Epidemiological and Survival Trends of Pediatric Cardiac Arrests in Emergency Departments in Korea: A Cross-sectional, Nationwide Report

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INTRODUCTION

Cardiac arrest (CA) in children is associated with high mortality rates. In Korea, cohort studies regarding the outcomes of pediatric CAs are lacking, especially in emergency departments (EDs) or in-hospital settings. This study was conducted to examine the trends in epidemiology and survival outcomes in children with resuscitation-attempted CAs using data from a cross-sectional, national, ED-based clinical registry. We extracted cases in which cardiopulmonary resuscitation and/or manual defibrillation were performed according to treatment codes using the National Emergency Department Information System (NEDIS) from 2008 to 2012. The total number of ED visits registered in the NEDIS during the 5-yr evaluation period was 20,424,530; among these, there were 2,970 resuscitation-attempted CAs in children. The annual rates of pediatric CAs per 1,000 ED visits showed an upward trend from 2.81 in 2009 to 3.62 in 2012 (P for trend = 0.045). The median number of estimated pediatric CAs at each ED was 7.8 (25th to 75th percentile, 4 to 13) per year. The overall rates for admission survival and discharge survival were 35.2% and 12.8%, respectively. The survival outcome of adults increased substantially over the past 5 yr (11.8% in 2008, 11.7% in 2010, and 13.6% in 2012; P for trend = 0.001); however, the results for children did not improve (13.6% in 2008, 11.4% in 2010, and 13.7% in 2012; P for trend = 0.870). Conclusively, we found that the overall incidence of pediatric CAs in EDs increased substantially over the past 5 yr, but without significantly higher survival outcomes.

Keywords: Pediatrics; Heart Arrest; Resuscitation; Outcome; Emergency Service, Hospital
logic characteristics and survival outcomes in children with resuscitated CAs in EDs using data from a cross-sectional, national ED-based registry.

MATERIALS AND METHODS

NEDIS database
Data were obtained from the NEDIS database, which is updated in real time by the National Emergency Medical Center (NEMC). The database was developed in 2004. Its quality control, feedback, and evaluation systems regarding emergency patients’ registration information were established in 2006 and 2007. We obtained official permission to use the extracted the NEDIS data set from the NEMC. This information included patients’ demographic characteristics, clinical parameters, ED diagnosis codes, core treatment parameters, patient disposition, and primary basic information regarding quality monitoring (11). As of 2012, all 23 level I regional centers and all 113 level II local centers had participated in the NEDIS project, accounting for more than 48.5% of the national overall ED census (Table 1). All patient-related information was automatically transferred from each hospital to a central government server within 2 or 14 days of the patient’s discharge from an ED or hospital ward, respectively. Inaccurate data were filtered by a data processing system. The health authority maintains an accuracy assessment system and annually reports the results to the Ministry of Health and Welfare.

Study population and variables
Our target was to record all cases of attempted CPR that began or continued in EDs upon arrival with OHCA (9, 12). Data for CPR-attempted CAs in EDs were extracted by the NEDIS. We used the following data from 2008 to 2012: 1) cardiac compression and/or manual defibrillation as treatment codes in the ED, 2) the ICD-10 code for CAs (I490-I469, I490, R02) in any disease field, and 3) the main symptom or diagnosis of CA, respiratory arrest, ventricular fibrillation (VF), or pulseless ventricular tachycardia (pVT) (9, 13). Cases involving death on arrival, do-not-attempt resuscitation, or pre-hospital return of spontaneous circulation were excluded.

The following variables were analyzed: patient and peri-event characteristics (i.e., sex and age [infants < 1 yr, children 1-11 yr, and adolescents 12-19 yr]), etiology (i.e., disease or injury), whether the ED diagnosis was shockable arrhythmia (i.e., VF or pVT) or if the event occurred during night duty (i.e., 11:00 PM to 07:59 AM), the admission day (i.e., weekday or weekend, and the day of the week), and the month of year (14-16).

Primary and secondary outcomes
The primary outcomes were estimated incidence and survival outcomes at admission and discharge. To understand which circadian, weekly, and monthly variations were associated with a temporal improvement in survival, we examined trend analysis as the secondary outcome (17, 18).

Statistical analysis
The overall resuscitated pediatric CAs in EDs from January 1, 2008 to December 31, 2012 were analyzed using IBM SPSS Statistics version 21.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were presented as medians and interquartile ranges (IQR; 25th and 75th percentiles). Categorical variables were presented as numbers and percentages. Chi-square or Mann-Whitney tests were performed during the univariate analysis of the survival outcomes. The annual changes from 2008 to 2012 were tested using a linear-by-linear association and expressed as a P value for the trend (19). All statistical tests were two-tailed.

Table 1. Characteristics of the National Emergency Department Information System participants and the national emergency census in Korea

| Year | Total | 2008 | 2009 | 2010 | 2011 | 2012 |
|------|-------|------|------|------|------|------|
| Pediatric subgroup in NEDIS |       |      |      |      |      |      |
| Pediatric, subtotal, No.     | 6,692,840 | 990,686 | 1,330,117 | 1,374,105 | 1,418,582 | 1,579,350 |
| Infants ( < 1 yr)            | 879,794  | 149,068 | 155,318  | 178,566  | 191,489  | 205,353  |
| Children (1-11 yr)           | 4,067,845 | 600,458 | 785,026  | 855,750  | 865,553  | 970,058  |
| Adolescents (12-19 yr)       | 1,745,201 | 241,160 | 389,773  | 339,789  | 370,540  | 403,939  |
| Pediatric CAs in EDs, No.    | 2,970    | 510   | 436    | 600     | 680     | 744     |
| Infants ( < 1 yr)            | 933      | 175   | 118    | 193     | 209     | 238     |
| Children (1-11 yr)           | 944      | 172   | 122    | 183     | 207     | 260     |
| Adolescents (12-19 yr)       | 1093     | 163   | 196    | 224     | 264     | 246     |
| CAs in EDs per 1,000 pediatric visits | 3.38 | 3.42 | 3.28 | 3.36 | 3.55 | 3.62 |
| Overall NEDIS database* (all ages) |       |      |      |      |      |      |
| ER visits in the NEDIS database, No. | 20,424,530 | 3,107,527 | 3,818,466 | 4,098,110 | 4,429,535 | 4,970,892 |
| National hospital-based census* |       |      |      |      |      |      |
| Total ER Visits in Korea, No. | 50,522,478 | 8,905,766 | 10,814,628 | 10,232,016 | 10,327,028 | 10,243,040 |
| NEDIS: national ER census ratio | 40.4%  | 34.9% | 35.3% | 40.1%  | 42.9%  | 48.5%  |

*Data source: 2008-2012 Yearbook of Emergency Medical Statistics (reference: http://www.nemc.or.kr/). CA, cardiac arrest; ED, emergency department; ER, emergency room; NEDIS, National Emergency Department Information System.
and \( P \)-values < 0.05 were considered statistically significant.

**Ethics statement**
The study was reviewed and approved by the institutional review board of Kyungpook National University Hospital (KNUH 201408006). Informed consent was waived by the board.

**RESULTS**

**Demographic characteristics**
The total number of emergency visits, registered in the NEDIS from 2008 to 2012, was 20,424,530. Among these, the total number of pediatric cases was 6,692,840, of which 2,970 cases received CPR in an ED, an average of 594 visits per year (Fig. 1). These visits represented 0.34% of all pediatric ED visits over the period (rate 3.38 per 1,000 ED visits, 95% confidence interval [CI]: 3.37-3.39). The annual rates of pediatric CAs per 1,000 ED visits showed an upward trend from 2.81 in 2009 to 3.62 in 2012 (\( P \)-for trend = 0.045; Table 1).

The median number of pediatric CAs in the ED at each hospital was 39 (25th to 75th percentile, IQR, 20 to 64). For estimated annual incidence, the median number of case at each hospital per year was 7.8 (IQR, 4 to 13). The maximal and minimal numbers of registered cases were 130 and 1, respectively.

Regarding age groups, 31.4% of the cases were infants and 36.8% were adolescents. Furthermore, 63.3% of the cases were male. The frequency of cases in which the ED diagnosis was pVT or VF was 2.8%; the frequency of cases in which the cause of CA was trauma, poisoning, or other injuries was 37.4%; and the frequency of cases during night duty (11:00 PM to 07:59 AM) was 33.3%. Public ambulance services were used in 59.7% of the ED cases. The characteristics of the overall and annual resuscitated pediatric CAs in EDs are shown in Table 2.

**Survival outcomes**
The overall rates for admission survival and discharge survival were 35.2% and 12.8%, respectively (Table 2). Among admitted patients, 149/339 (44.0%) infants, 97/324 (29.9%) children, and 133/382 (34.8%) adolescents survived at discharge (Fig. 1).

Of hospital factors, a greater survival at discharge was observed in hospitals located in the metropolitan area (odds ratio [OR], 1.41; 95% CI, 1.11-1.79, \( P \) = 0.005) and hospitals with higher annual CPR volume (OR, 1.38; 95% CI, 1.06-1.87, \( P \) = 0.034), but not high EMC levels (OR, 1.19; 95% CI, 0.92-1.53, \( P \) = 0.179).

**Circadian, weekly, and monthly variations**
The circadian variation among all children with a CA in the ED is shown in Fig. 2. Bimodal incidence peaks (one in the late morning and one in the afternoon) was observed; however, there was a trough at 2 to 3 AM (\( n = 78 \), 2.6%). The highest survival discharge rate was observed at 4 to 5 PM (29/147, 19.7%). Three lower troughs were detected at 7 to 8 AM (6/111, 5.4%), midnight to 2 AM (14/181, 7.7%), and 6 to 7 PM (14/169, 8.3%). The survival discharge rate was statistically different according to the hour of day (\( P \) = 0.028).

There was uniformity in the occurrence of CA by day of the week. The highest and lowest incidence rates were observed on Mondays (473 victims) and Tuesday (383 victims), respectively; however, the survival discharge rate was not significantly different (11.1% to 14.1%, \( P \) = 0.863). The months with the highest...
and lowest survival outcome were June (41/228, 18.0%) and December (27/277, 9.7%), respectively; however, there was no significant difference in the monthly variations of pediatric resuscitation-attempted CAs in EDs \( (P = 0.207) \).

**Comparison of survival outcome trends between children and adults**

In children, the trend for the discharge survival rate was similar in the two etiology groups of sudden cardiac death (Fig. 3A). In adults, survival rates of medical caused-CAs increased over time (13.8% in 2008, 13.5% in 2010, and 15.9% in 2012; \( P \) for trend = 0.001; Fig. 3B). Survival outcomes did not improve in injury-induced CAs in both children and adults (\( P \) for trend = 0.062 and 0.886). In adults, overall annual survival rates at discharge grad-

### Table 2. Trend of pediatric-resuscitated cardiac arrests in emergency departments

| Variables | Overall \( (n = 2,970) \) | 2008 \( (n = 510) \) | 2009 \( (n = 436) \) | 2010 \( (n = 600) \) | 2011 \( (n = 680) \) | 2012 \( (n = 744) \) | \( P \) for trend |
|-----------|-----------------------------|--------------------|-------------------|-------------------|-------------------|-------------------|----------------|
| Prevalence (per 1,000 ED visits) | 3.38 | 3.42 | 2.81 | 3.36 | 3.55 | 3.62 | 0.045 |
| Demographics, No. (%) | | | | | | | |
| Age, median (IQR) | | | | | | | |
| Infants (< 1 yr) | 5 (0-15) | 4 (0-14) | 8 (0-16) | 6 (0-15) | 7 (0-16) | 4 (0-14) | | |
| Children (1-11 yr) | 933 (31.4) | 175 (34.3) | 118 (27.1) | 193 (32.2) | 209 (30.7) | 238 (32.0) | 0.737 |
| Adolescents (12-19 yr) | 944 (31.8) | 172 (33.7) | 122 (28.0) | 183 (30.5) | 207 (30.4) | 260 (34.9) | | |
| Sex, male | 1,879 (63.3) | 321 (62.9) | 277 (63.5) | 383 (63.8) | 428 (62.9) | 471 (63.2) | 0.969 |
| Event time, No. (%) | | | | | | | |
| Night, 11 PM-8 AM | 981 (33.0) | 150 (29.4) | 124 (28.4) | 213 (35.5) | 217 (31.9) | 277 (37.2) | 0.002 |
| Weekend | 875 (29.5) | 147 (28.8) | 115 (26.4) | 182 (30.3) | 215 (31.6) | 216 (29.0) | 0.423 |
| Etiology of cardiac arrest, No. (%) | | | | | | | |
| Shockable rhythm (VF/pVT) | 84 (2.8) | 6 (1.2) | 10 (2.2) | 20 (3.4) | 20 (3.0) | 28 (3.8) | 0.063 |
| Medical disease progression | 1,857 (62.6) | 315 (62.0) | 237 (54.5) | 374 (62.4) | 452 (66.5) | 479 (64.4) | 0.012 |
| Trauma, poisoning, other injuries | 1,109 (37.4) | 193 (38.0) | 198 (45.5) | 225 (37.6) | 228 (33.5) | 265 (35.6) | 0.012 |
| Transport by public ambulance | 1,774 (59.7) | 321 (62.9) | 277 (63.5) | 383 (63.8) | 428 (62.9) | 471 (63.2) | 0.002 |
| Survival outcomes, No. (%) | | | | | | | |
| Survival at admission | 1,045 (35.2) | 192 (37.8) | 155 (35.6) | 185 (30.9) | 243 (35.7) | 270 (36.3) | 0.823 |
| Survival at discharge | 379 (12.8) | 69 (13.6) | 55 (12.6) | 68 (11.4) | 85 (12.5) | 102 (13.7) | 0.870 |

Data are shown as the number of events (column percentage); *Unknown or undetermined data: survival admission analysis (Year 2008 \( n = 2 \), Year 2010 \( n = 2 \)) and survival discharge analysis (Year 2008 \( n = 3 \), Year 2010 \( n = 2 \)). ED, emergency department; IQR, interquartile range; pVT, pulseless ventricular tachycardia; VF, ventricular fibrillation.

**Fig. 2.** Circadian survival rhythm of pediatric cardiac arrests (CAs) in the emergency department (ED).

**Fig. 3.** Trend plots of survival discharge in children (A) and adults (B) by calendar year. During the past 5 yr, the proportion of children survivors (overall, cardiac, and trauma group) did not improve (all \( P \) for trend > 0.05). However, the proportion of adult survivors (overall and non-traumatic group) increased over time (\( P \) for trend < 0.05).
 специально. Эти показатели были вдвое выше, чем те, что были отмечены в предыдущих исследованиях.

**DISCUSSION**

ранее были сосредоточены на экстренном лечении в больничных условиях. Согласно данным Корейского центра по контролю за инфекционными заболеваниями и предотвращению заболеваний (CAVAS проект), инцидентность несчастных случаев с ОИХ в Корее была 4,2 на 100,000 человек за год, с вероятностью выживания 4,9% с 2006 по 2007 годы (5). Однако, исследования, связанные с ОИХ, в ретроспективном анализе и проведенная в отдельном центре с только несколько лет данных, еще не привели к тенденции. Ранее проведенные исследования показали, что дети с ОИХ были более часто, чем ОИХ, в возрасте 0-15 лет, с процентом 8,1% в мета-анализе и 7-9% в некоторых популяционных исследованиях (5, 8, 26). Это означает, что некоторые шокирующие аритмии могут не быть связаны с ОИХ. Однако, другие исследования показывают, что у детей есть аритмии (8, 24-26). В отличие от других исследований, мы демонстрируем циркадный ритм артирий и вариаций в инцидентности и выживаемости детей с ОИХ в диапазоне от 7 до 8 AM и 6-7 PM. Дети с ОИХ в ночное время имели более высокую смертность, чем другие периоды. Это согласуется с результатами недавних исследований (13-16), но не с результатами исследования (13-16), но не со всеми результатами других исследований. Нам представляется хороший подход к улучшению педиатрической выживаемости.

Одним из наиболее влиятельных факторов, связанных с ОИХ, являются пациенты с ОИХ (21, 22). В первом исследовании было показано, что пациенты с ОИХ (0,3%) и 2,970 были проведены на педиатрических пациентах; поэтому, предсказанный процент реанимационных ОИХ составил 3,38 случая на 1,000 педиатрические ЭД приходится на 0,34%. Основываясь на том, что частота педиатрических аритмий и реанимационные усилия увеличились в течение года (P для тренда = 0.045). Однако, некоторые из них были недооценены (3,42 события на 1,000 педиатрические ЭД в 2008 vs. 2,81 в 2009) из-за необычно высокой частоты педиатрических ЭД в 2009, главным образом из-за пандемии гриппа A.

Для Южной Кореи были получены результаты, которые согласуются с результатами других исследований. Южная Корея предъявляет определенные требования к педиатрической медицине. Пациенты с ОИХ или реанимационные ОИХ, которые были проведены на педиатрических пациентах, обычно представляют собой острые и критические проблемы, и их уровень нестабильности может быть выше, чем у других пациентов. Основываясь на этих данных, нам представляется хороший подход к улучшению педиатрической выживаемости.

В прошлом были отмечены следующие результаты: в Южной Корее было 11,8% пациентов с ОИХ в 2008, 11,7% в 2010, и 13,6% в 2012; P для тренда = 0,001; Fig. 3B); однако, у детей уровень нестабильности улучшился (13,6% в 2008, 11,4% в 2010, и 13,7% в 2012; P для тренда = 0,870; Fig. 3A).
ent definitions and study designs. The coding rhythm in the present study was different from the actual monitored electrocardiogram because shockable rhythms were estimated from the ICD-10 codes (VF and VT) or attempted manual defibrillation.

Despite increased survival rates after CA in other countries, trends for survival outcomes of pediatric CAs did not improve in Korea during the 5 yr (24). The overall rate of survival at discharge of resuscitated pediatric CAs in EDs was 12.8% compared with 12.5% for adults. According to the trend analysis, a survival rate of resuscitated adult CAs in EDs improved from 2008 to 2012; however, that of resuscitated pediatric CAs remained unchanged. Although development of medical facility and an extended CPR training program have been continued, these resources only affected adult survival outcomes of ALS-attempted CAs in EDs and not children. Pediatric CA patients constitute a relatively small patient population in the ED. On average, the rate of pediatric CAs in the United States was 15 in-hospital and 6 out-of-hospital arrests per hospital per year. Similarly in this study, the median number of pediatric CAs in the ED at each hospital was 7.8 cases per year in Korea, which can consequently lead to unfamiliarity regarding proper pediatric CA procedures among hospital staff (1).

Regionalization of healthcare means providing high-quality and cost-effective care for patients in critical conditions. Therefore, CA centers have been suggested as a strategy to improve survival outcomes (9). Regarding inter-hospital variability of post-CA mortality, several researchers have previously reported that CA patients treated at higher volume centers admitted to the ICU or ED per year were significantly less likely to die in the hospital (21, 27). This provides support for regionalized CA care systems that include a designated high volume cardiac resuscitation center (16). Related hospital factors in the present study corresponded with the aforementioned studies in which a greater survival was reported in an urban location, a teaching hospital, a hospital with > 20,000 ED visits, a hospital with emergent intervention capability, and hospitals with high OHCA volume EDs (9, 16, 27). Similar to previous studies, a greater survival at discharge was observed in hospitals located in the metropolitan area and hospitals that had higher annual CPR volume, but not EMC levels.

This study has several limitations. Firstly, although a nationwide database was used, not all EDs in Korea were included. Pediatric resuscitation was not likely to be performed in locations with EDs below level III; therefore, we were able to identify a general trend for pediatric CAs using the NEDIS data, which included all level I and II EDs. Secondly, given the limited details of the NEDIS reports, data regarding long-term survival or neurologic status were not included in the analysis. Therefore, the final outcomes were determined at hospital discharge without 6-month survival and neurocognitive follow-up. However, previous researchers have indicated that survival outcome at discharge was not substantially different from status at 6 months and 1 yr post-arrest (28). Thirdly, we did not conduct subgroup analysis for OHCA and CAs that occurred in EDs. We were unable to separate the NEDIS dataset into OHCAs resuscitated in EDs and IHCA in EDs. Finally, it was difficult to compare CA characteristics over time with that of previous studies (CAVAS in Korea, Pediatric Emergency Care Applied Research Network, and Get With the Guidelines-Resuscitation Investigators group in the United States) because of differences in the inclusion criteria (e.g., including trauma victims) and definitions of CA (e.g., resuscitated with manual compression, adrenalin, and/or defibrillation) and the age of the pediatric group (e.g., less than 20 yr or 18 yr).

In conclusion, we found that the NEDIS-based nationwide incidence rate of resuscitated pediatric CAs in EDs was 3.38 per 1,000 ED visit per year. The overall rate of survival at discharge was 12.8%. In the trend analysis, the survival rate of resuscitated adult CAs in EDs improved from 2008 to 2012, but the survival rate of pediatric CA patients remained unchanged. Future studies are needed to determine the multidisciplinary hospital and patient factors responsible for improving CA survival in children.

DISCLOSURE

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTION

Conception & design of the study: Lee MJ. Acquisition of data and statistical analysis: Ahn JY, Kim H, Lee MJ. Data review: Yoon HD, Jang HY. Manuscript preparation: Ahn JY, Lee MJ. Revised manuscript: Kim H, Lee MJ. Manuscript approval: all authors.

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