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Reliability and validity of the Manchester Triage system in children, an observational study

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Introduction

At the emergency department (ED) it is crucial to give priority to critically ill patients. Many patients might arrive at the same time and it is impossible to see every single patient at once. It is important to reduce overcrowding in ED's because this can lead to compromising patient safety (1). Triage is a method that can improve the flow and the patient safety of the ED (2–4) and trained nurses use a triage system to properly determine the different levels of urgency.

Multiple triage systems have been developed. One of these triage systems is the Manchester Triage System (MTS). The MTS is one of the most commonly used triage systems in Europe and proved to be valid for triage in children at ED's(5). The MTS exists of 53 flowcharts, each for a different problem, of which 49 are also suitable for children (6,7).

The reliability and validity of the MTS could be different for children because not all flowcharts are applicable to children. The endpoint of a flowchart is one of the five urgency levels. These levels determine the priority in which a patient must be seen by the doctor. The levels of the MTS are: 1. Immediate (max. time 0 min.), 2. Very urgent (max. time 10 min.), 3. Urgent (max. time 60 min.), 4. Standard (max. time 120 min.) and 5. Non-urgent (max. time 240 min.) (6).

A risk of triage is misclassification, for example when a child who visits the ED is classified in a higher urgency level than necessary, which is called over-triage. Over-triage is not dangerous for that child, but it can cause obstruction for the flow of the ED. Patients can also be classified in a lower level than required, this is called under-triage. Under-triage can be dangerous, because the necessary care is not provided timely. Treating a patient too late may be harmful with negative effect on the long term outcome (8).

Of the children who visit the ED of an university medical centre 27.4% have comorbidity, which is a risk factor for under-triage (8,9,10). Children with chronic illness turn out to have a higher risk of under-triage (17%) versus children without chronic illness (11%) (9,11). It is unclear why these children have a higher risk of under-triage. It might be possible that nurses triage a child with a comorbidity differently because the MTS itself does not take comorbidity into account for determining the urgency level (5). The overall reliability of the MTS is acceptable (12). The interrater agreement of the MTS in paediatric emergency patients is good to very good, and even in the case of disagreement it is not depending on the patient's age (13). However, the interrater reliability of triage in children with chronic illness done by

nurses is unknown. Therefore the first aim of this study is to determine the interrater reliability for MTS urgency levels in scenarios of children with and without comorbidity.

Pre-hospital triage has a huge influence on the outcome of illness (14). Although injuries are a major cause of mortality in adolescence (15). Little is known about the in-hospital trauma triage of children. Within the MTS, trauma triage is included in the regular triage system. The overall validity of the MTS varies in different studies from fair to moderate to moderate-good (10,16,17). However, only limited research has been done on the validity of the MTS in children with minor and major trauma (10,16,18).

To be able to consider modifications to improve the MTS it would be relevant to determine the validity of the MTS in children with minor and major trauma including wounds, burns, bites and stings. Therefore, the second aim of this study is to validate the MTS for children with trauma.

Aim

Primary Objective

This study is twofold, the overarching aim of this study is to determine the reliability and validity of the Manchester Triage System in children at the emergency department.

This will be achieved by

1. Determining the interrater reliability for Manchester Triage System urgency levels in scenarios of children with and without comorbidity.
2. Validating the Manchester Triage System for children with trauma at the emergency department.

Method

Part 1 - interrater-reliability

Study design

This was a quantitative cross-sectional interrater-assessment study.
Different nurses, from four different European hospitals, triaged the same 11 written case scenarios by assigning an MTS urgency level (scale from 1-5, immediate to non-urgent).
In this study two types of data were used (figure 1). First, in two of the hospitals, nurses were included to triage 11 case scenarios in which five comorbidities were added using block randomization (appendix 1). Secondly, as part of another ongoing study on validation of the MTS. Twelve nurses already triaged the same 11 case scenarios which did not include comorbidity, this data was also included.

Sample size calculation

The sample size calculation was done with an expected reliability based on another reliability study in a comparable setting (teaching hospital and university hospital) and this study used partly the same scenarios. This study showed a reliability of 0.83 inter-rater agreement (12). A minimum reliability of 0.67 is seen as acceptable. With a power of 0.8 and a significance level of 0.05, at least 28 nurses needed to be included. This sample size calculation was based on a sample size calculation tool designed for intra-class coefficient analysis (ICC) (19). The analysis technique used in this study was also designed for calculating agreement in multiple raters, but there was no sample size calculation tool specifically for this statistical analysis. Therefore the sample size was calculated based on the ICC.

Insert figure 1 here

Data collection

The data was collected in two different ED's, an university medical centre with nearly 9000 paediatric visits annually and an inner-city teaching hospital with nearly 6500 paediatric visits annually. from March to May 2018. This was a convenience sample of the nurses present at the ED on the moments of data-collection. Only nurses who triaged patients at the ED and nurses who had at least one year experience with the MTS were included. The characteristics of the study population were: age in years, gender, workplace (hospital) and years of MTS triage experience.
The eleven written case scenarios of Bauman et al (20) included the following presenting problems: trauma & wounds in four cases, infectious disease in six cases and intoxication in

one case. The age of the children in the scenarios varied from 8 months to twelve years and 81,8% was male.

Study procedure

The presence of comorbidity varied over the scenarios. Comorbidity was defined as a non-complex or complex comorbidity according to the Pediatric Medical Complexity Algorithm (PCMA) (21). In the scenarios with added comorbidities, half of the nurses had three scenarios with non-complex comorbidity and two scenarios with complex comorbidities. The other half of the nurses, had two scenarios with non-complex comorbidity and three scenarios with complex comorbidities. The data was collected by visiting the ED's and requesting the nurses to participate in the study during shift changes.

The ED's were visited multiple times until the sample size was reached. The scenarios were presented on paper. To prevent bias, the nurses were told that the study was about the inter-rater reliability in general.

The study was conducted according to the principles of the Declaration of Helsinki (22) and in accordance with the Medical Research Involving Human Subjects Act (WMO) (23). The requirement for informed consent was waived by the medical ethical commission.

Statistical analysis

The interrater agreement of nurses over the triage urgency was analysed using Krippendorff's alpha (Kalpha) (24,25). The Kalpha was used because it is suited to determine a correlation coefficient with multiple raters and ordinal data. A Kalpha of >0.667 and <0.8 was seen as acceptable and a Kalpha of >0.8 was seen as reliable (25). Kalpha determines the percentage of agreement between multiple raters, rating the same scenarios. Although the comorbidities in the scenarios differ, they were treated as if they were similar. This way, the influence of comorbidity on the interrater reliability was measurable. To compare the triage levels of urgency between the scenarios with and without comorbidity a chi-square test was used. Scenarios with missing or multiple - urgency allocation were excluded.

Part 2 - validation

Study design

This secondary data-analysis was performed in children with trauma as part of an ongoing study on validation of the MTS. This was a quantitative cross-sectional study.
All children under sixteen years of age, who visited the ED of the Erasmus University Medical Centre – Sophia children's hospital in Rotterdam between August 5, 2009 and January 1, 2016, were included if they were triaged with a trauma flowchart. These trauma flowcharts are: bites and stings, burns and scalds, chemical exposure, corpus alienum, limb problems, head injury, limping child, assault, neck pain, back pain, major trauma, fall of height, wounds, torso injury, falls, abused or neglected child, major incidents-primary and major incidents-secondary. The reason for using the flowcharts as a definition for trauma or non-trauma is comparability to other validity studies, which used the same definition for trauma (10,16). The ED receives about 9000 children annually.

Sample size calculation

The sample size calculation was based on comparable research. An expected sensitivity of 0.55 with a width of 0.44 for the 95% confidence interval (CI) and an expected specificity of 0.95 with a width of 0.01 of a 95% CI were used and were based on comparable research in a teaching- and university hospital. The needed sample size was 1905 (9). The database for validating the MTS in children with trauma has a sufficient amount of children.

Data collection

The patients characteristics, MTS triage level, flowcharts, and discriminators were extracted automatically from the electronic information systems.

Study procedure

To validate the MTS in children with trauma the triaged urgency level was compared with a reference standard (figure 2). There was no validated 'golden' standard in trauma triage. To define an appropriate reference standard for children with trauma who entered the ED an adapted reference standard was designed, based on the reference standard of Zachariasse et al. (16). Two other reference standards and expert opinion were used to adapt this reference standard to children with trauma (10,16,27). The adapted reference standard includes: mortality, resuscitation, paediatric intensive care unit (PICU) admission, abnormal vital signs, abnormal consciousness, severe pain, hospital admission, imaging with CT or MRI, extended surgery and intravenous medication.

The reference standard exist of three categories: “C1 Immediate”, “C2 Urgent” and “C3 standard”. Three categories were used instead of the five MTS levels because of the low prevalence of the highest urgency level, better comparability to other studies and clinical relevance.
The patient was placed in the highest urgency category of the reference standard in which he/she meets at least one criteria (figure 2).
The study was conducted according to the principles of the Declaration of Helsinki (22) and in accordance with the Medical Research Involving Human Subjects Act (WMO) (23). The requirement for informed consent was waived by the medical ethical commission.

Insert figure 2 here

Statistical analysis
First, the validity of the MTS was determined by assessing the sensitivity and specificity. The triage levels of urgency were compared with the reference standard. There were three ordinal outcome variables of the reference standard: 1 immediate, 2 urgent and 3 standard. To calculate the sensitivity and specificity the data was dichotomized in: high urgency (urgency level 1 and 2 of the MTS and 1 of the reference standard) and low urgency (urgency level 3, 4 and 5 of the MTS and 2 and 3 of the reference standard). Second, the agreement between level 3 of the MTS and 2 of the reference standard was calculated by descriptive statistics. Furthermore, the percentages of over- and under-triage were determined in subgroups to explore groups with more prevalent over- or under-triage. This was done for ‘age’ and flowchart’. In case of missing data, only the available data was used, because missing data was not likely to be random, for example less vital signs were measured in non-urgent patients. Outliers were checked and in case of extreme outliers these values were excluded. An extreme outlier was defined as a clinically impossible outcome.

Results

Part 1: interrater-reliability

37 Nurses were asked to participate, but one nurse did not return the written case scenarios and another nurse gave multiple urgency allocations at two scenarios, these were excluded. In total 36 nurses triaged 394 scenarios. The mean years of experience working with the MTS was 9.2. Of the nurses who were primarily included in this study, the mean age was 44 years old and 45.8% were female.
Further characteristics of the study population are shown in table 1A.

Insert table 1A here

The Kalpha for all scenarios was acceptable (0.65 95%CI:0.60-0,69), results for scenarios without comorbidity were similar (0.64 95%CI 0.60-0.69). The Kalpha for scenarios with added comorbidities was higher (0.71 95%CI: 0.66-0.75) and when looking at the Kalpha for the different types of comorbidity, the Kalpha for non-complex comorbidity was 0.78 (95%CI 0.73-0.82). Which was slightly higher than for complex comorbidity (0.69 95%CI 0.64-0.73) (table 2). The Kalpha was acceptable in the scenarios with and without comorbidity.

Insert table 2 here

In the scenarios with comorbidity more cases were triaged as immediate or very urgent (figure 3). A significant difference was found between triage level in scenarios with- and without comorbidities (X^2test p=0.01).
Although no difference was found between non-complex and complex comorbidities, when looking at the level of the triage urgency children with complex comorbidities might have a higher urgency level, although not statistically proven (figure 4).

Insert figure 3 here
Insert figure 4 here

Part 2: validation

In total, 14,535 children were triaged with a trauma flowchart from the 44,016 children who visited the ED. Of the trauma children 7% was triaged as immediate or very urgent with the MTS, 59.2% was male and the most frequently used flowchart was limp problems with 54.6%.
Further characteristics of the study population are shown in table 1B.

Insert table 1B here

The Manchester triage system was compared with the reference standard (figure 5). In the category ‘immediate’ there was 65% agreement between the MTS and the reference standard, Of the children who should have been triaged as ‘immediate’ 114 children were under-triaged, of whom 25 (7.7%) children were under-triaged as ‘standard’. In the category ‘urgent’ there was 62% agreement and in category ‘standard’ 55% agreement was reached. Of the children who should have been triaged as ‘standard’ by the reference standard 244 (2.5%) were over-triaged as ‘immediate’.

Insert figure 5 here

The sensitivity of all children who visited the ED and were triaged with the MTS (with and without trauma flowchart) was 65 (95%CI 63-66) and their specificity was 89 (95%CI 89-90) (table 3). The sensitivity (65%) was the same for children with and without trauma. The specificity was 94 (95%CI 94-95) in children with trauma and 87 (95%CI 86-87) in children without trauma. When the trauma children were separated in minor- and major trauma, there was a difference in sensitivity and specificity. In children with minor trauma the sensitivity was low (50 95%CI: 43-56) and specificity was high (95 95%CI 95-96). In major trauma the sensitivity was high (94 95%CI: 88-97) and the specificity was low (20 95%CI: 15-26) (table 3).

Insert table 3 here

Under and over-triage differed per age category and per flowchart. Under-triage was more common in children under 12 months old (15.5%) compared to older children (8%) ($p<0.01$) (figure 6). Between the different flowcharts the following flowcharts showed more under-triage: ‘corpus aliena’, ‘head injury’ and ‘falls’. On the other hand, over-triage was more common in the flowcharts: ‘torso injury’, ‘back- and neck pain’ and ‘severe trauma’ (figure 7).

When looking at children under 12 months of old in different flowcharts ‘head injury’ showed a higher percentage of under-triage (28%) than other flowcharts. Although none of the flowcharts with N>100 in children under 12 months old showed less than 10% under-triage (figure 8).

Insert figure 6 here
Insert figure 7 here
Insert figure 8 here

Discussion

For measuring the quality of triage, the interrater reliability and validity are important. This research specifically focused on children with comorbidity and trauma. The Manchester Triage System is used in children and proven effective. This study showed that it can also be used in children with comorbidity, however in children with trauma under one year of age the validity was not optimal and needs improvement.

In the interrater study it seemed that comorbidity had a positive influence on the agreement between nurses of the MTS urgency level. This was an unexpected outcome since comorbidity was not a discriminator in the MTS.
Although there was no significant difference between the subcategories non-complex and complex comorbidity, the Kalpha of non-complex comorbidity might have been higher than for complex comorbidity. This study implicates that it is unnecessary to add comorbidity as a variable in the MTS for improvement of the interrater-agreement. However, this cannot be concluded since the validity of children with comorbidity is unknown. Besides, only nurses in two of the hospitals have triaged scenarios with comorbidity instead of the nurses of all four participating hospitals. It would be recommended to extend this study to multiple hospitals.
The frequency of usage of the individual urgency levels in this study (figure 3 & 4) was not representative for the frequency of usage of the urgency levels in real practice because these were written case scenarios with limited clinical information. Some of the definitions were also a limitation. For example, the use of 'complex comorbidity' in the interrater study was defined according to literature (21). However, it was unknown if nurses interpret the comorbidities as complex or non-complex. This could explain why no significant difference was found in urgency level between children with non-complex and complex comorbidities.
A strength of this study was the comparability with real clinical practice. For example, in the interrater study, 30% of the scenarios had an added comorbidity, this was comparable with the 27.4% comorbidity in children presenting at the ED of a university medical centre (9).
Another strength was the reached sample size. As well as the diversity in sex, age and working experience of the included nurses. Furthermore the risk of selection bias was minimal, because the written case scenarios were unchanged and the comorbidities were randomly added. Also, only one of the 37 nurses who was asked to participate did not return the written case scenarios.
When this study was compared to literature the Kalpha in this study seemed lower in children without comorbidity than the weighted kappa of another study with partially the same scenarios (weighted kappa 0,83 95% CI 0,74-0.91) (12). This might be explained because in this study only the scenarios with a reference level of very urgent, urgent or standard were

used. So, in all cases lower and higher triage was possible. This could have increased the chance of incorrect triage. Furthermore, this study was done in ED's with children and adults mixed, while the other study was performed on an ED with children only. Therefore, it could be that these nurses were more experienced or better trained in triaging children. Another study shows that training can improve the interrater reliability (28). However this study was conducted in a different setting.

In the validity study, the overall validity of the MTS in children with trauma seemed moderate to good. However, the sensitivity in minor trauma was poor. Especially in children with the flowcharts 'falls', 'head injury', 'corpus alienum' and in age category '0-1' there was more under-triage. In major trauma the sensitivity was excellent but the percentage of over-triage was very high. However, this was seen as acceptable because it was a small group in which under-triage could have a fatal outcome. On the other side, children with minor trauma do need further attention especially in the age group under 12 months. In children under 12 months of age with head injury under-triage was even more common. This can partially be explained because of the difficulty of recognising 'abnormal consciousness' in such small children. For children without 'abnormal consciousness' this was harder to explain. Therefore, another explanation for undertriage in children under 12 months of age could be children who were admitted for observation only or children who had a CT-scan to be sure there was no severe trauma. A solution could be to add the variable 'age 0-1' to the flowchart 'head injury' as very urgent. Another study showed that clinical prediction rules could also lower the use of the CT-scan (29). This might also help to prevent some undertriage. However, this was a single centre study, so it would be recommended to repeat this study in other settings first. Another limitation was that trauma was defined with the trauma flowcharts, because it was possible for non-trauma children to be triaged with a trauma flowchart. For example, the flowchart 'wounds' could also include children who revisited the hospital with problems because of a surgical wound. On the other hand, this method was comparable with other studies. Also, the reference standard was not validated, but there was no golden standard for the validation of triage systems at the time the study was conducted. This trauma reference standard was adapted from other used reference standards and with expert opinions to make it applicable in this study population.
A strength of this study was the large sample size, which made it possible to research different subgroups. Another strength of both the interrater study and the validity study was the objective reporting guideline (30). In the trauma study the sensitivity and specificity in children are comparable with the sensitivity and specificity of another study which used multiple hospitals (9). It might be that this specific trauma reference standard gave a slightly better outcome.

Conclusion and recommendations

The interrater reliability for children with comorbidity was acceptable. In children with comorbidity triage errs to the safe side and showed significant difference in urgency level compared to children without comorbidity. No difference was seen between non-complex and complex comorbidity. This study implicates for clinical practice that it would be unnecessary to add comorbidity as a variable in the MTS for improvement of the interrater-agreement. However, it is recommended to do further research of the influence of comorbidities on the interrater reliability with a larger sample size and to research the validity of the MTS in children with comorbidity.

The validity of the MTS in children with trauma was functional, the MTS distinguished the severe trauma's (high sensitivity) from the minor trauma's (high specificity). However, it is recommended to further study an improvement of the MTS in children under the age of 12 months and in children triaged with the flowcharts 'falls', 'head injury' and 'corpus alienum'.

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Tables and Figures

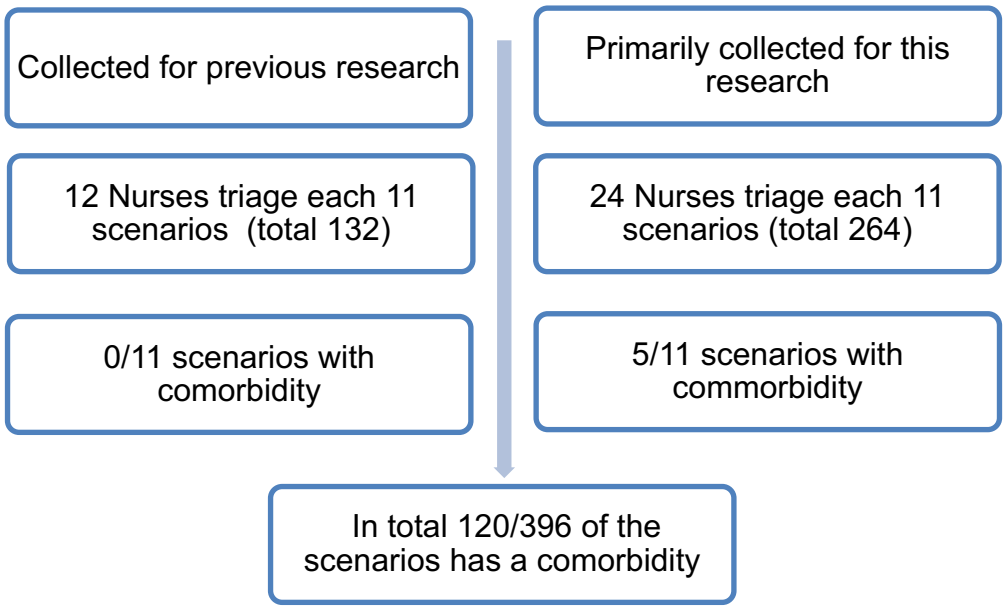

Figure 1. Study design for interrater-reliability of the MTS.

Reference Standard

Reference category	Corresponding MTS category	Maximum waiting time	Criteria
C1 Immediate	1 Immediate 2 Very urgent	0 minutes 10 minutes	• Mortality • Resuscitation • PICU admission • Abnormal vital signs • Abnormal consciousness, defined as 'unresponsive', 'currently fitting' or 'responds to voice or pain'. • Severe pain, defined as a pain score of 9-10 on a scale of 0-10.
C2 Urgent	3 Urgent	60 minutes	• Hospital admission • Imaging with CT or MRI • Extended surgery defined as: drains, tracheacanule, reposition or traction. • Intravenous medication
C3 Standard	4 Standard and 5 non-urgent	120-240 minutes	• None of the above

Figure 2. Reference standard.

Table 1A
Characteristic for the interrater-reliability part of this study

	Frequency	**Percentage**	**Not asked (%)**
Total	36	100%	
Collected for previous research	12	33.3%	
Collected for this research	24	66.7%	
Female	11	45.8%	13 (54.1%)
Male	13	54.1%	”
Dutch university hospital	17	47.2%	
Dutch teaching hospital	13	36.1%	
English university hospital	3	8.3%	
Austrian university hospital	3	8.3%	
	Mean	**Standard deviation**	**Not asked/missing (%)**
Age in years	44	12.1	13 (36.1%)
Years of working with children	8.7	7.9	15 (41.7%)
Years of experience with the MTS	9.2	5.1	

Table 1B
Characteristics for the trauma validation part of this study

	Frequency	**Percentage**
Total	14535	100%
MTS Urgency		
Immediate and very urgent	1021	7%
Urgent	6888	47.4%
Standard and non-urgent	6626	45.6%
Gender		
Male	8609	59.2%
Female	5926	40.8%
Age		
0-1 year	826	5.7%
1-3 year	2717	18.7%
3-8 year	4460	30.7%
> 8 year	6532	44.9%
Flowchart		
Head injury	1360	9.4%
Limp problem	7933	54.6%
Wounds	2444	16.8%
Falls	1187	8.2%
Corpus alienum	424	2.9%
Reference standard		
ICU admission or mortality	171	1.2%
Abnormal vital signs	1047	2.4%
Abnormal consciousness	1408	3.2%
Severe pain	38	0.3%
Hospital admission	1730	11.9%
Extended surgery	2199	15%
IV medication	944	6.5
CT or MRI	582	4%

Table 2
Agreement with and without comorbidity

	Krippendorff's alpha (95% CI)
Without comorbidity	0.64 (0.60-0.69)
With comorbidity	0.71 (0.66-0.75)
Non-complex comorbidity	0.78 (0.73-0.82)
Complex comorbidity	0.69 (0.64-0.73)
Total	0.65 (0.60-0.69)

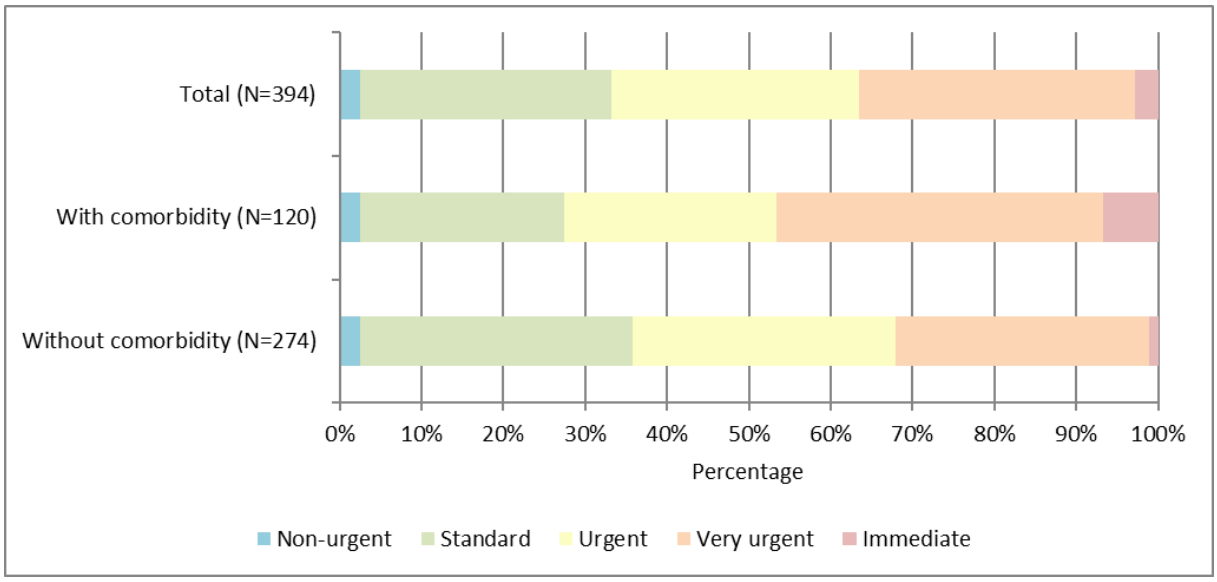

Figure 3. Triage urgency level with- and without comorbidity, based on the scenarios. N= the number of triaged cases.

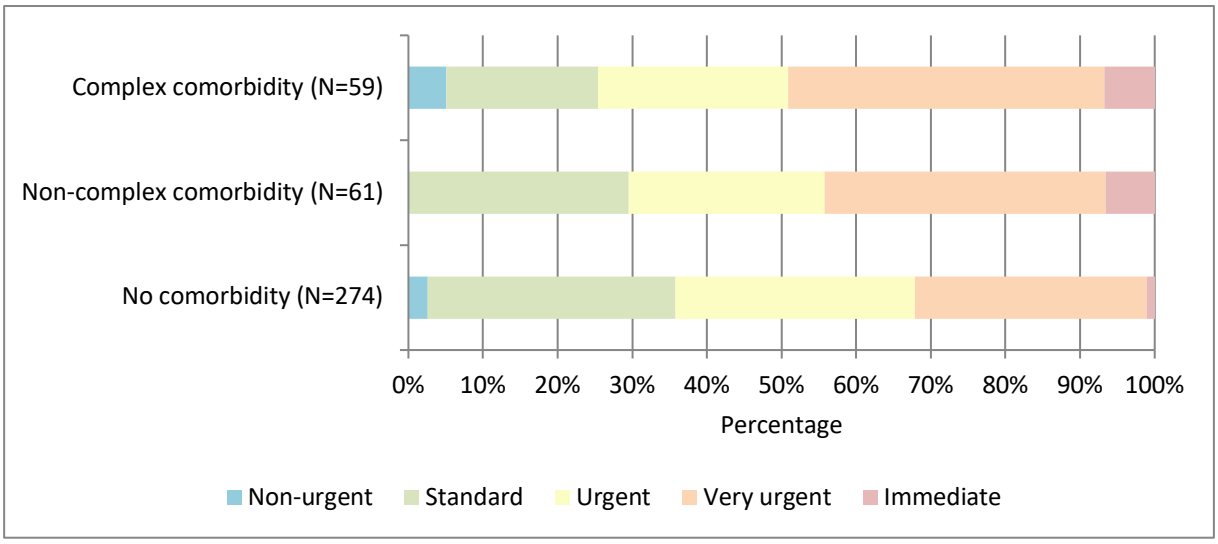

Figure 4. Triage urgency levels between types of comorbidity. N= the number of traiged cases.

		Reference standard			
		Immediate (%)	**Urgent (%)**	**Standard (%)**	**Total**
MTS triage	**Immediate**	210 (64,8)	567 (13)	244 (2,5)	1021
	Urgent	89 (27,5)	2686 (61,6)	4113 (41,8)	6888
	Standard	25 (7,7)	1108 (25,4)	5493 (55,8)	6626
	Total	324 (100)	4362 (100)	9850 (100)	14535

- *Correct triage*
- *1 level over-/ under-triage*
- *2 levels over-/ under-triage*

Figure 5. Overview of agreement in 14535 children (trauma study).

Table 3

Sensitivity and specificity (trauma study)

	N	Sensitivity (95% CI)	Specificity (95% CI)	DOR (95% CI)
Total – all children at the ED	44016	65 (63-66)	89 (89-90)	15.4 (14.2-16.6)
Trauma total	14535	65 (59-70)	94 (94-95)	30.4 (24-38.6)
Minor trauma	14216	50 (43-56)	95 (95-96)	20.5 (15.5-27.1)
Major trauma	319	94 (88-97)	20 (15-26)	3.8 (1.6-8.7)

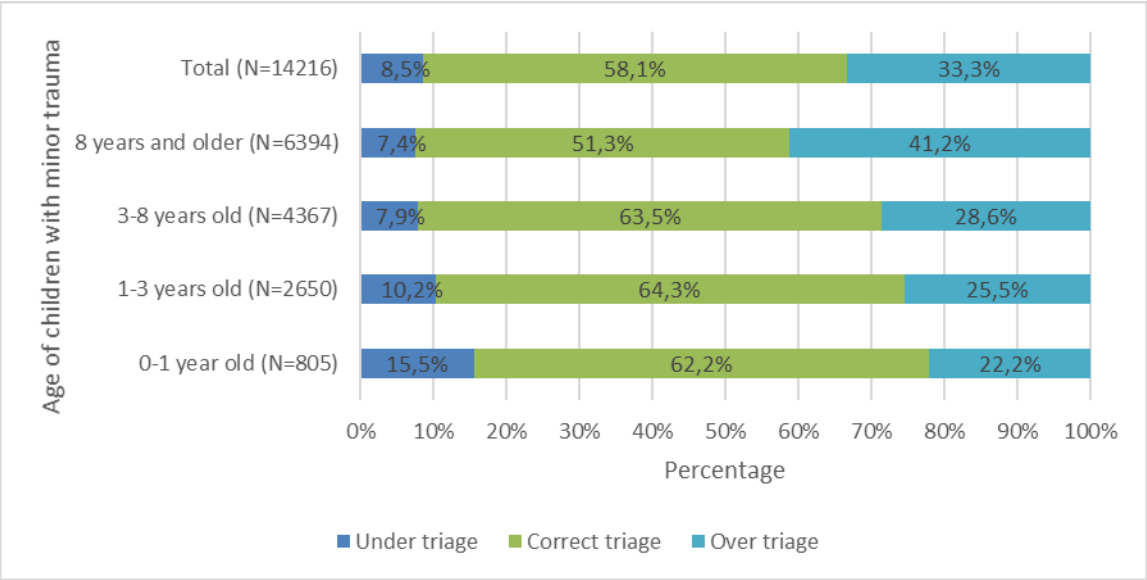

Figure 6. Under-, correct- and over-triage per age in children with minor trauma (trauma study).

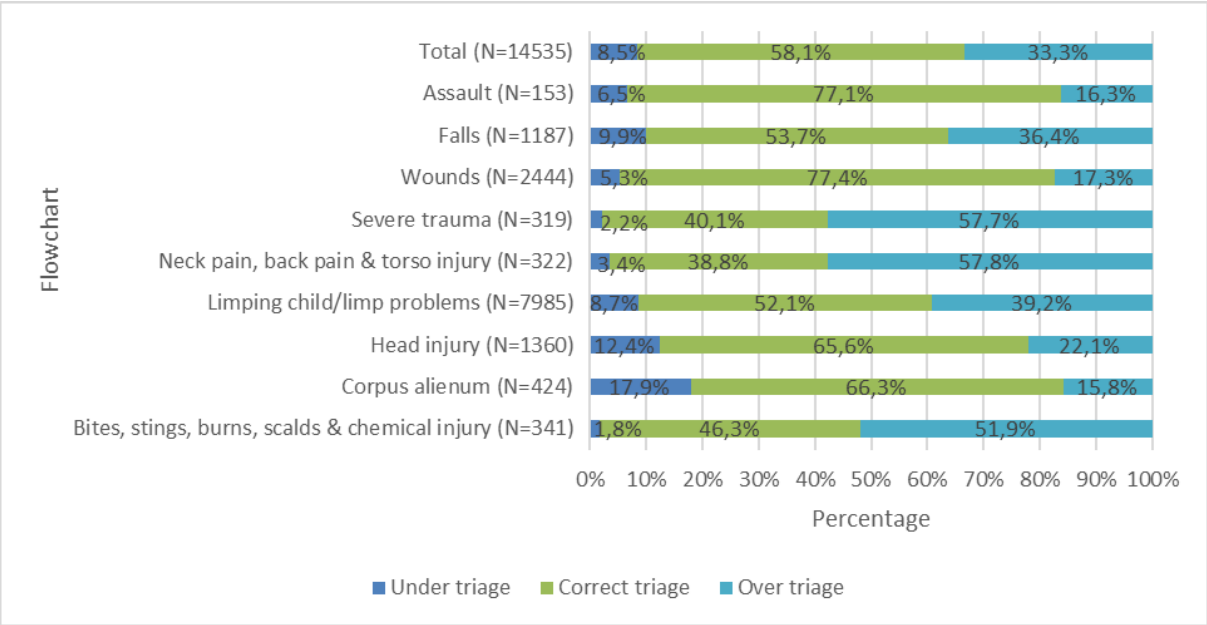

Figure 7. Under-, correct- and over-triage per flowchart in all trauma children (trauma study).

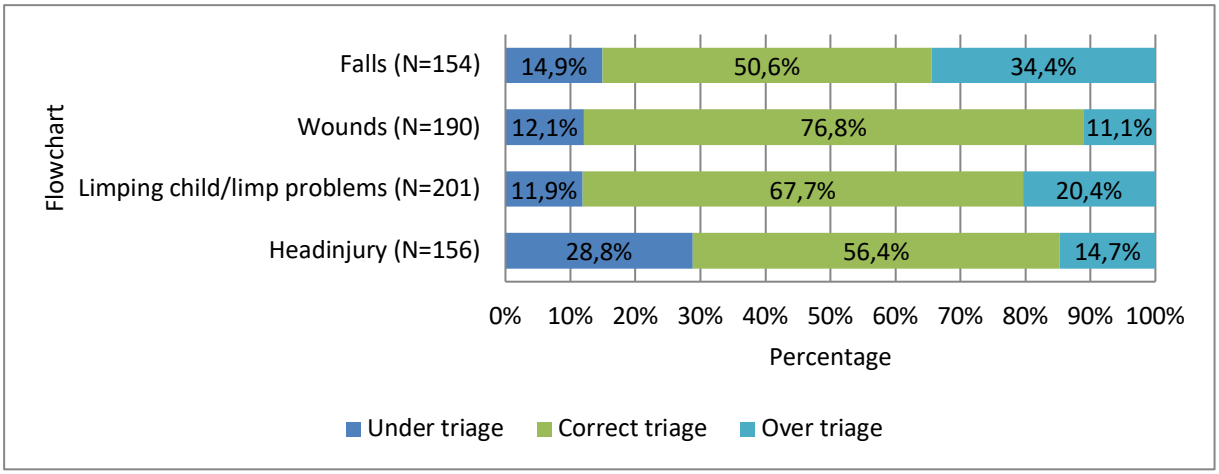

Figure 8. Under-, correct- and over-triage per flowchart in children aged younger than 12 months (trauma study). Only the flowcharts with N>100 are shown in this figure.