Improving the Safety of the Manchester Triage System for Children with Congenital Heart Disease

Franziska Leeb
Medical University Vienna
Ursula Sharma
Medical University Vienna
Lusine Yeghiazaryan
Medical University Vienna
Henriëtte A. Moll
Erasmus MC-Sophia Children's Hospital
Susanne Greber-Platzer (susanne.greber-platzer@meduniwien.ac.at)
Medical University Vienna https://orcid.org/0000-0002-3706-8370

Research Article

Keywords: Emergency Medicine, Manchester triage system, Safety, Modification, Children with congenital heart disease

Posted Date: December 21st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1138328/v1

Abstract

This study is a prospective evaluation of the validity of a Manchester Triage System (MTS) modification for detecting under-triaged pediatric patients with congenital heart disease (CHD). Children with CHD visiting the emergency unit of the Department of Pediatrics and Adolescent Medicine, Vienna General Hospital, in 2014 were included. The MTS modification updated the prioritization of patients with complex syndromic diseases, specific symptoms related to chronic diseases, decreased general condition (DGC), profound language impairment, unknown medical history, or special needs. A four-level outcome severity index based on diagnostic and therapeutic interventions, admission to hospital, and follow-up strategies, was defined as a reference standard for the correct clinical classification of the MTS urgency level. Of the 19,264 included children, 940 had CHD. Of this group, 266 fulfilled the inclusion criteria for the modified triage method. The MTS modification was significantly more often applied in under-triaged (65.9%) than correctly or over-triaged (25%) children with CHD (*p*-value χ^2test <0.0001, OR 5.848 95% CI: 3.636-9.6).

Conclusion: The MTS urgency level upgrade modification could reduce under-triage in children with CHD. Applying a safety strategy concept to the MTS could mitigate under-triage in such a high-risk patient group.

What Is Known

- The Manchester Triage System is considered to be valid and reliable but tends to over-triage.
- A study by Zachariasse *et al. (2016)* showed poor performance in children with chronic illnesses.
- Research lacks evaluation of modifications to improve the triage of chronically ill pediatric patients.

What is New

- The symptom-based assessment update of the Manchester Triage System could decrease the number of under-triaged children with congenital heart disease.

Introduction

Triage systems are essential tools emergency units implement when at full capacity to safely and promptly manage patient flow according to clinical priority. The Manchester Triage System (MTS) is a five-level triage algorithm based on general and symptom-based flowcharts and discriminators to determine the urgency level (UL) [1]. Each UL is associated with a maximum waiting time: immediate (0 min), very urgent (up to 10 min), urgent (up to 60 min), standard (up to 120 min), and not urgent (up to 240 min) [2–3]. In previous studies, reference standards with three or five classes based on vital signs, diagnosis, diagnostic and therapeutic interventions, life-threatening conditions, admission to hospital, and follow-up data, were used to evaluate the MTS in pediatric patients [4–6]. The validity of the MTS in

pediatric emergency care is deemed moderate with a tendency to over-triage compared. Its sensitivity and specificity to identify high-urgency patients were 0.63 and 0.79, respectively [4].

Age-related modifications to discriminators with low performance in the MTS assessment of children increased the specificity (0.79 vs. 0.87), but with virtually no change in the sensitivity (0.63 vs. 0.64) [7]. Further adaptations improved classification regarding admissions to hospital with an increase for very urgent patients and consistent rates for those with low-risk ULs [8]. Vital signs as an additional discriminator for children led to a minimal improvement in the MTS performance [9].

To date, studies on the MTS for chronically ill children have registered poor performances and a higher under-triage risk in this category. [10, 11]. An early warning scoring tool for inpatient children, known as the Cardiac Children's Hospital Early Warning Score (C-CHEWS), can detect deterioration and prevent cardiopulmonary arrest [12].

Congenital heart defects account for nearly one-third of all severe congenital anomalies in Europe, with prevalence estimates of 8 per 1000 live births [13, 14].

Pediatric patients with CHD seem to be at high risk for cardiopulmonary insufficiency and rapid deterioration, especially those with infections or additional underlying conditions. A highly sensitive and specific scoring tool is therefore crucial for this patient group [11, 12].

Currently, there is no validated emergency unit scoring system for children with CHD or most other chronic diseases [11], and high-risk chronic diseases are underrepresented in the MTS. Only four specific discriminators describe a chronic disease (cardiac, allergic, respiratory, hematological history) and one indicates immunosuppression in few flowcharts (chest pain and palpitations, allergy, collapsed adult, rashes, shortness of breath in children, unwell baby, unwell child, urinary problems, and concerned parents) [1–3]. Thus, the need to integrate the MTS with first assessment guidelines for chronically ill patients [11].

The emergency unit of the Department of Pediatrics and Adolescent Medicine at the Medical University, Vienna, primarily treats self-referred patients up to 18 years. Approximately 25% of them present with chronic illnesses including congenital heart defects, inborn errors of metabolism, nephrology conditions, gastrointestinal, hepatic, or endocrine disorders, pulmonary, neurological psychosomatic, or autoimmune diseases, brain tumors, underwent organ transplantation, or are preterm infants.

Congenital heart defects represent a main focus (1/3 of all chronic diseases); therefore, a safe and swift approach should be guaranteed.

This study aimed to investigate over-triage, correct triage, and under-triage in CHD patients, the application of well-defined urgency level upgrade criteria, and compare the reference system to the original MTS levels.

Methods

Study design and study population

This prospective analysis gathered 23,258 patients who visited the emergency unit of the Department of Pediatrics and Adolescent Medicine, at the Medical University, Vienna, from January to December 2014. Exclusion criteria were age ≥18 years (n=74), or no record of the patient's MTS urgency level (n=1189), with missing diagnosis (n=2722), or no information on the follow-up procedure (n=9). Additionally, the MTS UL modification was introduced for patients with specific symptoms related to a chronic disease or other special features. The included children (n=19,264) were divided into two groups, one without (n=15,843) and the other with chronic diseases (n=3421). The group with congenital heart disease (CHD) consisted of 940 children (27.5%). Children with a CHD were categorized according to the 10th version of the International Classification of Diseases Code (ICD-10) using the EUROCAT (European Registration of Congenital Abnormalities and Twins) as the reference for CHD [15]. The children with CHD were sorted as follows: cyanotic heart defects (corrected/uncorrected/palliative), acyanotic heart defects (corrected/uncorrected/partially corrected), acquired heart defects, inflammatory heart diseases, cardiac insufficiency, cardiomyopathy, arrhythmia, or heart transplantation. With the MTS modification, 674 patients with CHD remained in the original MTS UL group, and 266 met clinically relevant criteria (cyanosis, abdominal symptoms, neurological symptoms, complexity with multiple abnormalities) or presented special features (language impairment, decreased general condition, unknown medical history, special needs) that made them eligible for the one-UL upgrade.

MTS and modification

Since 2012, the emergency unit of the Department of Pediatrics and Adolescent Medicine, Medical University, Vienna, has been using the 3rd German version of the international Manchester triage book published as Emergency Triage by the Manchester Triage Group (3rd edition) [1-2]. The MTS one urgency level upgrade modification was introduced in 2013. The MTS was applied by a pool of 17 triage nurses with a minimum of three years of extensive experience in pediatric emergency and a MTS basic course certification. In 2013 and 2014, the annual MTS audits showed 77,9% and 84,0% accuracy, and 11,2% and 5,8% incompleteness in random samples of 160 and 168 triage documentations, respectively.

The MTS modification with one UL upgrade was used to assess chronically ill children presenting with cyanosis (oxygen saturation) and heart defects, abdominal extension or vomiting in gastrointestinal, metabolic, or neurological diseases, as well as in preterms, and patients with complexity related to multiple abnormalities. In addition, the presence of one of the following factors automatically qualified the patients for the one UL upgrade: speech disorders, unknown clinical history, decreased general condition (DGC), or special needs (psychiatric disorders or neurodevelopmental delay).

Data analysis

A four-level outcome severity index (OSI), similar to existing reference standard classification systems[3-5, 16], was developed to evaluate the validity of the MTS at the emergency unit of the Department of Pediatrics and Adolescent Medicine, Medical University, Vienna. The OSI ranked priority based on diagnostic investigations (laboratory tests, chest radiography, ultrasonography, electrocardiogram, echocardiography, computed tomography scan), medical interventions at the emergency unit (e.g., intravenous medication or fluid, inhalation, nebulization, monitoring), hospital admission (intensive care unit (ICU) or inpatient ward), or a follow-up visit at the outpatient clinic or pediatrician's office. Children needing diagnostic investigations, hospital admission, or life-saving interventions were assigned a higher OSI level and presented with a more severe illness.

The highest level, OSI 1, was assigned if ICU admission or life-saving interventions and hospitalization were required. OSI 2 was indicated in case of hospital admission or interventions and follow-up at the outpatient clinic. OSI 3 was assigned to patients needing diagnostic investigations or medical interventions with follow-up at the outpatient clinic or the pediatrician's office. The lowest level, OSI 4, implied that no treatment at the emergency unit was required and follow-up at the pediatrician's office was sufficient.

Correspondence between MTS UL 1 and OSI 1 (MTS 1 = OSI 1), MTS UL 2 and OSI 1 or 2 (MTS 2 = OSI 1+2), MTS UL 3 and OSI 2 or 3 (MTS 3 = OSI 2+3), MTS UL 4 and OSI 3 or 4 (MTS 4 = OSI 3+4), and MTS UL 5 and OSI 4 (MTS 5 = OSI 4) indicated a correct triage. Matching the MTS ULs to the outcome classification optimized initial assessment accuracy. Under-triage occurred when the MTS UL was lower than the OSI, whereas over-triage occurred when the MTS UL was higher than the OSI.

Statistical analysis

Absolute and relative frequencies were calculated for each MTS UL and OSI classifications as well as for the under-triaged, over-triaged, and correctly triaged patients.

To capture the under-triage decrease rate in CHD patients, we constructed a frequency table and performed a χ^2 test.

We calculated the absolute and relative frequencies of original MTS patients, patients with MTS one-level upgrade modification, and all CHD patients to analyze the CHD subgroups.

The χ^2 test was performed to evaluate differences between MTS original and MTS modification subjects with regard to the subgroups.

Data collection

Patients' data were recorded either by manual-data entry or electronically imported. Data from additional examinations were registered in the electronic patient information system. Only authorized staff had access to the data collection. The Ethics Committee of the Medical University of Vienna, Austria, approved this study (No. 1405/2014). Data on the original MTS and clinical procedures were part of a

large international study called TrIAGE, conducted by Henriëtte A. Moll, Department of General Pediatrics, Erasmus MC - Sophia Children's Hospital, Rotterdam, CN, Netherlands. The TrIAGE study included no data on the MTS modification, the outcome severity index (OSI), the types of congenital heart diseases (Medical Ethics Committee Erasmus MC (MEC-2013-567), the Maasstad Ziekenhuis Board of Directors (Protocol L2013-103), the Joint Research Compliance Office (JRCO), Imperial College London (Reference number: 14SM2164, Ethics Committee Reference Number 14/WA/1051,) or the Comissão de Ética para a Saúde do Hospital, Prof. Dr. Fernando Fonseca, EPE (Reunião de 06 de Dezembro de 2017).

Results

In total, 19,264 children and adolescents were included in the study. The MTS one-level upgrade modification was indicated in 1141 cases (5.9%). The majority of patients (n=15843, 82.2%) had no chronic disease. Of this group, 539 (2,8% of n=19,264) cases needed the MTS UL upgrade. Chronic diseases were diagnosed in 3421 patients (17,8%), and the upgrade was necessary in 602 cases (3,1% of n=19264), which corresponds to approximately one-fifth (17,6%) of the group. Out of 3421 children with a chronic illness, 940 (proportionally 27.5%) had congenital heart disease (CHD). Among the CHD patients, 458 (48.7%) were females. The five age groups comprised ten newborns (up to 28 days), 221 infants (>28days to <1year), 351 toddlers (≥1year to <4years), 224 school-aged children (≥4 years to <10years), and 134 adolescents (≥10years to <18years). Hospitalization was indicated for 167 (17.7%) CHD cases, six of whom had to be admitted to the intensive care unit.

Under-triaged patients were 82 (8.7%), 54 (2/3) were upgraded; whereas correctly or over-triaged ones were 858 (91.3%), 212 (1/4) were upgraded.

According to the original MTS nine CHD patients were assigned the highest MTS UL (UL 1, immediate). Of these, five had cyanotic heart disease, three had an uncorrected acyanotic heart disease, and one had an acyanotic partially corrected heart disease. The MTS modification correctly up-triaged two patients with arrhythmia and one with acyanotic heart disease to MTS 1. Further details about the subgroups and MTS classification 1-5 (original/modification) are described in Figure 1 (MTS original categorization) and Figure 2 (MTS final categorization).

Among the 266 (100%) CHD subjects requiring upgrade, three (1.1%) were redistributed to the UL 1 (immediate), 25 (9.4%) to UL 2 (very urgent), 232 (87.2%) to UL 3 (urgent), and six (2.3%) to UL 4 (standard). Table 1 reports demographic data of the cumulative study population and chronic heart disease patients.

Table 1 Demographic data of the total study population and children with congenital heart disease

Demographics	n (%)
Total study population	19264 (100)
No chronic disease	15843 (82.2)
Chronic diseases	3421 (17.8)
Congenital heart disease	940
Other chronic diseases	2481
Congenital heart disease	940 (100)
Sex	
female	458 (48.7)
Age distribution	
newborn (≤28 days)	10 (1.1)
infant (>28 days - <1 year)	221 (23.5)
toddler (≥1 year - <4 years)	351 (37.3)
schoolchild (≥4 years - <10 years)	224 (23.8)
adolescent (≥10 years - <18 years)	134 (14.3)
Diagnostic examination	
Yes	463 (49.3)
Intervention	
Yes	228 (24.3)
Life-saving intervention	
Yes	4 (0.4)
Follow-up	
ICU admission	6 (0.6)
hospital admission	161 (17.1)
outpatient clinic	99 (10.5)
pediatrician	674 (71.7)

The three (1.1%) patients upgraded from UL 2 to UL 1 (immediate) needed additional diagnostic tests. One patient needed acute intervention and admission to the intensive care unit, another was admitted to the inpatient ward, and the third could be discharged and was recommended to schedule a follow-up appointment at the pediatrician's office.

Of the 25 (9.4%) patients upgraded from UL 3 (urgent) to UL 2 (very urgent), 22 (8.2%) needed diagnostic tests, and 12 (4.5%) interventions. Hospital admission was necessary for 14 patients (5.2%), while 11 (4.1%) could be discharged and scheduled for a follow-up visit at the pediatrician's office (nine patients) or in the outpatient clinic (two patients).

The largest group, 232 patients (87.2%), was upgraded from UL 4 (standard) to UL 3 (urgent). Diagnostic tests were performed on 134 patients (50.4%), 59 needed interventions (22.2%), and 49 admission to the hospital (18.4%). One hundred eighty-three patients (68.8%) could be discharged; of these, 35 (13.2%) were considered for a follow-up visit in the outpatient clinic, and 148 (55.6%) at the pediatrician's office.

Out of 22 patients classified as UL 5 (not urgent), six (2.3%) were reconsidered as UL 4 (standard). Only one needed an additional diagnostic examination. All six patients could be discharged and referred to the

pediatrician's office for a follow-up visit. (Table 2)

Table 2 Distribution of the Manchester Triage System (MTS) urgency level and outcome severity index (OSI) for children with congenital heart disease. Stated are the numbers of the original MTS and the MTS modification, the number of one-urgency level upgrading and the calculated value and percent of correct, over- and under-triage.

	Outcome severity index (n)				
MTS Urgency level (n)	OSI 1	OSI 2	OSI 3	OSI 4	Total
MTS 1 original	5	4	0	0	9
MTS 2 original	3	32	42	11	88
MTS 3 original	0	64	93	50	207
MTS 4 original	0	73	258	283	614
MTS 5 original	0	0	9	13	22
Total MTS original	8	173	402	357	940
MTS 1 modification	6	5	1	0	12
MTS 2 modification	2	46	49	13	110
MTS 3 modification	0	102	199	113	414
MTS 4 modification	0	20	145	223	388
MTS 5 modification	0	0	8	8	16
Total MTS modification	8	173	402	357	940
Upgrade (n)	OSI 1	OSI 2	OSI 3	OSI 4	Total
MTS 2 → MTS 1	1	1	1	0	3
MTS 3 → MTS 2	0	15	8	2	25
MTS 4 → MTS 3	0	53	114	65	232
MTS 5 → MTS 4	0	0	1	5	6
Total	1	69	124	72	266

	Original MTS	MTS modification
Under-triage	8.7 % (95% CI 7-10.71)	3 % (95% CI 1.99-4.28)
Correct triage	79.9 % (95% CI 77.19-82.41)	77.8 % (95% CI 74.97-80.39)
Over-triage	11.4 % (95% CI 9.42-13.59)	19.3 % (95% CI 16.78-21.92)

The MTS one-UL modification in children with CHD decreased under-triage by two-thirds, from 82 patients (8.7%, only original MTS) to 28 (3%; remaining after MTS modification), and increased over-triage, from 107 patients (11.4%; only original MTS) to 181 (19.3%; increase after MTS modification).

The MTS modification proved to be most effective for children assigned to OSI 2 (n=173) as under-triage rates plummeted from 73 patients (42.2%) to 20 (11.6%), correctly triaged went from 96 (55.5%) to 148 (85.6%), whereas over-triage remained almost constant(four; 2.3% with original MTS vs. five; 2.9% with modified MTS). Conversely, the MTS modification doubled the over-triage cases of patients assigned to OSI 4 (n=357), from 61 (17.1%) with the original MTS to 126 (35.3%) with the modified MTS. (Table 2)

In conclusion, the MTS modification reduced under-triage while increasing over-triage and showed no effect on the correct triage of children with CHD.

Under-triaged patients with CHD were more likely to be upgraded with the MTS modification than correctly or over-triaged ones [OR 5.767 (95% CI: 3.585 – 9.465); *p*-value χ^2 test <0.0001]. Table 3 shows detailed data of patients with congenital heart disease defined as under-triaged and correctly/over-triaged with reference to the original Manchester Triage System (MTS) and the MTS one-UL modification.

Table 3 Cross table for children with congenital heart disease defined as under-triage and correct/over-triage related to the original Manchester Triage System (MTS) and the MTS modification with one-level upgrading.

Children with congenital heart disease	**Original MTS n (%)**	**MTS modification with one-level upgrade n (%)**	**Sum n (%)**
Under-triage (original MTS)	28 (3.0)	54 (5.7)	82 (8.7)
Correct (original MTS)	542 (57.6)	209 (22.3)	751 (79.9)
Over-triage (original MTS)	104 (11,1)	3 (0,3)	107 (11.4)
Sum	**674 (71.7)**	**266 (28.3)**	**940 (100)**
OR 5.848 (95% CI: 3.636 – 9.6); p-value X^2 test <0.0001			

Table 4 includes a more in-depth analysis of the age distribution and CHD subgroups. Infants were more often upgraded by one UL (20.9% (original MTS) to 30.1% (modified MTS)), while adolescents tended to be assessed more often with the original MTS (16.8% (original MTS) to 7.9% (modified MTS)). CHD subgroups comprised cyanotic heart diseases (corrected/uncorrected/palliative), acyanotic heart diseases (corrected/uncorrected/partially corrected), acquired heart defects, inflammatory heart defects, cardiac insufficiency, cardiomyopathy, arrhythmia, or heart transplantation.

Table 4 Cross table with age and subgroup for children with congenital heart disease compared the original Manchester Triage System (MTS) to the MTS modification with one-level upgrading.

Children with congenital heart disease	**Original MTS n=674 (%)**	**MTS modification with one -level upgrade n=266 (%)**	Total n=940 (%)
Age distribution (mean)	4,26 (SD+/-4,8)	2,98 (SD+/-3,7)	3,92 (SD+/-4,6)
Newborn (≤28 days old)	8 (1,2)	2 (0,8)	10 (1,1)
Infant (>28 days old - <1 y.o.)	141 (20,9)	80 (30,1)	221 (23,5)
Toddler (≥1 y.o. - <4 y.o.)	251 (37,2)	100 (37,6)	351 (37,3)
School kid (≥4 y.o. - <10 y.o.)	161 (23,9)	63 (23,7)	224 (23,8)
Adolescent (≥10 y.o. - <18 y.o.)	113 (16,8)	21 (7,9)	134 (14,3)
CHD Subgroup			
Cyanotic heart disease	8 (1,2)	8 (3,0)	16 (1,7)
Cyanotic corrected surgery	61 (9,0)	32 (12,0)	93 (9,9)
Cyanotic palliative surgery	26 (3,9)	28 (10,5)	54 (5,7)
Acyanotic heart disease	310 (46,0)	123 (46,2)	433 (46,1)
Acyanotic corrected surgery	99 (14,7)	16 (6,0)	115 (12,2)
Acyanotic partially corrected	43 (6,4)	8 (3,0)	51 (5,4)
Spontaneous closure	20 (3,0)	2 (0,8)	22 (2,3)
Arrythmia	31 (4,6)	26 (9,8)	57 (6,1)
Cardiomyopathy	12 (1,8)	3 (1,1)	15 (1,6)
Acquired heart disease	23 (3,4)	3 (1,1)	26 (2,8)
Inflammatory heart disease	1 (0,1)	0 (0)	1 (0,1)
Heart transplantation	9 (1,3)	3 (1,1)	12 (1,3)
Cardiac insufficiency	1 (0,1)	1 (0,4)	2 (0,2)
Ablatio	5 (0,7)	0 (0)	5 (0,5)
Others	25 (3,7)	13(4,9)	38 (4,0)
p-value X^2 test <0.0001			

In total, children with cyanotic heart defect, even after palliative heart surgery or with arrhythmia, were significantly more often upgraded by one UL than children with acyanotic heart defect (with or without a corrective heart surgery or spontaneous closure), as shown in Table 4. (*p*-value χ^2test <0.0001)

Discussion

The Manchester Triage System is a valid and reliable triage tool in pediatric emergency units but tends to over-triage [4–6]. As the assessment of chronically ill children pivots on safety and reliability, the need for validated triage systems for this patient group is of utmost importance [10–12]. Seiger *et al*. proved that children with a chronic heart disease had a higher risk for under-triage (24.9%) than children without (11%) [11].

Adaptations of the triage system for certain vulnerable pediatric patients with regard to specific chronic diseases, clinically relevant criteria, or other special features seem to be a practical approach to prevent under-triage and increase correct triage, especially in children with CHD [9, 17]. Therefore, the emergency unit of the Department of Pediatrics and Adolescent Medicine, Medical University, Vienna adopted the MTS one-urgency level upgrade modification. This study could confirm that under-triage is a common problem in children with chronic diseases, especially congenital heart diseases [10, 11]. Our findings estimated the original MTS under-triage at 8.7% among children and adolescents with CHD, and revealed a reduction to 3% when implementing the MTS one-UL upgrade modification to assess patients with defined clinically relevant criteria or other special features. (Table 3)

The four-level outcome severity index (OSI) was developed as a reference standard for the correct triage, under-triage, and over-triage, and comprised additional clinical examinations and interventions, hospital admission, or outpatient follow-up. OSI 1, the highest category, matched the MTS UL 1 (immediate) and 2 (very urgent) (OSI 1 = MTS 1+2), OSI 2 corresponded to MTS UL 2 and 3 (urgent) (OSI 2 = MTS 2+3), OSI 3 to MTS UL 3 and 4 (standard) (OSI 3 = MTS 3+4) and OSI 4, the lowest category, coincided with MTS 4 and MTS 5 (not urgent) (OSI 4 = MTS 4+5). Under-triage was most frequent in patients who met the OSI 2 priority criteria and had to be re-triaged from the original MTS UL 4 to MTS UL 3. We observed that over-triage increased from 11.4–19.3% in the effort to prevent under-triage in children with CHD. (Table 2) Ultimately, while avoiding under-triage remains a significant concern as a predictor of clinical deterioration, a slight increase in over-triage is inevitable. Therefore, patient safety and immediate initiation of treatment especially for children with cyanotic heart defects and arrhythmias are crucial to patient outcomes.

Zachariasse *et al.* proved that children aged <3 months had the highest risk for under-triage (OR 2.87; 95% CI 2.00-4.10) [10]. The present study produced comparable evidence in newborns and infants with CHD but the modified MTS (20.9% from original MTS to 30.1% with MTS modification) was more often utilized in this group than in older children and adolescents. This strategy reduced or prevented under-triage in such a vulnerable cohort. Additionally, since chronically ill children appear to be underrepresented in the MTS flowcharts, chronic illnesses and clinically relevant criteria and features should be acknowledged in the triage assessment to improve patient safety and minimize under-triage. Limitations of this study may be the limited number (266) of patients with CHD and MTS one-UL upgrade modification. A larger sample size would generate more accurate results and more precise statistical analysis of the CHD subgroups including cyanotic heart disease, acyanotic heart disease, arrhythmia, and other cardiac diseases.

Limitations And Perspectives

A limitation of this study may be the limited number (n=266) of patients with a wide spectrum of CHD with need for MTS one-UL upgrade modification.

For a larger sample size multicenter studies can be required, but our results present the first data based on the MTS modification with one-level upgrading at our pediatric emergency unit and could show the reduction of undertriage in patients with CHD.

Ultimately, avoiding under-triage is the main focus for chronic ill patients and therefore it seems tolerable that a slight increase of over-triage occurs. For confirmation of this statement further studies may be indicated.

Conclusion

We can conclude that the MTS modification with a one urgency level upgrade in CHD with clinically relevant criteria or patients with other special features reduces under-triage, with the most evident effects in newborns and infants.

Abbreviations

C-CHEWS	Cardiac Children's Hospital Early Warning Score,
CHD	congenital heart disease,
CI	confidence interval,
ICU	intensive care unit,
MTS	Manchester Triage System,
OR	odds ratio,
OSI	outcome severity index,
UL	urgency level

Declarations

Funding: No funding source.

Conflict of interest/Competing interests: The authors declare that they have no conflict of interest.

Availability of data and material: The study has associated data in a data repository of the Medical University of Vienna.

Code availability: Data available on request from the authors.

Authors` Contributions:

Susanne Greber-Platzer conceptualized and designed the study, designed the data collection instruments, drafted the initial manuscript, and reviewed and revised the manuscript.

Franziska Leeb drafted the revised manuscript, reviewed and revised the data and statistics, added missing information regarding subgroups and age distribution, created new tables, and answered the reviewer's comments.

Ursula Sharma designed the data collection instruments, collected data, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content.

Lusine Yeghiazaryan carried out statistical analyses and critically reviewed the manuscript for important intellectual content.

Henriette A. Moll contributed to the interpretation of data and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Acknowledgements

We acknowledge Pinky-Rose Espina for helping conceptualize and design the study, Eleonore Pablik for performing the first statistical analyses, and the students of the Medical University of Vienna for their contributions to data collection.

Ethicals approval: This study was approved by the Ethics Committee of the Medical University of Vienna, Austria (No. 1405/2014). All data was processed pseudo-anonymously, according to the privacy legislation.

Consent to participate: not applicable

Consent for publication: not applicable

References

1. Mackway-Jones K, Marsden J, Windle J (2014) Emergency triage. Third edition. John Wiley & Sons Limited. Chichester, West Sussex, UK

2. Krey J, Moecke H (2011) Ersteinschätzung in der Notaufnahme. Das Manchester-Triage-System. 3. überarbeitete und ergänzte Auflage. Verlag Hans Huber, Bern

3. Mackway-Jones K, Marsden J, Windle J, Krey J, Moecke H (2020) Ersteinschätzung in der Notaufnahme. Das Manchester-Triage-System. 5. überarbeitete und ergänzte Auflage. Verlag Hogrefe, Bern

4. van Veen M, Steyerberg EW, Ruige M, van Meurs AH, Roukema J, van der Lei J, Moll HA (2008) Manchester triage system in paediatric emergency care: prospective observational study. BMJ 337: a1501. https://doi.org/10.1136/bmj.a1501

5. Zachariasse JM, Seiger N, Rood PP, Alves CF, Freitas P, Smit FJ, Roukema GR, Moll HA (2017) Validity of the Manchester Triage System in emergency care: A prospective observational study. PLoS One 12(2): e0170811. https://doi.org/10.1371/journal.pone.0170811

6. Roukema J, Steyerberg EW, van Meurs A, Ruige M, van der Lei J, Moll HA (2006) Validity of the Manchester Triage System in paediatric emergency care. Emerg Med J 23(12):906-10. https://doi.org/10.1136/emj.2006.038877

7. van Veen M, Steyerberg EW, Van't Klooster M, Ruige M, van Meurs AH, van der Lei J, Moll HA (2012) The Manchester triage system: improvements for paediatric emergency care. Emerg Med J 29(8):654-9. https://doi.org/10.1136/emermed-2011-200562

8. Seiger N, van Veen M, Almeida H, Steyerberg EW, van Meurs AH, Carneiro R, Alves CF, Maconochie I, van der Lei J, Moll HA (2014) Improving the Manchester Triage System for pediatric emergency care: an international multicenter study. PLoS One 9(1):e83267. https://doi.org/10.1371/journal.pone.0083267

9. Zachariasse JM, Maconochie IK, Nijman RG, Greber-Platzer S, Smit FJ, Nieboer D, van der Lei J, Alves CF, Moll HA (2021) Improving the prioritization of children at the emergency department: Updating the Manchester Triage System using vital signs. PloS One 16(2):e0246324. https://doi.org/10.1371/journal.pone.0246324

10. Zachariasse JM, Kuiper JW, de Hoog M, Moll HA, van Veen M (2016) Safety of the Manchester Triage System to Detect Critically Ill Children at the Emergency Department. J Pediatr 177:232-237.e1. https://doi.org/10.1016/j.jpeds.2016.06.068

11. Seiger N, van Veen M, Steyerberg EW, van der Lei J, Moll HA (2013) Accuracy of triage for children with chronic illness and infectious symptoms. Pediatrics. 132(6):e1602-8. https://doi.org/10.1542/peds.2013-1076

12. McLellan MC, Gauvreau K, Connor JA (2014) Validation of the Cardiac Children's Hospital Early Warning Score: an early warning scoring tool to prevent cardiopulmonary arrests in children with heart disease. Congenit Heart Dis 9(3):194-202. https://doi.org/10.1111/chd.12132

13. Dolk H, Loane M, Garne E; European Surveillance of Congenital Anomalies (EUROCAT) Working Group (2011) Congenital heart defects in Europe: prevalence and perinatal mortality, 2000 to 2005. Circulation. 123(8):841-9. https://doi.org/10.1161/CIRCULATIONAHA.110.958405

14. van der Linde D, Konings EE, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJ, Roos-Hesselink JW (2011) Birth prevalence of congenital heart disease worldwide: a systematic review and meta-

analysis. J Am Coll Cardiol 58(21):2241-7. https://doi.org/10.1016/j.jacc.2011.08.025

15. EUROCAT (2013) EUROCAT Guide 1.4: Instruction for the registration of congenital anomalies. EUROCAT Central Registry, University of Ulster. https://eu-rd-platform.jrc.ec.europa.eu/sites/default/files/Full_Guide_1_4_version_28_DEC2018.pdf. Accessed 10 June 2020

16. Nijman RG, Borensztajn DH, Zachariasse JM, Hajema C, Freitas P, Greber-Platzer S, Smit FJ, Alves CF, van der Lei J, Steyerberg EW, Maconochie IK, Moll HA (2021) A clinical prediction model to identify children at risk for revisits with serious illness to the emergency department: A prospective multicentre observational study. PloS One 16(7):e0254366. https://doi.org/10.1371/journal.pone.0254366

17. van de Maat J, Jonkman H, van de Voort E, Mintegi S, Gervaix A, Bressan S, Moll H, Oostenbrink R (2020) Measuring vital signs in children with fever at the emergency department: An observational study on adherence to the NICE recommendations in Europe. Eur J Pediatr 179(7): 1097-1106. https://doi.org/10.1007/s00431-020-03601-y

Figures

Figure 1

See image above for figure legend.

Figure 2

See image above for figure legend.