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Original Research

A Nationwide Retrospective Analysis of Out-of-Hospital Pediatric Cardiopulmonary Resuscitation Treated by Helicopter Emergency Medical Service in the Netherlands

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A B S T R A C T

Objective: There is generally limited but conflicting literature on the incidence, causes, and outcomes of pediatric out-of-hospital cardiac arrest. This study was performed to determine the incidence and outcome of pediatric out-of-hospital cardiac arrest reported by all helicopter emergency medical services in the Netherlands and to provide a description of causes and treatments and, in particular, a description of the specific interventions that can be performed by a physician-staffed helicopter emergency medical service.

Methods: A retrospective analysis was performed of all documented pediatric (0 < 18 years of age) out-of-hospital cardiac arrests from July 2015 to July 2017, attended by all 4 Dutch helicopter emergency medical service teams.

Results: Two hundred two out-of-hospital cardiac arrests were identified. The overall incidence in the Netherlands is 3.5 out-of-hospital cardiac arrests in children per 100,000 pediatric inhabitants. The overall survival rate for out-of-hospital cardiac arrest was 11.4%. Eleven (52%) of the survivors were in the drowning group and between 12 and 96 months of age.

Conclusion: Helicopter emergency medical services are frequently called to pediatric out-of-hospital cardiac arrests in the Netherlands. The survival rate is normal to high compared with other countries. The 12- to 96-month age group and drowning seem to have a relatively favorable outcome.

Cardiorespiratory arrest is a rare event during childhood that needs immediate treatment in order to achieve the best chances of survival without neurologic damage. There is a lack of studies on the incidence, causes, and outcome of pediatric out-of-hospital cardiac arrest (OHCA) as a result of a missing reporting system in the Netherlands. Internationally reported pediatric OHCA incidences range widely from 6.0 to 19.7 per 100,000 pediatric person years,[1-5] as do reported survival rates (from 0%-19%).[1-8] One study reported 233

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The Medical Ethical Committee of the Erasmus University Medical Center (MEC-2017-346) approved this study.

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pediatric OHCA cases with a survival rate of 9% during a study period of 4 years in a part of the Netherlands.[9]

Paramedics in the Netherlands are all registered nurses, the vast majority of whom have a background as intensive care unit, emergency department, or anesthetic nurses. In addition, they receive 9 months of training followed by an examination before they are allowed to work individually within emergency medical services (EMS). The EMS protocol in the Netherlands is a nationwide protocol with a precise description of procedures to follow, but the ambulance crew is limited in expertise and experience in vitally compromised children.[10,11] Nevertheless, as state in the nationwide protocol, EMS is authorized to perform advanced life support procedures on pediatric patients.

Helicopter emergency medical service (HEMS) was introduced in order to deliver a trained medical specialist (physician), anesthesiologist, or surgeon to the scene in addition to a regular ambulance crew. There are 4 HEMS teams covering the entire area of the Netherlands. Pediatric OHCA is 1 of the primary dispatch criteria for HEMS in the Netherlands.[10,12] There are limited data on the incidence and outcome of pediatric OHCA in the Netherlands and the benefit of HEMS deployment in this.

The primary aim of this study was to assess the incidence and outcome of pediatric OHCA reported by all HEMS services in the Netherlands. Additionally, the causes and treatments of pediatric OHCA were analyzed as well as the specific interventions performed by HEMS. The aim of this study was to gain insight into the presumed added value of HEMS on pediatric OHCA in the Netherlands and secondarily to identify which pediatric patients are more at risk and which are surviving in order to adjust training or create awareness.

Methods

Study Setting

The Netherlands has a population of over 17 million people covering an area of 41,543 km^2. In 2020, there were approximately 2.9 million people younger than 18 years of age living in the Netherlands.[13] HEMS is dispatched either primarily according to national protocol by EMS dispatch or secondarily by the EMS at the incident location. When HEMS became operational in 1995, EMS frequently secondarily asked for assistance because of limited expertise and experience in vitally compromised children.[10,11] After a few years (well before the study period), it became standard protocol to activate HEMS primarily in vitally compromised children.[12] Since February 2011, HEMS has been available 24/7 by helicopter, but if the weather conditions are below limitations or the incident is nearby, a specially designed emergency vehicle is used to transport the HEMS team. Since the start of HEMS in 1995, all 4 HEMS stations have received over 80,000 calls, of which around 35,000 were canceled by EMS before arriving. Nowadays, 22% of the patients treated are under 18 years of age.

Study Design

A retrospective analysis was performed on all 4 HEMS databases in which all patients treated by 1 of 4 HEMS are registered. When needed, additional data were obtained from the receiving hospitals. Patients were selected who had a documented OHCA and were under the age of 18 on the day of the emergency call between July 2015 and July 2017. A 1-year follow-up was performed to determine if patients were still alive. Survival status was obtained by inquiry of the civil registry from the government. The latest date of follow-up was considered June 18, 2018.

Data Collection

Inclusion was based on a documented OHCA, either confirmed by clinical assessment by EMS/HEMS personnel or by a shockable rhythm on automatic external defibrillator analysis before EMS arrival. This was done to avoid the inclusion of pediatric patients with poor but spontaneous circulation.[14] Patients primarily treated in other hospitals and then transferred by HEMS were excluded.

All cases were divided into the following groups based on Utstein Resuscitation Registry templates for OHCA: medical, traumatic, drug overdose, drowning, electrocution, asphyxia, and not recorded.[15] Because of the high prevalence in the Netherlands of home delivery, a specific group of resuscitation at birth was made.[16] The following data were extracted from the registries: age, initial rhythm, defibrillation, time to HEMS on scene, medical interventions, vascular access, administered medication, airway intervention, outcome, and primary cause of cardiac arrest.

Statistical Analyses

Categoric variables are presented as numbers and percentages. Complete case analyses were performed.

Results

Patient Characteristics and the Incidence of Pediatric OHCA

During the study period, 202 pediatric OHCA cases were identified. Seventeen patients were excluded because of missing baseline data (Fig. 1). In 19 patients, no exact age was recorded (only age in years) and could not be determined afterward. The baseline characteristics are presented in Table 1. Table 2 provides an overview of the causes of OHCA. Most patients were between 12 and 96 months of age, and this was also the group with the highest survival percentage. Fifty-eight percent of patients were male, and 42% were female. In the group of pediatric patients with a medical cause of OHCA, 45 (41%) had a previous medical history. The overall incidence of OHCA in the Netherlands is 3.5 OHCAs per 100,000 pediatric inhabitants (0 < 18 years of age), but it varies by region between 0 and 17.2 per 100,000 pediatric inhabitants (Table 3).

Initial Rhythm and Advanced Life Procedures

Nonshockable rhythm was the most often observed initial rhythm (77%); asystole was identified in 62%, and pulseless electrical activity in 15% of pediatric patients. Shockable rhythms were present in 8% and varied with age (Table 1). In 15% of the cases, no record of the initial rhythm could be found (Table 1).

In pediatric patients, endotracheal intubation is performed by HEMS in 88% and 91% in the first or second attempt, respectively. Eventually, none of the intubations performed by HEMS were inserted into the esophagus. In 4% (6 cases), intubation was unsuccessful; this was caused by stiffness of the jaw or the pediatric patient had a syndrome associated with a difficult airway. In 1 of these cases, a surgical airway was performed; the other 5 remained on bag-valve-mask ventilation, which was successful (adequate movement of the chest). In 2 cases, dislocation of the endotracheal tube occurred, but this was quickly recognized, and the tubes were immediately reinserted.

Nineteen (12%) intubations were performed by EMS. In 10 cases, EMS tried to intubate but failed. In 4 patients, the endotracheal tube was placed in the esophagus and had to be correctly inserted by HEMS on arrival. One endotracheal tube was placed too deep and had to be corrected on HEMS arrival. One endotracheal tube was too small, and ventilation was ineffective. This tube was replaced by HEMS on arrival. The insertion of a laryngeal mask airway was performed in 10 cases; in 1 case, this was not successful.

In OHCA cases caused by trauma, 10 thoracostomies and 2 thoracotomies were performed.

HEMS established 32 intraosseous (IO) accesses. In 1 case, HEMS used ultrasound for intravenous access. EMS performed 61 IO access procedures. Of them, 16 (27%) IO needles/accesses were not placed correctly.

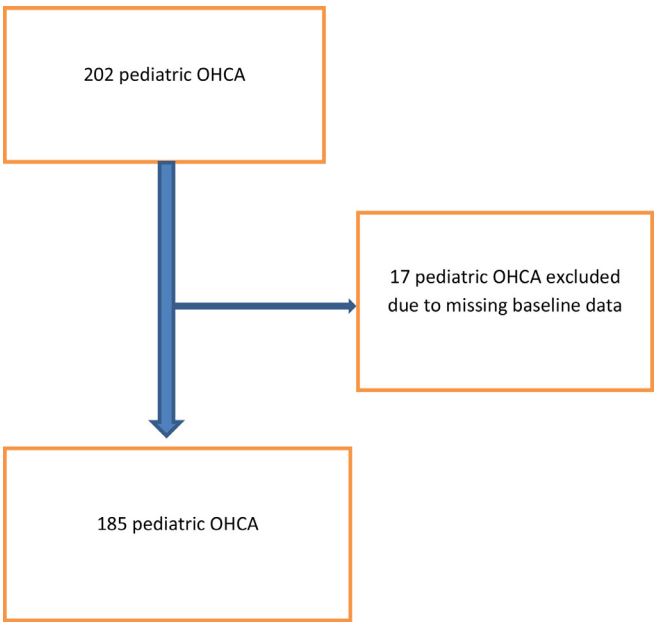

Figure 1. Pediatic OHCA cases.

In 23 OHCA cases, cardiopulmonary resuscitation (CPR) was discontinued according to the decision of the HEMS after on-scene evaluation. EMS was not able to make the decision for discontinuing or not starting with CPR, but it was obvious for HEMS that these patients were diseased because of a prolonged time before starting CPR or extensive trauma.

HEMS follows the European Resuscitation Council guidelines[14] for the administration of medication during CPR, as does EMS. HEMS more often administers adrenaline; EMS is allowed to give this medication as well because EMS could not obtain intravenous/IO access, and even when access was achieved, EMS sometimes did not administer adrenaline. Before and after CPR, HEMS is allowed to give all kinds of medication not listed in the nationwide EMS protocols, such as sedation, relaxation, antibiotics, and blood pressure medication, which is frequently administered by HEMS.

Transport Mode and Timelines

Seventy-seven percent of calls were executed by helicopter and 23% by car. The median time from the initial 112 call to HEMS arrival on scene was 18 minutes (range, 3-40 minutes). HEMS responds by car if the incident is nearby, if the weather conditions are too poor to fly, or if maintenance is being performed on the helicopter.

Survival

In the 185 pediatric patients who could be followed up for mortality data, 21 patients survived 1 year after discharge from the hospital (11.4%). Survival with a shockable rhythm was higher (18.2%) compared with a nonshockable rhythm (5.3%). Of the 21 survivors, 11 suffered from drowning. The surviving patients who drowned were all in the 12- to 96-month age category. In the 1- to 12-month age group, there were no survivors.

Table 2
Cause of Out-of-Hospital Cardiac Arrest (OHCA) and Survival

Cause of OHCA		Survival, n (%)
Medical	104 (56)	4 (4)
Traumatic	30 (16)	1 (3)
Drug overdose	1 (1)	0
Drowning	26 (14)	11 (42)
Electrocution	0	0
Asphyxial	14 (8)	3 (21)
OHCA during birth	10 (5)	2 (20)
Not recorded	0	0
Total	185	21 (11)

Discussion

In this nationwide retrospective database study, 202 pediatric patients with OHCA were identified. The highest number of OHCAs in pediatric patients occurred in the 2 ambulance regions with the largest cities of the Netherlands. In these 2 cities (Amsterdam and Rotterdam), 2 of the 4 HEMS are situated. The volume of pediatric prehospital care is normally higher in urban regions than in rural areas,[17,18] as can be seen in Table 2. The other 2 ambulance regions where HEMS are stationed received 9.6 (Groningen) and 6.2 (Gelderland-Midden) pediatric OHCAs per 100,000 pediatric inhabitants. These 2 HEMS are active in a more rural area. This can also be seen in the response times (Table 4); the time from the initial 112 call and HEMS arriving on scene is prolonged in these 2 rural areas because of the increased distance to the scene. Other differences between the different HEMS team could not be found (eg, difference in success rate for intubations, IO insertion, etc.) because of small numbers.

This study showed a 11.4% survival rate, which is a little higher than a previous study performed in 1 region in the Netherlands that showed a survival rate of 9%[9] but is within the normal to high range compared with other studies.[1-8] In only 1 study was a 19.4% survival rate[8] found because they added respiratory arrest and cardiac arrest together. Six of 31 pediatric patients survived, but 4 of them only had respiratory arrest and no cardiac arrest. The pediatric patients in our study were all in full cardiac and pulmonary arrest. Excluding this previous study, the Netherlands has a relatively high number of cases of pediatric OHCA survival.

Although shockable rhythms are not frequent in children, the presence of ventricular fibrillation or pulseless ventricular tachycardia as the initial rhythm represented higher chances of sustained return of spontaneous circulation and higher survival at hospital discharge compared with asystole and pulseless electrical activity.[19] This study showed that 14 of 185 (8%) patients had a shockable rhythm and had a 18.2% chance of survival. There were even 2 patients in the 1- to 12-month age group who had an initial

Table 1
1- Year Survival and the Initial Rhythm by Age

Age (mo)	Total	VF/VT, n (%)	PEA, n (%)	Asystole, n (%)	Unknown Rhythm, n (%)	Survival, n (%)
0-1	27	0	6 (22)	16 (59)	5 (19)	4 (15)
1-12	41	2 (5)	2 (5)	31 (76)	6 (15)	0
12-96	59	4 (7)	9 (15)	39 (66)	7 (12)	12 (20)
96-216	58	8 (14)	11 (19)	29 (50)	10 (17)	5 (9)
Total	185	14 (8)	28 (15)	115 (62)	28 (15)	21 (11)

PEA = pulseless electrical activity; VF = ventricular fibrillation; VT = ventricular tachycardia (without output).

Table 3
The Number of Pediatric Out-of-Hospital Cardiac Arrest (OHCA) Cases per 100,000 Inhabitants (0 < 18 Years of Age)

Region	Number of Pediatric OHCA Cases	Inhibitants (0 < 18 Years of Age)	Number of Pediatric OHCA Cases per 100,000 Inhabitants (0 < 18 Years of Age)
1.Groningen	10	104,444	9.6
2.Friesland	7	121,646	5.8
3.Drenthe	9	85,462	10.5
4.Ijsselland	4	93,540	4.3
5.Twente	0	118,139	0
6.Noord-Oost Gelderland	3	139,854	2.1
7.Gelderland-Midden	7	112,424	6.2
8.Gelderland-Zuid	3	88,335	3.4
9.Utrecht	9	188,039	4.8
10.Noord-Holland-Noord	9	108.431	8.3
11.Zaanstreek-Waterland	6	54,063	11.1
12.Kennemerland	8	89,581	8.9
13.Amsterdam Amstelland	23	133,708	17.2
14.Gooi en Vechtstreek	4	40,810	9.8
15.Haaglanden	13	168,848	7.7
16.Hollands-Midden	7	123,536	5.7
17.Rotterdam-Rijnmond	32	215,794	14.8
18.Zuid-Holland-Zuid	6	70,330	8.5
19.Zeeland	4	66,967	6.0
20.Midden-West Brabant	11	178,719	6.2
21.Brabant Noord	12	110,170	10.9
22.Brabant Zuid-Oost	4	115,405	3.5
23.Limburg-Noord	4	83,674	4.8
24.Limburg-Zuid	0	98,880	0
25.Flevoland	7	71,813	9.7

Population by security region.
Data from Centraal Bureau voor Statistiek (www.cbs.nl).

Table 4
HEMS average time (and range) from initial 112 call to arrival on scene

HEMS team	Helicopter	Emergency vehicle
Lifeliner 1 (Amsterdam)	17,9 (8-34)	13,6 (5-40)
Lifeliner 2 (Rotterdam)	15,7 (4-37)	14,8 (3-39)
Lifeliner 3 (Nijmegen)	20,1 (8-28)	30,8 (23-36)
Lifeliner 4 (Groningen)	19,5 (7-34)	11,7 (4-25)

shockable rhythm (Table 1). This percentage was also seen in a larger study in 1,193 pediatric patients by Fukuda et al,[20] which stated that 7.1% had a shockable rhythm in an out-of-hospital setting. The better prognosis in patients with shockable rhythms implies their greater reversibility potential. Therefore, focusing efforts on early CPR, shockable rhythm recognition, and rapid defibrillation should remain a priority alongside a focus on airway and ventilations.

The patients in the drowning group seem to be in favor of surviving. Of the 21 survivors, 11 (52%) suffered from drowning so they could be more in favor of surviving. Before the drowning occurs, these patients are healthy and only suffer from sudden hypoxia. If health care providers or laypersons can quickly react and reverse this hypoxia, these children seem to have the highest chance of survival. The patients with the lowest survival belong to the medical and trauma group.

Ten OHCAs occurred in pediatric patients during birth. Two (20%) survived 1 year after until discharge from the hospital. In the Netherlands in 2016, there were 21,434 planned home births guided by midwives alone without further obstetric assistance, accounting for 12.7% of all births that year.[16] It seems that in only a small amount of patients the assistance of HEMS is needed, which is in line with a previous study performed in the Netherlands.[16]

As can be seen in the Results section, intubation by EMS has a high failure rate (46%) and should not be performed by EMS in the Netherlands anymore. This high intubation failure rate was also found by a previous study[21] in the Netherlands. When placing an IO access, HEMS has no failure rate. The failure rate by EMS for IO access is 27%.

Pediatric OHCA is a primary deployment criteria for HEMS; thus, all 112 calls regarding pediatric OHCA should lead to the deployment of HEMS. Two regions have no deployments for HEMS in pediatric OHCA. These 2 regions (Twente and Limburg-Zuid) are the 2 regions that are the farthest away to reach by helicopter. In the early years, these 2 regions could receive additional medical help from a German HEMS but only during daylight. A few years ago, it became standard to deploy HEMS from the Netherlands because they are available 24/7, but there are apparently still no deployments for OHCA in pediatric patients. One of the reasons could be that paramedics in these regions do not want to wait for HEMS and perform a scoop and run to the nearest hospital. However, a previous study by our group showed there were no survivors in the Netherlands in pediatric patients after a scoop and run in OHCA was performed.[21]

The regions with an urban area have more than 7 OHCAs in pediatric patients per 100,000 pediatric inhabitants. Only 1 region (Utrecht) is below this number. Utrecht is an urban region, and one could expect that there should be more pediatric OHCAs. One of the reasons could be that HEMS is not easily deployed in that region.

Study Limitations

Because only a nationwide mandatory reporting system for OHCA in pediatric patients, which is still not present in the Netherlands, would ensure capture of all OHCA cases, we might have missed some cases. Although pediatric OHCA is a primary deployment criteria for HEMS, we could have missed some cases in which HEMS was activated but the time to scene was prolonged and EMS performed a scoop and run to the nearest hospital, which could have occurred in the Twente or Zuid Limburg region.

Another limitation is the database itself. We searched 4 databases and found incomplete data, which is an inherent limitation of a retrospective database research.

Conclusion

HEMS is frequently called to pediatric OHCA in the Netherlands. Survival until discharge with a follow-up to 1 year after the incident is 11.4% and higher than average in Europe. The overall incidence in the Netherlands is 3.5 OHCAs per 100,000 pediatric inhabitants (0 < 18 years of age), but not all provinces in the Netherlands are equally represented in the number of pediatric OHCAs. The 12- to 96-month age group and drowning show a relatively favorable outcome. A shockable rhythm is rare but can still be found. These patients have a higher chance of sustained return of spontaneous circulation and a higher survival at hospital discharge. EMS has poor success with pediatric intubation.

Recommendations

The data in this study suggest that better education/training/skills for the EMS providers could improve patient outcomes. Creating a national database for pediatric OHCA with neurologic follow-up would allow stratification of the outcome for survival.

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