the initiation of treatment is delayed. To reach this aim, specific discriminators are needed which can correctly identify patients with high urgent conditions. The patient group who presents at the ED represents a wide range of different problems. Secondly, the triage assessment should be very short in order

not to delay treatment by the triage process itself, so only easily identifiable discriminators can be used for a triage assessment. It follows that highly specific discriminators which can be used for triage do probably not exist. A triage system with a high sensitivity and high specificity is therefore probably impossible to develop. A system with a high sensitivity will optimally identify high urgent cases. However, the consequence of a low specificity will result in many patients who have to be seen within a very short time frame. If the ED capacity is not sufficient, all high urgent patients (true-positive and false-positive), have to wait longer than their maximum time frame. A high specificity with a low sensitivity will result in more false-negative cases.

An optimal balance between the number of false-negative and false-positive classifications can be determined in discussion with experts. In chapter 4 we showed that the under-triaged patients (the false-negative patients) may result in severe consequences in 70% of the cases, according to the experts. Actual effects of under- and over-triage are hard to study since many factors more than the triage process determine morbidity and mortality.

Furthermore, a formal decision-analytic perspective can be used. A relatively simple approach is to consider the 'net benefit' of a triage system.[8,9] The net benefit is a weighted sum of true-positive and false-positive classifications, where the relative weight of false-positive classifications is given by the odds of the decision threshold to define an urgent versus a non-urgent case. With a low threshold, the relative weight is low, and true-positive classifications are far more important than false-positive classifications. The net benefit calculation indicates whether the model is beneficial in terms of clinical consequences, compared to treating all patients as high urgent or all patients as low urgent.

A more extensive approach is a formal cost effectiveness study. Costs of the effect of a longer waiting time on short and long term consequences as discussed by the experts can be calculated.

When a triage system is not sensitive and specific enough, more physicians should be hired in order to see patients within a sufficient time frame. However, we have to take into account that presentation of level 1 urgency patients, who require very time consuming care, is difficult to predict based on historical data, since they do not present often. A simulation model could possibly be developed to determine optimal time frames in which patients are

seen, based on distribution of urgency levels, time of presentation, the aimed sensitivity and specificity of the triage system along with the additional costs.

Low urgent patients at the emergency department

In chapter 7 we studied safety of the MTS to identify low urgent patients. We estimated that referral for specific patient groups will be safe; depending on the proportion of patients who are hospitalized when they consult the ED. Safely identified low urgent patients could be seen by another caregiver such as a general practitioner.

In chapter 8 compliance and effects on costs when MTS low urgent patients are actually referred to the general practitioner cooperative (GPC) were evaluated. Referring low urgent self referred children to a GPC resulted in a small cost reduction, while patient were satisfied, but compliance of referral was low.

The sample size of this study was too small to detect effects of referral on hospitalizations, as a proxy for safety. Larger studies should be performed comparing proportion hospitalization when low urgent patients consult the ED and when they are referred to the GPC.

Several GPCs are now located next to the ED and some have one entry for all patients. In this way a triage system can advice patients if they should go to the ED or GPC.

However, for this purpose it is unclear which triage system is valid and effective. We studied the MTS for its ability to identify low urgent patients for the ED setting. Patients presenting to the GPC will have a lower prevalence of conditions that require urgent consultation. For this patient group, triage criteria should be less conservative.

A new triage system, the Netherlands Triage System (NTS) was developed and based on the MTS, the Dutch National Telephone guidelines and a Dutch protocol aiming to guide pre-hospital transportation. The aim of the system was to correctly triage patients at the ED and GP setting and to provide an advice on which caregiver the patient should consult. The system was studied in a small data set during the implementation process of the system.[10] It was shown to be reliable but many patients triaged as low urgent were hospitalized (ED setting) or referred to the ED (GP setting). The power of the study was not sufficient to confirm neither reliability nor validity of the system when applied to children.

Further research should focus on the validity and improvements of this system as well, and should compare the validity of the MTS with the NTS, to see which system is superior to use at the ED setting and for the combined GPC/ED setting.

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Samenvatting

SAMENVATTING

Hoofdstuk 1 geeft een overzicht van de literatuur over de betrouwbaarheid en validiteit van triage systemen voor kinderen op de spoedeisende hulp.
Het Manchester Triage System (MTS), de Emergency Severity Index (ESI), de Paediatric Canadian Triage and Acuity Score (paedCTAS) en de Australasian Triage Scale (ATS) zijn veel gebruikte triage systemen en bevatten specifieke onderdelen voor kinderen.
Wij concludeerden dat het MTS en de paedCTAS beide valide triage systemen zijn voor kinderen op de spoedeisende hulp. De validiteit is redelijk voor het MTS en bewezen voor het CTAS, maar niet onderzocht voor de meest recente versie van het ESI, die specifieke criteria voor kinderen met koorts bevat. De betrouwbaarheid van het MTS is goed, van het ESI redelijk tot goed en redelijk voor het paedCTAS. Meer onderzoek is nodig om te concluderen welke van de triage systemen het meest valide is op de spoedeisende hulp.

Vervolgens evalueerden we de betrouwbaarheid en validiteit van het MTS bij kinderen op de spoedeisende hulp. De onderzoeken werden verricht op de spoedeisende hulp van het Erasmus MC –Sophia Kinderziekenhuis en het Haga ziekenhuis, Juliana Kinderziekenhuis.
In **hoofdstuk 2** onderzochten wij de betrouwbaarheid van het MTS. We verrichtten een 'inter-rater agreement' onderzoek waarbij alle spoedeisende hulp verpleegkundigen twintig patiëntencasussen trieerden. Tevens werden patiënten, die zich presenteerden op de spoedeisende hulp, tweemaal getrieerd, middels het MTS.
De inter-rater agreement was goed tot uitstekend (gewogen kappa van 0.83, 95% B.I 0.74-0.91) bij het gebruik van patiënten casussen en goed (gewogen kappa of 0.65, 95% B.I. 0.56-0.72) wanneer werkelijke patiënten getrieerd werden.
In **hoofdstuk 3** evalueerden wij de validiteit van het MTS in een grote prospectieve observationele studie bij 17,600 kinderen in 2006/2007. Het MTS werd toegepast bij kinderen die de spoedeisende hulp bezochten. Aan de hand van kenmerken van het spoedeisende hulp consult werd de urgentie bepaald volgens een onafhankelijke, vooraf gedefinieerde referentie standaard voor urgentie. Urgentie 1 werd toegekend aan patiënten met abnormale vitale kenmerken bij presentatie. Patiënten met een potentieel levensbedreigende diagnose kregen urgentie 2. De combinatie van de verrichtte diagnostiek, therapie, of de patiënt opgenomen werd en de geplande vervolgbezoeken bepaalde of een patiënt urgentie 3, 4 of 5 kreeg.
Verpleegkundigen pasten het MTS toe bij 95% van de patiënten. De MTS urgentie kwam overeen met de referentiestandaard urgentie in 4,582 van de 13,554 (34%) kinderen. In

7,311 (54%) gaf het MTS een te hoge urgentie (over-triage) en in 1,661 (12%) een te lage urgentie (onder-triage). De sensitiviteit van het MTS om correct hoog urgente patiënten te identificeren was 63% (95% B.I. 59-66) en de specificiteit om correct laag urgente patiënten te identificeren was 79% (95% B.I. 79-80).

De 'likelihood ratio' was 3.0 (95% B.I. 2.8-3.2) voor een hoge urgentie en 0.5 (0.4-0.5) voor een lage urgentie. De 'likelihood ratios' waren lager voor patiënten die zich presenteerden met een niet-traumatisch probleem (2.3, 95% B.I. 2.2-2.5) versus 12.0, 95% B.I. 7.8-18.0 voor patiënten met een traumatisch probleem en bij jonge kinderen (2.4, 95% B.I. 1.9-2.9) van 0-3 maanden versus 5.4 (95% B.I. 4.5-6.5) bij kinderen van 8-16 jaar.
Wij concludeerden dat het MTS een redelijke validiteit heeft bij kinderen op de spoedeisende hulp. Misclassificatie lijkt aan de veilige zijde te zitten met meer over-triage dan onder-triage, in vergelijking met een onafhankelijke referentiestandaard. Triage is minder vaak correct bij patiënten met een niet-traumatisch probleem en bij jonge kinderen.
In **hoofdstuk 4** evalueerden wij, middels een case studie, de patiënten die ernstig ondergetrieerd werden. We evalueerden de patiënten die laag urgent (urgentie 3-5) getrieerd werden door het MTS en hoog urgent door de referentiestandaard (urgentie 1 of 2), met minstens 2 urgenties verschil tussen het MTS en de referentiestandaard. Drie experts in spoedeisende kindergeneeskundige bediscussieerden de patiëntencasussen. Om determinanten voor onder-triage te bepalen, verrichtten wij univariate en multivariate logistische regressie analyse.
In totaal werden 152 van de 13,554 (1.1%) patiënten ondergetrieerd, waarvan 70% (107/152) als ernstig bediscussieerd werd. De urgentie van de referentiestandaard werd bij 83 patiënten (78%) bepaald door afwijkende vitale kenmerken. Jonge kinderen, met name onder de 3 maanden en kinderen getrieerd met de flowchart 'onwel geworden kind' werden vaker ondergetrieerd dan kinderen getrieerd met andere flowcharts, bij zowel univariate als in multivariate analyse. Onder-triage komt niet vaak voor maar kan ernstige klinische consequenties hebben. Het MTS zou verbeterd kunnen worden door afwijkende vitale kenmerken als discriminator toe te voegen voor jonge kinderen en in de MTS flowchart 'onwel geworden kind'.
In **hoofdstuk 5** bestudeerden wij de waarde van lichaamstemperatuur gecombineerd met leeftijd en het presenterend probleem, om een hoge urgentie te voorspellen volgens de referentie standaard voor urgentie.
Temperatuur alleen had een redelijke discriminerende waarde om urgentie te voorspellen (AUC 0.58, 95% B.I. 0.56-0.60). Echter deze verbeterde als temperatuur werd gecombineerd met leeftijd en presenterend probleem. (AUC 0.75, 95% B.I. 0.73-0.76) Temperatuur bepaalt

urgentie met name bij patiënten die zich presenteren met bovenste luchtweginfecties en urinewegproblemen. Wij concludeerden dat lichaamstemperatuur, in combinatie met leeftijd en presenterend probleem, een belangrijke discriminator in triage systemen is. Gecombineerd kunnen deze discriminatoren bijdragen om triage beslissingen te differentiëren en kunnen zij geïmplementeerd worden in verschillende triage systemen.

Wij pasten het MTS aan voor kinderen met koorts gebaseerd op leeftijd en presenterend probleem en voor andere specifieke patiëntengroepen, zoals voor patiënten met alleen een recent probleem als discriminator. Vervolgens werd het aangepaste MTS geïmplementeerd op beide spoedeisende hulpen. In **hoofdstuk 6** evalueerden we de externe validiteit van het gemodificeerde MTS bij 11,481 patiënten door de gemodificeerde MTS urgentie te vergelijken met de referentiestandaard urgentie, in beiden ziekenhuizen in 2007/2008. In vergelijking tot het originele MTS verbeterde de specificiteit van 79% (95% B.I. 79-80%) naar 87%, (95% B.I. 86-87%) terwijl de sensitiviteit niet veranderde (63%, 95% B.I. 59-66%) versus (64%, 95% B.I. 60-68%). De diagnostische odds ratio nam toe van 4.1 (95% B.I. 3.2-5.1) tot 11 (95% B.I. 9.6-14).
We concludeerden dat de modificaties van het MTS resulteerden in een verbeterde specificiteit terwijl de sensitiviteit niet veranderde. Verder onderzoek zal zich moeten richten op het verbeteren van de sensitiviteit.

In het laatste gedeelte (**hoofdstuk 7 en 8**) focusseerden we op de mogelijkheid van het MTS om laag urgente patiënten te identificeren zodat deze naar een andere zorgverlener verwezen zouden kunnen worden.
In **hoofdstuk 7** evalueerden wij opname na het spoedeisende hulp consult, als een proxy voor veiligheid, en determinanten voor opname voor laag urgente (MTS urgentie 4 of 5), zelf verwezen patiënten. Ontslagen patiënten kregen 2-4 dagen na ontslag van de spoedeisende hulp, een telefonisch consult. Van de 5425 patiënten werden er 191 (3.5%) opgenomen. Kinderen onder het jaar (OR 3.0, 95% B.I. 2.2-4.1) en kinderen die zich presenteerden met dyspnoe (OR 2.5, 95% B.I. 1.5-4.1), gastro-intestinale problemen (OR 3.5, 95% B.I. 2.5-4.9) of koorts zonder andere specifieke klachten (OR 2.8, 95% B.I. 1.1-7.2) werden vaker opgenomen. 3975 van de 5234 (76%) patiënten konden bereikt worden na het ontslag. Na ontslag werden 6 (0.15%) patiënten alsnog opgenomen. Verwijzing van laag urgente, zelf verwezen patiënten naar een andere zorgverlener, lijkt veilig, behalve voor kinderen onder de leeftijd van één jaar of als deze zich presenteren met dyspnoe, gastro-intestinale problemen of koorts zonder andere symptomen.

In **hoofstuk 8** evalueerden we de compliantie en het effect op kosten als laag urgente, zelf verwezen kinderen, die de spoedeisende hulp bezochten, naar de huisartsenpost werden verwezen. Gedurende 6 maanden werden 140 patiënten verwezen naar de huisartsenpost. 101 van de 140 patiënten werd bereikt middels een telefonisch consult. Na ontslag hadden zeven patiënten (7%) een ongepland tweede bezoek bij een arts. Geen enkele patiënt werd vervolgens opgenomen. Ouders waardeerden de zorg met een gemiddeld cijfer van 6.6 (95% B.I. 6.2-7.1). 275 patiënten werden geïncludeerd om de compliantie van verwijzing te onderzoeken. 95 van de 247 (38%) patiënten werden verwezen naar de huisartsenpost. 46 van de 247 ouders (19%) weigerden verwijzing. Bij 106 van 247 patiënten (43%) werd verwijzing niet geïnitieerd door de verpleegkundige, in verband met comorbiditeit of als de verpleegkunde verwachtte dat ze ouders niet kon overtuigen. Gegevens van 28 van de 275 patiënten (10%) ontbraken. De gemiddelde kosten per laag urgente patiënt was €106, als ze gezien werden op de spoedeisende hulp en €101 na implementatie van verwijzing naar de huisartsenpost. Grotere kostenbeperkingen zijn haalbaar als meer patiënten verwezen zouden worden en als patiënten ook overdag verwezen zouden worden.
We concludeerden dat ouders en kinderen redelijk tevreden waren en dat verwijzing resulteerde in een kleine kostenbesparing. Effectiviteit was niet optimaal aangezien slechts een minderheid van de patiënten verwezen kon worden en veel patiënten verwijzing weigerden.

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AFFILIATION CO-AUTHORS

Author	Affiliation
C. Hablé, MD	Stichting Mobiele Artsen Service Haaglanden (SMASH), The Hague
M. van 't Klooster, MD	Department of Paediatrics, Erasmus MC-Sophia Children's Hospital, Rotterdam
J. van der Lei, MD, PhD	Department of Medical Informatics, Erasmus MC, Rotterdam
L. Lettinga, MD	Department of Paediatrics, Erasmus MC-Sophia Children's Hospital, Rotterdam
A.H.J. van Meurs, MD	Department of Paediatrics, Haga Hospital, Juliana Children's hospital, The Hague
H.A. Moll, MD, PhD	Department of Paediatrics, Erasmus MC-Sophia Children's Hospital, Rotterdam
M.J. Poley, MSc, PhD	Department of Paediatric Surgery, Erasmus MC-Sophia Children's Hospital, Rotterdam
	Institute for Medical Technology Assessment (iMTA), Erasmus University Rotterdam, Rotterdam
M. Ruige, MD	Department of Paediatrics, Haga Hospital, Juliana Children's hospital, The Hague
J. Roukema, MD, PhD	Department of Paediatrics, Erasmus MC-Sophia Children's Hospital, Rotterdam
N. Seiger, MD	Department of Paediatrics, Erasmus MC-Sophia Children's Hospital, Rotterdam
E.W. Steyerberg, MSc, PhD	Center for Medical Decision Making, department of Public Health, Erasmus MC, Rotterdam
Tania D. Strout, RN, BSN, MSc	Department of Emergency Medicine, Maine Medical Center, Portland, ME, USA
V.F.M. Teunen-van der Walle, Master in advanced nursing practice	Department of Paediatrics, Haga Hospital, Juliana Children's hospital, The Hague
F. ten Wolde, MD	Department of Paediatrics, Erasmus MC-Sophia Children's Hospital, Rotterdam

ABBREVIATIONS

CTAS	Canadian Triage and Acuity Scale
ED	Emergency Department
ESI	Emergency Severity Index
GP	General practitioner
GPC	General Practitioners Cooperative
IQR	Interquartile range
ICC	Intraclass correlation coefficient
MTS	Manchester Triage System
95% C.I.	95% Confidence Interval

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Mam, Pap, Kees en Carla, Thomas, Ana en Jeroen, dank dat jullie er altijd voor mij zijn.

Mirjam van Veen

PhD PORTFOLIO
SUMMARY OF PhD TRAINING AND TEACHING ACTIVITIES

Erasmus MC department: General Paediatrics

Research school: NIHES

PhD period: 1 january 2006-1 oktober 2009

Promotors: H.A. Moll, E.W Steyerberg

General academic skills	**Year**	**Workload (ECTS)**
Biomedical English Writing and communication, Erasmus MC Rotterdam	2007	4.0
Integrity in research	2008	0.6
Research skills		
MSc Clinical epidemiology, NIHES	*2006-2008*	*70*
– Principles of research in medicine	2006	0.7
– Clinical decision analysis	2006	0.7
– Methods of clinical research	2006	0.7
– Clinical trials	2006	0.7
– Topics in evidence based medicine	2006	0.7
– Decision making in medicine	2006	0.7
– Study design	2006	4.3
– Classical methods for data analysis	2006	5.7
– Modern statistical methods	2006	4.3
– Clinical epidemiology	2007	5.7
– Methodologic topics in epidemiologic research	2007	1.4
In depth courses		
– Advanced diagnostic research	2007	1.4
– Prognostic research	2007	1.4
– Good clinical practice	2007	0.7
– Epidemiology of infectious diseases	2008	1.4
– Paediatric drug research	2008	0.9

Conferences		
5th World Congress on Paediatric Critical Care, Geneva, Switzerland June 2007. Oral presentation :'Validation and pitfalls of the Manchester Triage System for paediatric patients' Abstract: Ped Crit Care Med, May 2007, Volume 8, Issue 3 Suppl.		1.4
29e congres van de Nederlandse Vereniging voor Kindergeneeskunde. Oral presentation: 'Validiteit en modificaties van het Manchester Triage Systeem voor kinderen'. Abstract: Tijdschrift voor Kindergeneeskunde. 2007; Supplement 1:20.		1.4
12th Biennial, Society for Medical Decision Making, European Meeting Engelberg, Switzerland, 2008 Oral presentations: 'Validity of a modified Manchester triage system for children' and 'Diagnostic value of C-reactive value in febrile children'. Abstracts: Medical Decision Making, 2008.		1.4
30e Congres van de Nederlandse Vereniging voor Kindergeneeskunde. Oral presentation:'Validiteit en veiligheid van een aangepast Manchester Triage Systeem voor kinderen op de spoedeisende hulp'. Abstract: Tijdschrift voor Kindergeneeskunde. 2008; Supplement 1:78.		1.4
27th Annual meeting of the European society for paediatric infectious diseases, Brussels, Belgium 2009. Poster presentation: 'How to determine urgency for children with fever in emergency care? A risk chart for triage' Abstract: Pediatr Infect Dis J. 2009 Jun;28(6): e76		1.4
31e Congres van de Nederlandse Vereniging voor Kindergeneeskunde. Oral presentation 'Verwijzing van laag urgent getrieerde kinderen naar de huisartsenpost: veiligheid en efficientie' Abstract: Tijdschrift voor Kindergeneeskunde. 2009; Supplement 1:112		1.4
Seminars and workshops		
PhD day, Erasmus MC Rotterdam	2006, 2007	0.6
Dag voor de jonge onderzoeker, Nederlandse Vereniging voor Kindergeneeskunde, Veldhoven	2007, 2008	0.6
Teaching activities		
Supervising Master's thesis (11 students)	2006 - 2009	26