Original Article

Validation of different pediatric triage systems in the emergency department

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BACKGROUND: Triage system in children seems to be more challenging compared to adults because of their different response to physiological and psychosocial stressors. This study aimed to determine the best triage system in the pediatric emergency department.

METHODS: This was a prospective observational study. This study was divided into two phases. The first phase determined the inter-rater reliability of five triage systems: Manchester Triage System (MTS), Emergency Severity Index (ESI) version 4, Pediatric Canadian Triage and Acuity Scale (CTAS), Australasian Triage Scale (ATS), and Ramathibodi Triage System (RTS) by triage nurses and pediatric residents. In the second phase, to analyze the validity of each triage system, patients were categorized as two groups, i.e., high acuity patients (triage level 1, 2) and low acuity patients (triage level 3, 4, and 5). Then we compared the triage acuity with actual admission.

RESULTS: In phase I, RTS illustrated almost perfect inter-rater reliability with kappa of 1.0 ($P<0.01$). ESI and CTAS illustrated good inter-rater reliability with kappa of 0.8–0.9 ($P<0.01$). Meanwhile, ATS and MTS illustrated moderate to good inter-rater reliability with kappa of 0.5–0.7 ($P<0.01$). In phase II, we included 1 041 participants with average age of 4.7±4.2 years, of which 55% were male and 45% were female. In addition 32% of the participants had underlying diseases, and 123 (11.8%) patients were admitted. We found that ESI illustrated the most appropriate predicting ability for admission with sensitivity of 52%, specificity of 81%, and AUC 0.78 (95%CI 0.74–0.81).

CONCLUSION: RTS illustrated almost perfect inter-rater reliability. Meanwhile, ESI and CTAS illustrated good inter-rater reliability. Finally, ESI illustrated the appropriate validity for triage system.

KEY WORDS: Triage; Pediatric; Emergency department

INTRODUCTION

Overcrowded emergency department (ED) leads to a delay in treatment of critically ill patients, increasing the rate of morbidity and mortality.[1] Therefore, the triage system in emergency care is an important tool to prioritize seriously ill children.[2] Triage system in children seems to be more challenging compared to adults because of their different response to physiological and psychosocial stressors.[3,4] There are four international triage systems:[5] Manchester Triage System (MTS), Emergency Severity Index (ESI) version 4, Pediatric Canadian Triage and Acuity Scale (CTAS), and Australasian Triage Scale (ATS), have been using for triage in children at ED.

However, Faculty of Medicine Ramathibodi Hospital,

Bangkok, Thailand, has invented and used its own triage system, which is called "Ramathibodi Triage System (RTS)". Up till now, no study has compared four international pediatric triage systems in emergency department in the same group population. Moreover, Thailand has no standard pediatric triage system. As a result, this leads to our objective to find the best triage system in predicting patient acuity. Nevertheless, there is no gold standard for decision of urgency of treatment. Therefore, our study used admission to imply severity of illness and urgency of treatment. The objective of this study were to assess and compare the reliability of 5 triage systems (CTAS, ESI, MTS, ATS and RTS), as well as its validity for predicting hospital admission in a prospective cohort of pediatric patients at emergency department.

METHODS

Study design

This study was conducted as prospective, single-center, and observational study to determine the reliability and validity of CTAS, ESI, MTS, ATS and RTS. The medical ethics committee of Mahidol University approved this study and informed consent was obtained from all the participants.

Study setting and population

This study was performed at Ramathibodi Hospital (tertiary care, university hospital with -hour ED services) with approximately 10 000 pediatric patients per annual. Ramathibodi Hospital has used RTS for more than a decade. Data were collected in all children aged under fifteen years old presenting to the ED from the period of April to July 2015 at Ramathibodi Hospital, Mahidol University. All pediatric triage nurses and pediatric residents in the study have been formally trained how to apply all triage systems. In this study, patients presented with trauma and incomplete records were excluded.

Triage system

Each triage system used chief complaint and physiological parameters such as body temperature, heart rate, respiratory rate, oxygen saturation, blood pressure, work of breathing, and capillary refill in prediction of illness's severity. Each triage system has five levels of severity. Level 1 triage is the most emergency treatment, whereas level 5 triage is the least emergency treatment.

Manchester Triage System (MTS)[6–11]

MTS was first used in the England. It has 52 flowcharts representing a chief complaint, of which 49 flowcharts are suitable for children. Based on the flowcharts, general discriminators such as life threatening conditions and conscious level are considered. Then selected discriminator identifies 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.

Emergency Severity Index version 4 (ESI)[12–13]

ESI was developed in the United States with five levels. Patients requiring immediate life-saving interventions and must be seen immediately are level 1. Patients in high risk conditions, who are confused, lethargic, disoriented, having severe pain, distress and highly abnormal vital signs and should be seen within ten minutes, are level 2. Level 3 is for patients who are expected to require two or more resources, which can be diagnostics in term of laboratory investigations or electrocardiogram. Level 4 is for patient who are expected to require one resource, and level 5 if no resources are expected to be required.[2] The specific flowchart for children with fever was added in the fourth version of ESI.[2]

Canadian Triage and Acuity Scale (CTAS)[14–19]

CTAS is based on a list of patients presenting complaints with first- and second-order modifiers for specific conditions. Its principle operational objective determines the time for the patient's initial assessment by a physician.[3] 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.[4]

Australasian Triage Scale (ATS)[20–22]

ATS can be divided into primary and secondary triage decisions. Primary triage decisions are based on the triage assessment, allocation of a triage category and patient deposition. Meanwhile secondary triage decisions are based on the initiation of nursing interventions for emergency care and promote patient comfort.[2] Medical care should be delivered immediately for level 1, within 10 minutes for level 2, within 30 minutes for level 3, within 60 minutes for level 4 and within 120 minutes for level 5.

Ramathibodi Triage System (RTS)[23]

RTS has five levels. It uses computer for patient's categorization, which are based on chief complaint and vital signs. Criteria of each level of triage were constructed by experts and specialists.[5] Medical care should be delivered immediately for level 1, within 30 minutes for level 2 and non-urgency for level 3, 4, 5.

Admission

Decision of admission were made by proxy of severity of illness and based on the decision of each pediatric resident in the department.

Study protocol

This study was conducted in two phases. The first phase of the study was to determine the inter-rater reliability between each triage. Two triage pediatric residents and two nurses were blindly asked to determine the triage level in each patient for the first twenty patients. Inter-rater reliability between pediatric triage nurses and pediatric residents, among pediatric residents and between the nurses were measured using Kappa statistics.

After ensuring good inter-rater reliability (>0.70), the second phase of the study was started. The five triage systems were conducted by pediatric triage nurses and pediatric residents during each shift. To analyze validity

of each triage system, patients were divided into high acuity (triage level 1, 2) and low acuity (triage level 3, 4, 5). Then the levels of acuity were compared with admission, which implied the severity of illness and urgency of treatment. Validity was measured using area under the receiver operating characteristics ROC curves.

Data analysis
Sample size
Sample size was calculated from the probability of expected sensitivity of 0.63 in the previous study.[7] Therefore, our sample size of 920 patients was sufficient to validate the five triage systems.

Statistical analysis
All data were collected and reviewed by both authors. All statistical analyses were performed using SPSS version 17.0 (IBM corporation, Armonk, New York).

RESULTS
In phase I, RTS illustrated perfect inter-rater reliability with kappa of 1 ($P<0.01$). ESI and CTAS illustrated good inter-rater reliability with kappa of 0.8–0.9 ($P<0.01$). ATS and RTS illustrated moderate to good inter-rater reliability with kappa of 0.5–0.7 ($P<0.01$). These results were shown in Table 1.

Phase II illustrated that ESI was the most appropriate predictor of admission and urgency treatment. A total of 1 103 patients were enrolled during the study period. We excluded 62 patients due to incomplete record and exclusion criteria. Thus, 1 041 participants with average age of 4.7±4.2 years were included for validation analyses, of which 55% were male and 45% were female. In addition 32% of the participants had underlying diseases, and 123 (11.8%) patients were admitted. Diagnoses were categorized according to the systems and were summarized along with patient demographic data as illustrated in Table 2. The second phase determined the predicting ability of each triage system using area under the receiver operating characteristics curves (AUC), sensitivity and specificity as shown in Table 3 and Figure 1.

Table 1. Inter-rater reliability with Kappa analysis

Triage system	Doctor - Doctor	Nurse - Nurse	Doctor - Nurse
MTS	0.72	0.61	0.56
ESI	0.81	0.73	0.9
CTAS	0.818	0.72	0.81
ATS	0.69	0.68	0.55
RTS	1	1	1

$P<0.01$.

Table 2. Patient characteristics

Characteristics	N	Cumulative percentage (%)
Gender	1 041	100
Male	598	57.4
Female	443	42.6
Underlying diseases		
None	691	66.4
Yes	350	33.6
Hematology	94	9.0
Allergy	75	7.2
Respiratory	76	7.3
Neurologic	42	4.0
Gastrointestinal	17	1.6
Cardiovascular	16	1.5
Genetics	7	0.7
Renal	3	0.3
Endocrine	1	0.1
Miscellaneous	19	1.8
Chief complaint		
Fever	358	34.4
Gastrointestinal	247	23.7
Respiratory	220	21.1
Skin and mucosa	69	6.6
Neurology	26	2.5
Ear problem	26	2.5
Eye problem	23	2.2
Hematology	15	1.4
Musculoskeletal	11	1.1
Renal	7	0.7
Cardiovascular	6	0.6
Miscellaneous	33	3.2
Diagnosis		
Respiratory	376	36.1
Gastrointestinal	241	23.2
Infectious	244	23.4
Skin	52	5.0
Neurology	27	2.6
Hematology	19	1.8
Allergy	13	1.2
Renal	9	0.9
Cardiovascular	7	0.7
Muscle strain	11	1.1
Endocrine	1	0.1
Miscellaneous	41	3.9

Table 3. Sensitivity, specificity and ROC curve of five triage systems

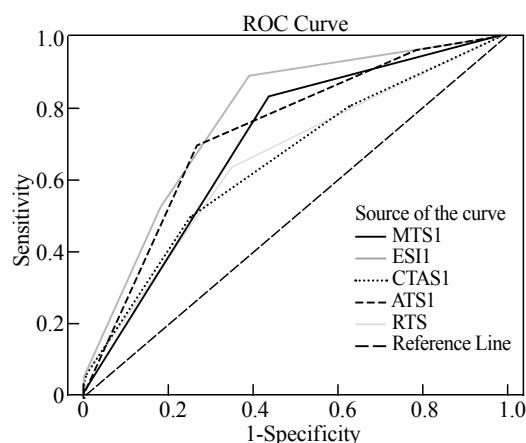| Triage system	Sensitivity	Specificity	ROC curve
MTS	57%	69%	0.70 (95%CI 0.66–0.744)
ESI	52%	81%	0.78 (95%CI 0.73–0.81)
CTAS	50%	74%	0.64 (95%CI 0.59–0.70)
ATS	13%	94%	0.73 (95%CI 0.69–0.77)
RTS	64%	64%	0.66 (95%CI 0.60–0.70)

Figure 1. ROC curves of five triage systems.

We found that ESI illustrated the most appropriate predicting ability for admission, i.e., AUC 0.78 (95%*CI* 0.74–0.81), sensitivity of 52% and specificity of 81%. MTS illustrated AUC 0.7 (95%*CI* 0.66–0.74), sensitivity of 57% and specificity of 69%. CTAS illustrated AUC 0.64 (95%*CI* 0.59–0.70), sensitivity of 50% and specificity of 74%. ATS illustrated AUC 0.73 (95%*CI* 0.69–0.77), sensitivity of 13% and specificity of 94%. Finally, RTS illustrated AUC 0.66 (95%*CI* 0.60–0.70), sensitivity of 64% and specificity of 64%.

DISCUSSION

Four triage systems are extensively used to triage children in emergency department across different part of the world. Several studies were performed to assess the reliability and validity of these systems in children. The best triage was the one that can accurately detect urgency of treatment, leading to decreases in overcrowded emergency department, morbidity and mortality.[24–25]

Study on reliability of pediatric triage systems using inter-rater agreement analyzed by Cohen's kappa. The interpretations of kappa (*K*) are: poor if *K*<0.20, fair if 0.21<*K*<0.40, moderate if 0.40<*K*<0.60, good if 0.61<*K*<0.80 and very good if *K*>0.80 (95% confidence interval).[26] Most of the studies using written case scenarios for testing triage reliability. The studies of ESI[12–13] seem to be the most reliability which has very good inter-rater agreement (kappa 0.84–1). MTS study from the Netherlands[8] has a good reliability, kappa 0.62–0.83. CTAS study[15] found that the reliability was moderate (kappa 0.51–0.61). The study of ATS from Australia[22] has poor to moderate reliability (kappa 0.21–0.4) respectively. The results of our study showed the same trend. The most reliability of different five triage systems are very good for RTS (kappa 1) and ESI (kappa 0.81–0.90), good for CTAS (kappa 0.72–0.82), moderate for MTS (kappa 0.56–0.72) and moderate for ATS (kappa 0.55–0.69) with better inter-rater reliability compared to previous study.[22] Computerized triage systems showed a better agreement compared to the triage without the computerized system, and resulted in better triage reliability.[27] This may explain our result of a perfect inter-rater reliability of RTS (kappa 1), which using computerized application for triage in the study compared to the other triage systems without computerized application. Therefore, a computerized application of triage system should be used for the reliability of triage.

Since the measurements used for validity of studies are different, a comparison between triage systems cannot be made on how they predict the "true" urgency. Different approaches are used to assess validity of triage. The outcome measurement such as ICU admission, hospitalization, resource uses, length of stay in ED or the cost of ED consultation are used.[13,15] However, from the previous studies and the design of the triage systems, some important points can be made. Study on outcome measurement by using admission rate found that both ESI[13] and CTAS[15] triage system can predict the admission and have a good correlation between urgency and admission. One study showed the other aspect of outcome measurement by comparison of three triage systems [Informally Structured Triage System (ISS), ESI and MTS] with the reference standard (vital signs, diagnosis, resource use, admission rate, and follow-up) and found that they were equally valid. However, the ESI showed the highest percentage of under triage whereas the ISS showed the lowest percentage of undertriage.[28] Another study compared the MTS with the reference standard, showing sensitivity of 63% (95%*CI* 59–66) and specificity of 79% (95%*CI* 79–80).[8] Our study was different from other studies as we compared between each triage and admission (implied urgency treatment). However, the measurement of outcome was similar to previous studies. In particular, our study showed the sensitivity and specificity of MTS of 57% and 69%, respectively. In overall, the results of our study showed that ESI expressed the best validity followed by ATS, MTS, RTS and CTAS based on outcome measurement by using triage urgency for prediction of admission respectively.

Limitations

Our study had some limitations which were quite similar to other studies.[25] Now there is no gold standard for decision of urgency of treatment. Therefore, our study used admission to imply severity of illness and urgency of treatment. The under or over triage categorized maybe the appropriate outcome measurement in the further study. The other limitation was that our study investigated only at a single pediatric hospital, and the results may not be generalizable to other institutions.

Area of future research

We think it would be important for future studies to investigate multiple pediatric hospitals as the results would be more generalized and reliable. Another important area would be searching for a gold standard for detecting severity of illness and urgency of treatment, and accurately determining the best triage system.

CONCLUSION

In conclusion, our study showed that RTS was the most appropriate triage system in term of reliability among

five triage systems. In particular, RTS showed almost perfect inter-rater reliability with kappa of 1 ($P<0.01$). In the aspect of triage validity, we found that ESI illustrated the most appropriate validity for triage system by express highest AUC to predicting ability for admission.

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