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Progression of vital signs during ambulance transport categorised by a paediatric triage model: a population-based historical cohort study

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ABSTRACT

Objectives To examine the severity and progression of acute illness or injury in children using vital signs obtained during ambulance transport and categorised according to a paediatric triage model.

Design A population-based historical cohort study using data from prehospital patient medical records linked to a national civil registration database.

Setting Emergency medical services providing ground-level transport in a mixed urban–rural region with three hospitals in Denmark.

Participants 25 039 events with patients aged <18 years attended by emergency medical services dispatched after a 1-1-2 emergency call during the years 2006–2018.

Primary and secondary outcome measures Distribution of the first observed vital signs according to a paediatric triage model: heart rate, Glasgow Coma Score, respiratory rate, oxygen saturation and oxygen treatment, and proportion of patients progressing to a triage score with a lower level of urgency during ambulance transport.

Results The proportion of patients with the first observed vital signs outside the normal age-specific range was as follows: 33.6% for heart rate, 15.3% for Glasgow Coma Score, 17.4% for respiratory rate and 37.4% for oxygen saturation regardless of oxygen treatment. The proportion of patients progressing to a triage score with a lower level of urgency during transport varied with age: 146/354 (41.2%) for age 0–2 months, 440/986 (44.6%) for age 3–11 months, 1278/3212 (39.8%) for age 1–2 years, 967/2814 (34.4%) for age 3–7 years and 4029/13 864 (29.1%) for age 8–17 years (p<0.001). One-day mortality was 3.05 deaths per 1000 patient-days (95% CI 2.43 to 3.83).

Conclusions One third of the patients' condition progressed to a triage score with a lower level of urgency during ambulance transport. Vital sign documentation in paediatric patients was incomplete, and educational initiatives should be taken to increase documentation of vital signs, especially in patients aged ≤2 years.

INTRODUCTION

The clinical assessment of a child with symptoms of acute illness or injury can be difficult for emergency medical service (EMS) professionals because the majority of those in our EMS systems are adult and elderly patients.[1] [2] Especially infants and toddlers are frequent patient groups, and they can be difficult to assess due to a variety of factors: different normal ranges for vital signs, interaction with both patient and caregivers, and the fact that clinical deterioration can occur more abruptly in children than in adults due to prolonged physiological compensation for an acute illness or injury.[2–4] Caring for paediatric patients may be stressful for EMS professionals due to inadequate training related to clinical judgement and treatment of children with acute illness or injury.[5–8] A low frequency of life-threatening events among paediatric patients highlights the challenge of identifying patients at risk of clinical deterioration among the many other children with minor or non-urgent illnesses or injuries in acute care settings.[9–11]

The concept of paediatric early warning scores (PEWS) and triage models was developed for early recognition and treatment of critical illness to avoid adverse outcomes, based on the fact that abnormal values often precede an adverse event such as intensive care admission or death.[10] [12–14] A single deviating vital sign may be predictive of an

Strengths and limitations of this study

► A large and consecutive study population, who have had free and equal access to emergency medical services, limits the risk of selection bias.
► Use of personal identification numbers ensures minimal loss to follow-up.
► Children with no or invalid personal identification number were excluded since an exact age could not be calculated.
► Missing data were unevenly distributed across age groups with less thorough documentation in the younger age groups.

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adverse outcome in children with acute illness or injury, and a wide variety of PEWS and triage models are used internationally.[14–20] A recent randomised controlled trial of more than 144 000 hospital discharges of paediatric patients reported a significant decrease in the occurrence of predefined clinical deterioration events at hospitals using PEWS compared with hospitals with usual care, suggesting a clinical benefit from the use of early warning scores.[11] In context of the serious outcomes admission to an intensive care unit (ICU) or death being rare events among paediatric patients, and deviating vital signs preceding clinical deterioration events, we suggest using progression of vital signs during ambulance transport as an outcome measure of clinical improvement for future prehospital prospective studies. The first step is to illustrate the extent of vital sign documentation, the proportion of patients with deviating vital signs and progression of those. Accordingly, the study objectives are to (1) classify patients' first observed vital signs according to a paediatric triage model and (2) examine the progression of patients' vital signs during ambulance transport categorised according to this model.

METHODS
Study design
This study is a population-based historical cohort study based on data from prehospital patient medical records. All patients were attended by ground-level EMS following a 1-1-2 emergency call (the national emergency telephone number).

Setting
The study was conducted in North Denmark in a regional EMS covering mixed urban–rural areas (7933 km^2) with 119 506 inhabitants below 18 years of age (2020Q2).[21] The Danish healthcare system is tax-supported with free access to acute care including ambulance services. 1-1-2 emergency calls related to health emergencies are forwarded from the police to a regional emergency medical coordination centre that assesses the level of urgency and coordinates response by ambulances, lay-person first responders, rapid response cars staffed by paramedics, mobile emergency care units and national helicopter EMS, with the latter two staffed by paramedics and anaesthesiologists. Paramedics are trained in providing advanced life support along with competencies to administer several pharmacological treatments on scene either independently or delegated at the discretion of a prehospital physician consulted by telephone or present on scene. The ambulance service in the North Denmark Region is run by a private operator (Falck) in contract with regional health services.[2] All ground-level prehospital units have the same electronic medical records system (amPHI) in which EMS professionals can type in medical history, vital signs and administered treatments. Data are integrated into the region's hospitals' electronic medical records system and are visible to receiving

emergency department personnel. Time stamps and locations of dispatched units exist in a separate logistic system (before 2016, in EVA 2000 and thereafter in Logis CAD) (Logis Solutions, Naerum, Denmark).[2] Data originated from both the logistic system and the prehospital electronic patient medical records from 4 April 2006 to 31 December 2018 plus 2 days of follow-up.

Participants
All paediatric patients attended by EMS personnel following a 1-1-2 emergency call were included in the study, including unique patients with more than one event during the study period—in total, 25 039 events. Patients without a valid CPR number (a national unique civil registration number) could not be included as we could not be certain that the patient was below 18 years of age and because outcomes were to be assessed using a paediatric triage model with specific age group limits.

Patient and public involvement
Patients were not involved in the design or conduct of this study.

Variables and outcomes
One event was defined as one ambulance that attended a patient, regardless of whether the patient was brought to a hospital. In Danish EMS systems, the triage system is named the Paediatric Triage Model. The variables heart rate, Glasgow Coma Score, respiratory rate and oxygen saturation (SpO$_2$) were defined as being in or outside the normal age-specific range according to the paediatric triage model, and limits are outlined in online supplemental file 1 and grouped accordingly in the 'Results' section. For the variables heart rate and respiratory rate, green represents normal ranges, and any value above or below the normal range is referred to as 'tachycardia' or 'tachypnoea' or 'bradycardia' or 'bradypnoea' for that age group, respectively. The variable oxygen treatment was binary with options 'atmospheric air' and 'oxygen' regardless of the flow by nasal catheter, reservoir mask, Hudson mask, nebuliser, continuous positive airway pressure or tracheal intubation. As oxygen is a medical treatment, EMS professionals are legally obligated to enter oxygen treatment in the patient's medical record, and based on this assumption no entry is equal to no oxygen treatment.[22] Age groups and ranges of vital signs were chosen to match the paediatric triage model used in ground EMS services nationally (online supplemental file 1). Age groups are hereafter designated as 'newborns' (0–2 months), 'infants' (3–11 months), 'toddlers' (1–2 years), 'preschool and school children' (3–7 years) and 'adolescents' (8–17 years).

For a triage score (triage colour), the patient must have at least one vital sign documented. Red denotes 'life-threatening' events; orange, 'urgent' events; yellow, 'less urgent' events; and green, 'not urgent' events. Triage scores were based on the first documentation of each vital sign. If a vital sign had only one value documented during

the entire transport, this value was only included in the first triage score. The last triage score was deemed missing if the first single vital sign was yellow, orange or red and the last same vital sign was a missing value. If oxygen treatment was documented in the time frame from arrival at scene to 15 min past the first documented SpO_2 (real-time documentation), it was included in both the first and last triage scores. If oxygen treatment was documented later, then it was only included in the last triage score.

Data sources, access and linkage

The source of data for vital signs was the prehospital patient medical records. Respiratory rate and Glasgow Coma Score were entered by the treating EMS professionals. Measures of SpO_2 and heart rate were transmitted to the medical record directly from a monitor (LIFEPAK 12/15-Monitor; Physio-Control, Redmond, Washington, USA). The authors had full access to the database from which the study population was included. The unique CPR numbers ensured nearly complete follow-up as time of death was collected from the Danish Civil Registration System.[23] For definitions of time stamps and variables linking each ambulance run to a specific patient and medical record, we refer to previous work.[24 25] Data from the year 2015 were excluded due to system updates in the electronic patient medical records system and consequent possible incomplete registrations. Data from prehospital patient medical records were linked on patient level by CPR number and time stamps to a national civil registration system to retrieve vital status. As CPR numbers are unique to the patient, linkage is considered to be of high quality. In case the patient lived in another country or in another Danish region than North or Central Denmark, vital status could not be retrieved.

Missing data

Missing data were unevenly distributed across age groups with less thorough documentation at younger ages (≤2 years). If time from arrival at scene to arrival at hospital is judged to be short by the attending EMS professionals, they might find it unnecessary to document vital signs more than one time. To check the extent of this potential source of bias, we identified only approximately 10% of events as having less than 15 min from arrival at scene to arrival at hospital. A hypothesis regarding systematic bias in missing data led us to investigate whether missing values were missing at random or whether EMS professionals tended to document fewer vital signs if they regarded the patient's condition as being 'not urgent'. We compared vital sign documentation done in ambulances with vital sign documentation done on arrival at emergency department performed by the attending nurse in a random sample of 275 patients for a 2-month period, both summer and winter seasons. Data for this investigation were collected from in-hospital patient medical records and managed using REDCap (Research Electronic Data Capture) tools hosted at the North Denmark Region.[26]

Statistical methods

Data were pseudoanonymised before analysis. Quantitative variables are presented as frequencies (proportions) and tested by χ^2 tests with a significance level set at 0.05. The proportions of patients having at least one abnormal vital sign at first observation were estimated for age categories in a univariate binomial regression. The proportions were compared with the age category 'newborns' (0–2 months) by relative risks. We performed a Poisson regression with robust variance estimation for 1-day mortality defined as death on the same date as the 1-1-2 emergency call or the following date. If a patient had more than one event on the same date, only the last event was included. Data management was run using SAS Enterprise Guide V.8.2 (SAS Institute, Cary, North Carolina, USA), and statistical analyses were performed with Stata/MP V.15.1 (Stata, College Station, Texas, USA).

RESULTS
Participants

During the study period, 300 528 calls were made to the 1-1-2 emergency number regarding patients at all ages potentially eligible for our study. In total, 25 493 events were related to patients below 18 years of age who had been attended by EMS professionals. Patients without a valid CPR number were excluded (454 events), equalling 25 039 events to be included and analysed. One patient could have been attended more than one time during the study period, and 16 342 patients had only one event, whereas 2053 patients had two events and 1004 patients had three or more events during the entire study period. Follow-up was nearly complete, with only 2.7% missing vital status and excluded from mortality analysis.

Descriptive data

The children included in the study population had an equal gender distribution; 12 860/25 039 patients (51.4%) were of male gender. The total number of events per year increased over time, and more events occurred in the older age groups: 556 events among newborns (0–2 months), 1446 events among infants (3–11 months), 4362 events among toddlers (1–2 years), 3424 events among preschool and school children (3–7 years) and 15 251 events among adolescents (8–17 years). Time from arrival at scene to arrival at hospital was a median of 35 min (IQR 23–49 min), with missing data on transport time in 2433 events (9.7%). In the majority of events, the patient was brought to a hospital within the region (21 106/25 039 (84.3%)). In 11 400/25 039 events (45.5%), the patient was admitted to hospital after arrival at emergency department; however, 75.9% of these patients had a hospital stay of 1 day or less. Transferral to an ICU at any time point during the hospital stay occurred in 2590/25 039 events (10.3%). In all, 329 deaths occurred, with a 1-day mortality rate of 3.05 (95% CI 2.43 to 3.83) deaths per 1000 patient-days (n=24 285).

Table 1 First heart rate documented by emergency medical service professionals categorised by a paediatric triage model

First heart rate, min⁻¹	1	2	3	4	3	2	1
0–2 months Non-missing/N=340/556							
Range	<50	50–69	70–89	90–180	181–205	206–239	>230
n (%)	<5 (<1.5)	9 (2.6)	18 (5.3)	283 (83.2)	15 (4.4)	<5 (<1.5)	<5 (<1.5)
3–11 months Non-missing/N=848/1446							
Range	<40	40–59	60–79	80–160	161–190	191–230	>230
n (%)	7 (0.8)	26 (3.1)	72 (8.5)	513 (60.5)	188 (22.2)	37 (4.4)	<5 (<1.0)
1–2 years Non-missing/N=2712/4362							
Range	<40	40–58	59–74	75–130	131–165	166–200	>200
n (%)	11 (0.4)	70 (2.6)	150 (5.5)	921 (34.0)	1047 (38.6)	478 (17.6)	35 (1.3)
3–7 years Non-missing/N=2540/3424							
Range	<40	40–54	55–69	70–110	111–125	126–165	>165
n (%)	10 (0.4)	34 (1.3)	80 (3.1)	1154 (45.4)	470 (18.5)	714 (28.1)	78 (3.1)
8–17 years Non-missing/N=13 611/15 251							
Range	<40	40–44	45–49	50–110	111–120	121–140	>140
n (%)	20 (0.1)	15 (0.1)	26 (0.2)	10 443 (76.7)	1548 (11.4)	1210 (8.9)	349 (2.6)
All ages Non-missing/N=20 051/25 039							
%	0.3	0.8	1.7	66.4	16.3	12.2	2.4

Green represents the normal range for the particular age group.
1 (red): Life-threatening; 2 (orange): Urgent; 3 (yellow): Less urgent; 4 (green): Not urgent.

Outcome data

Tables 1–4 display vital signs according to the paediatric triage model limits and age groups. More than half of the patients (66.4%) had a heart rate that was categorised as normal (green), though among toddlers (1–2 years) it was only 34.0%, whereas more patients had tachycardia (table 1). The proportion of patients with an altered level of consciousness was fairly even across age groups, with 10.1%–16.4% having a Glasgow Coma Score of less than 15 (table 2). Tachypnoea was frequently present in toddlers (1–2 years) and in preschool and school children (3–7 years), but among adolescents (8–17 years) considerably fewer had a respiratory rate outside the age-specific normal range (table 3). Among newborns

Table 2 First Glasgow Coma Score (GCS) documented by emergency medical service professionals categorised by a paediatric triage model

First GCS		1 GCS ≤8	2 GCS 9–13	3 GCS 14	4 GCS 15
0–2 months Non-missing/N=191/556	n (%)	9 (4.7)	16 (8.4)	6 (3.1)	160 (83.8)
3–11 months Non-missing/N=761/1446	n (%)	28 (3.7)	33 (4.3)	16 (2.1)	684 (89.9)
1–2 years Non-missing/N=2647/4362	n (%)	145 (5.5)	201 (7.6)	89 (3.4)	2212 (83.6)
3–7 years Non-missing/N=2737/3424	n (%)	143 (5.2)	222 (8.1)	75 (2.7)	2297 (83.9)
8–17 years Non-missing/N=13 252/15 251	n (%)	407 (3.1)	813 (6.1)	803 (6.1)	11 229 (84.7)
All ages Non-missing/N=19 588/25 039	%	3.7	6.6	5.0	84.7

1 (red): Life-threatening; 2 (orange): Urgent; 3 (yellow): Less urgent; 4 (green): Not urgent.

Table 3 First respiratory rate documented by emergency medical service professionals categorised by a paediatric triage model

First respiratory rate, min^{-1}		1	2	3	4	3	2	1
0–2 months Non-missing/N=235/556	Range	<10	10–19	20–29	30–60	61–80	81–90	>90
	n (%)	<5 (<1.0)	<5 (<2.0)	49 (20.9)	171 (72.8)	<5 (<1.0)	0 (0.0)	0 (0.0)
3–11 months Non-missing/N=673/1446	Range	<10	10–19	20–29	30–60	61–70	71–80	>80
	n (%)	<5 (<1.0)	16 (2.4)	261 (38.8)	375 (55.7)	6 (0.9)	<5 (<1.0)	<5 (<1.0)
1–2 years Non-missing/N=2235/4362	Range	<10	10–14	15–19	20–30	31–40	41–50	>50
	n (%)	9 (0.4)	10 (0.4)	115 (5.1)	1516 (67.8)	466 (20.9)	74 (3.3)	45 (2.0)
3–7 years Non-missing/N=2110/3424	Range	<10	10–12	13–15	16–24	25–30	31–35	>35
	n (%)	8 (0.4)	17 (0.8)	52 (2.5)	1336 (63.3)	389 (18.4)	200 (9.5)	108 (5.1)
8–17 years Non-missing/N=11 112/15 251	Range	<8	8–9	10–11	12–25	26–30	31–35	>35
	n (%)	35 (0.3)	10 (0.1)	29 (0.3)	10 123 (91.1)	565 (5.1)	123 (1.1)	227 (2.0)
All ages Non-missing/N=16 365/25 039	%	0.4	0.4	3.1	82.6	8.7	2.5	2.4

Green represents the normal range for the particular age group.
1 (red): Life-threatening; 2 (orange): Urgent; 3 (yellow): Less urgent; 4 (green): Not urgent.

(0–2 months) and infants (3–11 months), a respiratory rate below the normal range limit (30 breaths per minute) was more frequent compared with the other age groups. Hypoxia was more common in newborns (0–2 months), infants (3–11 months) and toddlers (1–2 years) compared with the two older age groups, although more patients aged ≤7 years had received oxygen treatment as part of their prehospital care compared with the patients aged 8–17 years (table 4). For all vital signs, the proportion of missing data decreases with increasing age group (tables 1–4).

The proportion of events with patients who had at least one abnormal vital sign at first observation varied with age and was 53.7% in newborns (reference), 62.6% in infants (relative risk 1.17, 95% CI 1.06 to 1.29), 66.4% in toddlers (relative risk 1.24, 95% CI 1.13 to 1.36), 64.6% in preschool and school children (relative risk 1.20, 95% CI 1.10 to 1.32) and 49.5% in adolescents (relative risk 0.92, 95% CI 0.84 to 1.01) (missing data in 1673/25 039 events).

Main results

As a patient needs at least one vital sign documented to receive a triage score (colour), among all events, 23 366 (93.3%) had data for a first triage score and 21 230 (84.8%) had data for both first and last triage scores as an indicator of development. The four vital signs for the first triage score were all documented within a median time interval of 6 min (IQR 2–13 min), and the four vital signs for the last triage score were all documented within a median time interval of 4 min (IQR 0–13 min). Figure 1 illustrates the changes in distribution of colours of the first and last triage scores according to age group, calculated using data from tables 1–4 and categorised as 'not urgent' (green), 'less urgent' (yellow), 'urgent' (orange) or 'life-threatening' (red) levels. The proportion of events with patients whose score progressed to a less urgent level during ambulance transport was 146/354 (41.2%) for newborns (missing data in 202 patients), 440/986 (44.6%) for infants (missing data in 460 patients), 1278/3212 (39.8%) for toddlers (missing data in 1150 patients), 967/2814 (34.4%) for preschool and school children (missing data in 610 patients) and 4029/13 864 (29.1%) for adolescents (missing data in 1387 patients) (χ^2 (4, n=21 230) = 235.8, p<0.001). For progression of each of the four vital signs during ambulance transport, refer to online supplemental file 2.

Other analyses

A comparison of vital sign documentation in the ambulance with the first set of vital signs documented on arrival at hospital in a random sample of 275 patients was performed to challenge the hypothesis of EMS professionals documenting fewer than all four vital signs only in patients triaged as 'not urgent' on hospital arrival. The comparison revealed no systematic pattern of missing values; the proportion of patients with green ('not urgent') triage scores was similar among patients who did

Table 4 First peripheral oxygen saturation (SpO$_2$) documented by emergency medical service professionals categorised by a paediatric triage model

First SpO$_2$ and O$_2$ treatment		1	2	3	4
0–2 months Non-missing/N=336/556	n (%)	51 (15.2)	39 (11.6)	72 (21.4)	174 (51.8)
3–11 months Non-missing/N=834/1446	n (%)	115 (13.8)	139 (16.7)	167 (20.0)	413 (49.5)
1–2 years Non-missing/N=2706/4362	n (%)	342 (12.6)	404 (14.9)	817 (30.2)	1143 (42.2)
3–7 years Non-missing/N=2491/3424	n (%)	201 (8.1)	273 (11.0)	607 (24.4)	1410 (56.6)
8–17 years Non-missing/N=13 261/15 251	n (%)	507 (3.8)	884 (6.7)	2730 (20.6)	9140 (68.9)
All ages Non-missing/N=19 628/25 039	%	6.2	8.9	22.4	62.6

1 (red): SpO$_2$ <85% without O$_2$ or SpO$_2$ <90% with O$_2$.
2 (orange): SpO$_2$ 85%–92% without O$_2$ or SpO$_2$ 90%–96% with O$_2$.
3 (yellow): SpO$_2$ 93%–94% without O$_2$ or SpO$_2$ ≥97% with O$_2$.
4 (green): SpO$_2$ ≥95% without O$_2$.
1 (red): Life-threatening; 2 (orange): Urgent; 3 (yellow): Less urgent; 4 (green): Not urgent.
O$_2$, oxygen.

not have all four vital signs documented in the ambulance and patients who had had all four vital signs documented in the ambulance (green triage score in 41% vs 46%) (χ^2 (3, n=239) = 5.1, p=0.166).

DISCUSSION
Principal findings
Fifty-five per cent of the events had patients with at least one abnormal vital sign at first observation. The vital signs most often observed outside the age-specific normal ranges were oxygen saturation and heart rate, with a third of the patients experiencing either bradycardia or tachycardia, which was most frequent among toddlers (1–2

Figure 1 Distribution of first and last triage score colour categories according to age groups. Non-missing/ N=21 230/25 039.

years). Regarding respiratory rate, tachypnoea was most frequently present in patients aged 1–7 years, whereas a respiratory rate below the age-specific normal range limits was more frequent among newborns and infants (<1 year). Among patients aged ≤2 years, hypoxia was more common than in the older age groups, although proportionally the younger age groups had more often received supplemental oxygen as part of their prehospital treatment. Across all age groups, the proportion of patients with an altered level of consciousness was low. With no regard to the specific age groups, the extent of missing data for each of the vital signs was acceptable, except for respiratory rate which had missing values in a third of all events. This challenge is well in line with previous studies.[10 17 19] Triage score progression to a lower level of urgency during ambulance transport differed by age group, with the outcome being present in every third patient overall.

Limitations
The study is strengthened by a large, consecutive study population combined with access to free-of-charge EMS limiting the risk of selection bias due to patients' social or economic resources. Yet 454 events with no or invalid personal identification number were excluded because a valid age could not be determined. This exclusion could have biased the selection of patients, possibly in a way that patients, with whom EMS professionals could not communicate well and get a valid CPR number, have been excluded. From previous work, we have learnt that the data quality of vital signs is high with few implausible outliers.[27] The proportion of missing data was uneven across age groups and particularly high among patients aged ≤2 years, which might reduce the
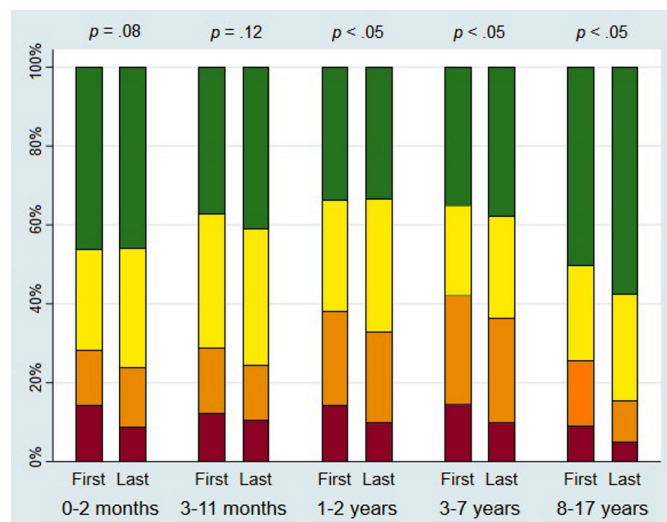
representativeness of the sample. Missing data could be a matter of confounding by indication; EMS professionals may tend to observe and document vital signs only in children whom they assess as having a poor general condition. However, 55% of patients had at least one abnormal vital sign at first observation and our finding of no difference in the proportions of patients with a green triage score in the sample comparing prehospital vital signs with those documented by the receiving hospital staff does not support this hypothesis.

When a prehospital physician is present on scene, additional treatment options are available, which might increase the chance of progression to a triage score with a lower level of urgency. However, with a prehospital physician involved in only 11% of events, we consider this confounder to have had a minor impact on study results. The exact time stamps of each documented vital sign were not used to define which vital sign values to include in a triage score, and this is a potential confounder when the four vital signs could have actually been observed several minutes apart. However, the short IQRs for the time intervals in which the four vital signs were documented, for both the first and last triage scores, lead us to judge this confounder to have had little impact on the results.

Relation to other studies
In our study population, considerably more patients experienced tachycardia compared with similar studies, whereas the proportion of patients with an altered level of consciousness was comparable.[1 28] The differences may be due to the fact that the age-specific limits defining tachycardia were generally lower in our study, especially in younger age groups below 8 years. The pattern of respiratory rate among newborns and infants (<12 months) with tachypnoea being infrequent, and a respiratory rate below the age-specific normal range limit (30 breaths per minute) in 23.9% and 42.2%, respectively, is different from the findings of Drayna et al, who reported tachypnoea among 19.1% and bradypnoea among 9.3% of patients in the same age group, however using a lower normal range limit of 24 breaths per minute.[28] A recent registry-based study of 253 169 ambulance runs revealed a normal distribution of respiratory rates manually counted and a narrow IQR similar to the IQR of automatic respiratory rate measurements by capnography,[27] indicating that the manual respiratory rate measurements by EMS professionals in our regional service are of proper quality, even though they may be less accurate in the very young children. Our finding that 55% of all patients had at least one abnormal vital sign at first observation is consistent with the aforementioned study on patients with trauma,[28] where 61.5% had any abnormal initial vital sign and considerable differences among age groups equivalent to the findings in our study. In a recent national validation study of PEWS (Scotland), about half of the population had a first score of ≤2 (mean score value of 2.95 and median of 2).[10] This corresponds to our finding of 41.9% of patients having a green ('not urgent') first triage score.

PEWS (Scotland) scores comprising prehospital vital sign measurements were independent predictors of the combined outcome ICU admission within 48 hours or 30-day mortality.[10] Comparison is not directly possible as the two scoring systems in Scotland and Denmark differ in both age group limits and normal range limits, and that measures of temperature, systolic blood pressure and capillary return are included in PEWS (Scotland). We trust that generalisability of the results on deviating vital signs to other paediatric EMS populations in areas with similar acute healthcare services can be regarded as fair. Use of this paediatric triage model to investigate the progression of vital signs is only generalisable within the country of Denmark, where all health regions' EMS use this particular triage model.

Implications and future research
According to tables 1–4, documentation of all vital signs increases with increasing age group and was less thorough among patients aged ≤2 years compared with patients aged ≥3 years. Clinical assessment of newborns and infants is difficult for a non-paediatrician healthcare professional, and educational initiatives and training improve vital sign documentation in the prehospital setting.[11 29] Such initiatives should be started and eventually evaluated for the purpose of improving observation and documentation of vital signs in children with acute illness or injury. One third of the patients' condition progressed to a triage score with a lower level of urgency during ambulance transport and concurrent care. Thus, improvement in vital signs categorised by triage scores during the course of prehospital treatment and care is a possible outcome measure in future studies of paediatric care in EMS settings, although linkage to prognostic outcomes is required in future investigations.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval North Denmark Region permitted the collection and storage of data according to the General Data Protection Regulation (GDPR) standards (project ID 2018-168). The management at Aalborg University Hospital and the Danish Patient Safety Authority waived the need for individual patient consent to access electronic patient medical records (record number 3-3013-1675/3). According to Danish law, no approval from an ethics committee is needed for registry-based studies with no patient encounters.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Data on which this study is based are available from the North Denmark Region; however, legal restrictions apply to the availability of data, which means that access to data is conditioned by having a license from the Danish

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REFERENCES

1 Demaret P, Lebrun F, Devos P, *et al*. Pediatric pre-hospital emergencies in Belgium: a 2-year national descriptive study. *Eur J Pediatr* 2016;175:921–30.
2 Christensen EF, Larsen TM, Jensen FB, *et al*. Diagnosis and mortality in prehospital emergency patients transported to hospital: a population-based and registry-based cohort study. *BMJ Open* 2016;6:e011558.
3 Andersen K, Mikkelsen S, Jørgensen G, *et al*. Paediatric medical emergency calls to a Danish emergency medical dispatch centre: a retrospective, observational study. *Scand J Trauma Resusc Emerg Med* 2018;26:2.
4 Lissauer T, Clayden G. *Illustrated textbook of paediatrics*. 4th ed. Elsevier Ltd, 2012.
5 Guise J-M, Hansen M, O'Brien K, *et al*. Emergency medical services responders' perceptions of the effect of stress and anxiety on patient safety in the out-of-hospital emergency care of children: a qualitative study. *BMJ Open* 2017;7:e014057.
6 Öberg M, Vicente V, Wahlberg AC. The emergency medical service personnel's perception of the transportation of young children. *Int Emerg Nurs* 2015;23:133–7.
7 Rahman A, Curtis S, DeBruyne B, *et al*. Emergency medical services provider comfort with prehospital analgesia administration to children. *Prehosp Disaster Med* 2015;30:66–71.
8 Houston R, Pearson GA. Ambulance provision for children: a UK national survey. *Emerg Med J* 2010;27:631–6.
9 Kaji AH, Santillanes G, Claudius I, *et al*. Do infants less than 12 months of age with an apparent life-threatening event need transport to a pediatric critical care center? *Prehosp Emerg Care* 2013;17:304–11.
10 Corfield AR, Silcock D, Clerihew L, *et al*. Paediatric early warning scores are predictors of adverse outcome in the pre-hospital setting: a national cohort study. *Resuscitation* 2018;133:153–9.
11 Parshuram CS, Dryden-Palmer K, Farrell C, *et al*. Effect of a pediatric early warning system on all-cause mortality in hospitalized pediatric patients: the EPOCH randomized clinical trial. *JAMA* 2018;319:1002–12.
12 Gold DL, Mihalov LK, Cohen DM. Evaluating the pediatric early warning score (PEWS) system for admitted patients in the pediatric emergency department. *Acad Emerg Med* 2014;21:1249–56.
13 Akre M, Finkelstein M, Erickson M, *et al*. Sensitivity of the pediatric early warning score to identify patient deterioration. *Pediatrics* 2010;125:e763–9.
14 Seiger N, Maconochie I, Oostenbrink R, *et al*. Validity of different pediatric early warning scores in the emergency department. *Pediatrics* 2013;132:e841–50.
15 Chapman SM, Wray J, Oulton K, *et al*. Systematic review of paediatric track and trigger systems for hospitalised children. *Resuscitation* 2016;109:87–109.
16 Lambert V, Matthews A, MacDonell R, *et al*. Paediatric early warning systems for detecting and responding to clinical deterioration in children: a systematic review. *BMJ Open* 2017;7:e014497.
17 Corfield AR, Clerihew L, Stewart E, *et al*. The discrimination of quick paediatric early warning scores in the pre-hospital setting. *Anaesthesia* 2020;75:353–8.
18 Newgard CD, Cudnik M, Warden CR, *et al*. The predictive value and appropriate ranges of prehospital physiological parameters for high-risk injured children. *Pediatr Emerg Care* 2007;23:450–6.
19 Newgard CD, Rudser K, Atkins DL, *et al*. The availability and use of out-of-hospital physiologic information to identify high-risk injured children in a multisite, population-based cohort. *Prehosp Emerg Care* 2009;13:420–31.
20 Maconochie IK, de Caen AR, Aickin R, *et al*. Part 6: pediatric basic life support and pediatric advanced life support. *Resuscitation* 2015;95:e147–68.
21 Statistics Denmark. Population figures 2020Q2 by gender, time, age and area. Available: https://www.statistikbanken.dk/statbank5a/selectvarval/saveselections.asp [Accessed 13 May 2020].
22 Danish Medicines Agency. Available: https://laegemiddelstyrelsen.dk/en/ [Accessed 23 Jun 2020].
23 Pedersen CB, Gøtzsche H, Møller JO, *et al*. The Danish civil registration system. A cohort of eight million persons. *Dan Med Bull* 2006;53:441–9.
24 Frischknecht Christensen E, Berlac PA, Nielsen H, *et al*. The Danish quality database for prehospital emergency medical services. *Clin Epidemiol* 2016;8:667–71.
25 Jørgensen MD, Christensen EF, Mulvad T. Præhospitale Patientforløb Projektrapport, 2019.
26 Harris PA, Taylor R, Minor BL, *et al*. The REDCap Consortium: building an international community of software platform partners. *J Biomed Inform* 2019;95:103208.
27 Poulsen NR, Kløjgård TA, Lübcke K, *et al*. Completeness in the recording of vital signs in ambulances increases over time. *Dan Med J* 2020;67:A07190421.
28 Drayna PC, Browne LR, Guse CE, *et al*. Prehospital pediatric care: opportunities for training, treatment, and research. *Prehosp Emerg Care* 2015;19:441–7.
29 Hewes H, Hunsaker S, Christensen M, *et al*. Documentation of pediatric vital signs by EMS providers over time. *J Pediatr Surg* 2016;51:329–32.

Supplementary File 1. The Paediatric Triage Model used in Danish emergency medical services (Danish Regions, 2012).

Paediatric Triage Model

Triage level	1 Life-threatening	2 Urgent	3 Less urgent	4 Not urgent
A	Airway obstruction	Partial airway obstruction	Partial airway obstruction only at physical activity	No airway obstruction
B	SpO_2 < 85% with no O_2 SpO_2 < 90% with O_2 Respiratory rate red	SpO_2 85-92% with no O_2 SpO_2 90-96% with O_2 Respiratory rate orange	SpO_2 93-94% with no O_2 SpO_2 ≥ 97% with O_2 Respiratory rate yellow	SpO_2 ≥ 95% with no O_2 Respiratory rate green
C	Heart rate red	Heart rate orange	Heart rate yellow	Heart rate green
D	Unconscious GCS ≤ 8	Altered level of consciousness or irritability GCS 9-13	Awake or can be awakened but fussy GCS 14	Awake or can be awakened and alert GCS 15

Respiratory rate

Child age	1	2	3	4	3	2	1
0-2 mo.	<10	10-19	20-29	30-60	61-80	81-90	>90
3-11 mo.	<10	10-19	20-29	30-60	61-70	71-80	>80
1-2 years	<10	10-14	15-19	20-30	31-40	41-50	>50
3-7 years	<10	10-12	13-15	16-24	25-30	31-35	>35
≥ 8 years	<8	8-9	10-11	12-25	26-30	31-35	>35

Heart rate

Child age	1	2	3	4	3	2	1
0-2 mo.	<50	50-69	70-89	90-180	181-205	206-230	>230
3-11 mo.	<40	40-59	60-79	80-160	161-190	191-230	>230
1-2 years	<40	40-58	59-74	75-130	131-165	166-200	>200
3-7 years	<40	40-54	55-69	70-110	111-125	126-165	>165
≥ 8 years	<40	40-44	45-49	50-110	111-120	121-140	>140

Supplementary File 2. Vital sign progression.

Supplementary File 2. Vital sign progression, n (%) N = 25,039	Heart rate	Glasgow Coma Score	Respiratory rate	SpO$_2$ ± oxygen*
First and last values are both within the normal age-specific range	11,554 (46.1%)	14,388 (57.5%)	9,407 (37.6%)	14,186 (56.7%)
First and last values are both outside the normal age-specific range	3,874 (15.5%)	1,581 (6.3%)	1,200 (4.8%)	760 (3.0%)
First value is outside and last value is within the normal age-specific range	2,365 (9.4%)	1,033 (4.1%)	966 (3.9%)	2,052 (8.2%)
First value is within and last value is outside the normal age-specific range	993 (4.0%)	174 (0.7%)	260 (1.0%)	1,275 (5.1%)
Less than 2 observations of that particular vital sign	6,253 (25.0%)	7,863 (31.4%)	13,206 (52.7%)	6,766 (27.0%)

Vital sign progression during ambulance transport showing events with patients of all age groups.

*Change in SpO$_2$ from either ≥95% or below 95% regardless of oxygen treatment.