Critical incidents associated with pediatric anesthesia: changes over 6 years at a tertiary children’s hospital

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Background: Sustained interest is needed in the characteristics of critical incidents in pediatric anesthesia and related changes, for determining the causes and degree of potential harm; this will also improve the quality of medical care. This study aimed to analyze the incidence of critical incidents recorded in 2014–2019, and to compare them with those in 2008–2013.

Methods: Critical incidents associated with pediatric anesthesia, including cardiac arrest, recorded in a voluntary departmental reporting system between January 2014 and December 2019 were compared with those reported between January 2008 and August 2013 using chi-square test.

Results: We identified 295 (0.55%) critical incidents from 53,541 cases of pediatric anesthesia (3,471 cardiothoracic surgeries); this is consistent with the previously reported incidence of 0.46%. Among the critical incidents, the incidences of adverse events, sentinel event, near miss case and no-harm events were 93.9%, 1.7%, 0%, and 6.1% in 2014–2019, whereas those were 98.3%, 2.6%, 1.7%, and 0% in 2008–2013 (P = 0.023, 0.686, 0.080, and < 0.001, respectively). Cardiac arrest accounted for 25 (8.5%) cases of the 295 critical events, which significantly lower than that previously reported (18.3%; P = 0.020). Human factor-related events accounted for 61.0% of all critical incidences; this was similar to the previous data (58.5%).

Conclusions: Over six years, there has been no significant difference in the total incidence of critical events. Despite the decrease in the incidence of serious critical events, perioperative care in pediatric anesthesia can be further improved.

Keywords: Anesthesia; Child; Incident reportings; Intraoperative complications; Medical errors; Perioperative care.

INTRODUCTION

Pediatric patients are vulnerable to critical incidents associated with anesthesia [1]; moreover, their perioperative care is challenging and requires a specialized pediatric anesthesia care team [2]. Reporting and analysis of perioperative critical incidents allow identification of the cause of critical incidents, understanding of the current situation, and the
development of a prevention strategy [3]. To improve the quality of perioperative care and patient safety, it is important to determine the characteristics of critical incidents and their temporal changes.

There have been several reports regarding critical incidents and cardiac arrests during the perioperative period in the pediatric population [4–9]. We previously analyzed critical incidents related to pediatric anesthesia, that occurred between 2008 and 2013 at a teaching children’s hospital [5]. The rate of critical incidents was 0.5%; in addition, > 50% of all critical incidents were preventable [5]. There have been ensuing changes in our medical field, including in anesthesia practice and manpower. For example, point-of-care ultrasonography has been introduced and widely adapted. Devices for difficult airway management, including a high flow nasal cannula, supraglottic airway device, and videolaryngoscope, have been increasingly employed in routine anesthesia practice. Furthermore, surgical procedures have become less invasive.

Since 2017, the number of pediatric anesthesia specialists of our institute has gradually increased. In particular, it increased from an average of 4.8 to 6.2 persons between 2008–2013 and 2014–2019. The average cumulative career years per junior staff were 1.3 and 4.25 years in 2013 and 2019, respectively. In addition, there was a gradual increase in anesthesia cases in the outside operating room.

We speculated that changes in the above factors over time may have contributed to the decreased occurrence of critical events [8]. Therefore, this study aimed to analyze the characteristics of critical incidents, including cardiac arrest, recorded between 2014 and 2019, and compare them with those recorded between 2008 and 2013.

MATERIALS AND METHODS

Study design, center, and population

This retrospective observational study was performed at the tertiary teaching children’s hospital, and the study protocol was approved by the Institutional Review Board of our hospital (no. 2005-161-112), which waived the requirement for written informed consent. This study was performed according to the ethical standards set by the 1964 Declaration of Helsinki and its later amendments.

Data from patients aged ≤ 18 years at the time of surgery, between January 2014 and December 2019 were included in the analysis. The number of operating rooms and the “call for help” system were unchanged. If monitoring medical personnel encountered problems, they could call for the backup anesthesiologists using a speakerphone in the operating room; these encountered problems and critical incidents were recorded using our own reporting form (Fig. 1A). The patient monitors in each operating room were installed in the central monitoring room (Fig. 1B); therefore, from 2012, vital signs could be conveniently checked in the central monitoring room.

Definitions

Data were collected using a critical incident reporting form and electrical medical charts. A critical incident was defined as (i) any incident that altered the patients’ vital signs and affected patient management under the anesthesiologist’s care, and (ii) patient injury or accidents that affected patient safety due to human error. However, simple vital sign changes, such as transient desaturation which was spontaneously recovered or caused by motion artifact, were excluded. The critical incidents were categorized in more detail according to the patient safety policy of the Joint Commission International (JCI), including near miss, no-harm, adverse, and sentinel events (Fig. 2). A near miss is an event that could have resulted in harm to a patient, but did not affect the patient. A no-harm event is an event, that affects the patient but does not result in harm, and an adverse event is an event that is harmful to the patient; it is defined as an unintended injury to a patient as a result of hospital care and not by the course of disease [10]. A sentinel event is an adverse event that affects patients resulting in harm such as death, permanent harm, or severe temporary harm resulting in additional invasive intervention. Based on the change in definitions, the previous data were reclassified as per the new definitions and compared with those from 2014–2019.

Cardiac arrest was defined as any event requiring chest compression for maintaining cardiac output, with these events being separately analyzed. For cases of cardiac arrest, the type of problem was classified according to the pediatric advanced life support guidelines. Human factor-related critical incidents included those that could have been prevented with more caution, knowledge, advanced techniques, and early detection.

Data collection and analysis

Three anesthesiologists reviewed the electronic medical
charts for all reported critical incident cases. Each reported critical incident cases was from voluntary reporting system. Subsequently, the critical incidents were classified into five major classifications (respiratory, cardiovascular, pharmacological, equipment, and others) based on the causes. All events were classified by two anesthesiologists and additionally evaluated by another. Disagreements regarding categorization were resolved through consultation with two other pediatric anesthesiologists [5]. When multiple events occurred simultaneously in one patient, each event was counted as one case. The primary outcome of this study was to evaluate changes in the patterns of critical incidents by com-
paring the incidence of critical incidents on the present and previous data [5] and the secondary outcome was to assess quality improvement of perioperative management by comparing the incidence of cardiac arrest, and human related critical incidents on the present and previous data. Additionally, the sample size for analysis was determined by setting the period after the period of the previous study. The chi-square test was used for subgroup comparisons between the two selected time intervals (2008–2013 and 2014–2019), and mean differences of proportions with 95% confidence interval (CI) were calculated. Statistical analysis was performed using MedCalc (ver. 12.7.7, MedCalc, Belgium). P < 0.05 was considered to indicate statistical significance.

RESULTS

Between January 2014 and December 2019, 53,541 cases of pediatric anesthesia (3,471 cardiothoracic surgeries) were recorded. We identified 295 critical incidents which represented the incidence of 0.55% (295/53,541). This value was similar to the 0.46% reported between 2008 and 2013 (mean difference, 0.09%; 95% CI, –0.04 to 0.14%; P = 0.287). The incidence of detailed categorized critical incidents differed between 2008–2013 and 2014–2019.

Among the critical incidents, the incidences of each event according to patient safety policy in 2014–2019 and in 2008–2013 are as follow; adverse events 93.9% vs. 98.3% (mean difference, 4.4%; 95% CI, 0.8 to 8.0%; P = 0.023), sentinel event 1.7% vs. 2.6% (mean difference, 0.9%; 95% CI, –1.86 to 4.1%; P = 0.686), near miss case 0% vs. 1.7% (mean difference, 1.7%; 95% CI, –0.06 to 4.4%; P = 0.08) and no-harm events 6.1% vs. 0% (mean difference, 6.1%; 95% CI, 3.2 to 9.5%; P < 0.001) respectively (Supplementary Table 1).

The incidence of critical events was higher among infants < 1-year-old (103/10,847, 0.95%) than among children aged above 1-year (192/42,694, 0.45%). The incidence of critical events was higher in patients with American Society of Anesthesiologists classification of 3 and 4 (61/4,215, 1.45%) than in those with American Society of Anesthesiologists classifications of 1 and 2 (232/49,306, 0.47%; Table 1). The incidences of critical incidents related to cardiac and non-cardiac surgery were 23/3,471 (0.7%) and 272/50,070 (0.54%), respectively.

Primary outcome

1. Total critical incidents

The comparison of incidence of each critical event by the classification between 2008–2013 and 2014–2019 are presented in Supplementary Table 1. Table 2 and Fig. 3A present the characteristics of all the critical incidents that occurred between 2014 and 2019. Total critical incidents were not signifi-

Table 1. ASA Classification and Age Distribution of Total Anesthetics Administered (n = 53,541) and Critical Incidents (n = 295)

| Patient characteristics | Total anesthetics (n = 53,541) | Critical incidents (n = 295) | Critical incidents/total anesthetics (%) |
|-------------------------|-------------------------------|----------------------------|----------------------------------------|
| ASA classification      |                               |                            |                                        |
| I                       | 34,400                        | 135                        | 0.4                                    |
| II                      | 14,906                        | 97                         | 0.7                                    |
| III                     | 3,941                         | 51                         | 1.3                                    |
| IV                      | 274                           | 10                         | 3.6                                    |
| V                       | 18                            | 2                          | 11.1                                   |
| VI                      | 2                             | 0                          |                                        |
| Age                     |                               |                            |                                        |
| < 1 years old           | 10,847                        | 103                        | 0.95                                   |
| ≥ 1 years old           | 42,694                        | 192                        | 0.45                                   |

Values are presented as number only. ASA: American Society of Anesthesiologists.
Table 2. Classification of Total Critical Incidents

| Major classification | Detailed classification | Cardiac surgery | Non-cardiac surgery | Total |
|----------------------|-------------------------|-----------------|---------------------|-------|
| Respiratory (n = 172) | Tracheal tube related*  | 0 (0)           | 65 (22.0)           | 65 (22.0) |
|                      | Laryngospasm            | 0 (0)           | 54 (18.3)           | 54 (18.2) |
|                      | Ventilatory failure     | 1 (0.3)         | 30 (10.1)           | 31 (10.5) |
|                      | Supraglottic device – unfitting | 0 (0) | 13 (4.4) | 13 (4.4) |
|                      | Lower airway obstruction| 0 (0)           | 3 (1.0)             | 3 (1.0) |
|                      | Pulmonary aspiration    | 0 (0)           | 2 (0.7)             | 2 (0.7) |
|                      | Glottis edema/obstruction by tongue | 0 (0) | 1 (0.3) | 1 (0.3) |
|                      | Pneumothorax            | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Hypoxia of unknown cause† | 0 (0) | 1 (0.3) | 1 (0.3) |
|                      | Pleural effusion        | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Total                   | 1 (0.3)         | 171 (58.0)          | 172 (58.3) |
| Cardiovascular (n = 42) | Anrhymia                | 9 (3.0)         | 4 (1.4)             | 13 (4.4) |
|                      | Hemorrhage/hypotension  | 2 (0.7)         | 9 (3.1)             | 11 (3.7) |
|                      | Hypovolemia             | 0 (0)           | 5 (1.7)             | 5 (1.7) |
|                      | Cardiogenic shock       | 2 (0.7)         | 3 (1.0)             | 5 (1.7) |
|                      | Cardiopulmonary bypass related | 2 (0.7) | 0 (0) | 2 (0.7) |
|                      | Electrolyte imbalance   | 0 (0)           | 2 (0.7)             | 2 (0.7) |
|                      | Fluid overloading       | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Error of surgeon        | 1 (0.3)         | 0 (0)               | 1 (0.3) |
|                      | Air embolism            | 1 (0.3)         | 0 (0)               | 1 (0.3) |
|                      | Hypotension of unknown cause† | 0 (0) | 1 (0.3) | 1 (0.3) |
|                      | Total                   | 17 (5.8)        | 25 (8.5)            | 42 (14.2) |
| Pharmacological (n = 24) | Medication error        | 0 (0)           | 20 (6.8)            | 20 (6.8) |
|                      | Adverse drug reaction   | 1 (0.3)         | 0 (0)               | 1 (0.3) |
|                      | Anaphylaxis             | 0 (0)           | 3 (1.0)             | 3 (1.0) |
|                      | Total                   | 1 (0.3)         | 23 (7.8)            | 24 (8.1) |
| Equipment (n = 24)    | Disconnection           | 1 (0.3)         | 21 (7.1)            | 22 (7.5) |
|                      | Ventilator failure      | 0 (0)           | 2 (0.7)             | 2 (0.7) |
|                      | Total                   | 1 (0.3)         | 23 (7.8)            | 24 (8.1) |
| Others (n = 33)       | IV disconnection/malfunction | 0 (0) | 7 (2.4) | 7 (2.4) |
|                      | Tooth extraction        | 0 (0)           | 7 (2.4)             | 7 (2.4) |
|                      | Inadequate anesthetich depth | 0 (0) | 4 (1.4) | 4 (1.4) |
|                      | Central catheter-related† | 1 (0.3) | 3 (1.0) | 4 (1.4) |
|                      | Complication during catheterization | 2 (0.7) | 2 (0.7) | 4 (1.4) |
|                      | Burn                    | 0 (0)           | 3 (1.0)             | 3 (1.0) |
|                      | Seizure                 | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Fall down               | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Fire hazard             | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Sore                    | 0 (0)           | 1 (0.3)             | 1 (0.3) |
|                      | Total                   | 3 (1.0)         | 30 (10.1)           | 33 (11.1) |
| Total critical incidents (n = 295) |                      | 23 (7.8)        | 272 (92.2)          | 295 (100) |

Values are presented as number (%). IV: intravenous. *Both tracheal and tracheostomy tube related, it includes accidental extubation, tracheal tube obstruction, endobronchial intubation or intubation failure. †Hypoxia was defined by pulse oximetry values lower than 90%. ‡Accidental withdrawals, malfunction or abnormal position of central catheter.

cantly changed in 2014-2019 compared with in 2008-2013, but critical incidents by classification was different in respiratory events and cardiovascular event between 2008-2013 and 2014-2019. Respiratory events were the most common critical events (172/295, 58.3%) during the perioperative period, similar to that during 2008-2013 (55.4%; mean difference, 2.9%; 95% CI, –5.9 to 11.7%; P = 0.565). They occurred in the following order: tracheal tube related complications (65/172,
Fig. 3. Detailed classification of critical incidents (A, B) and cardiac arrest (C, D) in 2014-2019 and 2008-2013. (A) Classification of total critical incidents; (B) Classification of human error-related critical incidents; (C) Classification of total cardiac arrest; (D) Classification of human error-related cardiac arrest. Data have been presented as percentages in (A) and (B), and the number of patients in (C) and (D). Data from 2008–2013 were previously published (data from the article of Lee et al. [Paediatr Anaesth 2016; 26: 409-17] [5]).

Cardiovascular events were the second most common (42/295, 14.2%); their incidence was lower than that of the previous data (60/229, 26.2%). The majority of cardiovascular events in 2014–2019 and 2008–2013 were arrhythmias (13/42, 31%) and hemorrhage or hypotension (22/60, 36.7%), respectively.

Similar to a previous report, the third most common cause of critical incidents was pharmacological problems. Medication error was the most common pharmacological event (20/24, 83.3%) and its incidence was higher than that observed between 2008 and 2013 (8/16, 50%; mean difference, 33.3%; 95% CI, 0.6 to 61.3%; P = 0.050).

The proportion of equipment problems was comparable between 2014–2019 (24/295, 8.1%) and 2008–2013 (14/229, 6.1%; mean difference, 2.0%; 95% CI, -2.9 to 6.6%, P = 0.480). Circuit disconnection was the most common in both 2014–2019 (22/24, 91.7%) and 2008–2013 (10/14, 71.4%). Critical incidents categorized as “others” significantly increased from 5.2% (12/229) in 2008–2013 to 11.2% (33/295) in 2014–2019 (mean difference, 6.0%; 95% CI, 1.0 to 10.9%; P = 0.020), and they were diverse. The most common critical incidents in the category “others” were intravenous (IV) disconnection/malfunction and tooth extraction, and each event accounted for 21.2% (7/33) of the cases.

37.8%), laryngospasm (54/172, 31.4%), and ventilator failure (31/172, 18.0%). The proportion of laryngospasm within respiratory event was increased from 17.3% in 2008–2013 (mean difference, 14.1%; 95% CI, 3.8 to 23.8%; P = 0.008).
Secondary outcome

1. Cardiac arrest

The incidence of cardiac arrest decreased from 18.3% (8.5 cases per 10,000 anesthetics) in 2008–2013 to 8.5% (4.7 cases per 10,000 anesthetics) in 2014–2019 (mean difference, –9.8%; 95% CI, –15.7 to –3.7%; P = 0.020). Table 3 and Fig. 3C present details regarding the cases of cardiac arrest. Anesthesia unrelated cardiac arrest (18/25, 72%) was more common than anesthesia related cardiac arrest (7/25, 28%). The most common cause of cardiac arrest was cardiovascular problems (21/25, 84%) and only 3 (12%) cases of cardiac arrest were associated with respiratory causes.

The mortality rate after cardiac arrest was 1.0% (3/295); this was not significantly lower than that in 2008–2013 (6/229, 2.6%; mean difference, –1.6%; 95% CI, –4.7 to 0.9%; P = 0.287). Two infants died owing to uncontrolled bleeding during craniotomy and tumor removal. Another 2-month-old preterm infant with multiple problems, including necrotizing enterocolitis, and kidney and hepatic failure with septic shock, developed cardiac arrest resulting from massive bleeding and died on postoperative day 1.

2. Human factors related critical incident

Human factors were involved in 180 (61.0%) critical incidents; this was similar to the incidence in 2008–2013 (134/229, 58.5%; mean difference, 2.5%; 95% CI, –6.19 to 11.21%; P = 0.625). Details were presented in Table 4 and Fig. 3B. Respiratory events were the most common critical incidents involving human error (95/180, 52.8%); this was similar to that in 2008–2013 (72/134, 53.7%; mean difference, –0.9%; 95% CI, –12.4 to 10.7%; P = 0.970). All human factor-related pharmacological events comprised medication errors and equipment problems were circuit disconnections.

The incidence of human factor-related events was similar between cardiac (14/23, 60.9%) and non-cardiac surgery (166/272, 61.0%). As seen from the total critical incidents, the most common human factor-related critical incident in cardiac surgery was related to cardiovascular events (10/14, 71.4%), whereas respiratory events were the most common human factor-related critical incidents in non-cardiac surgery (95/166, 57.2%).

Fig. 3D demonstrates the numbers of human factor-related cardiac arrests in each period. The proportion of human factor related cardiac arrest in 2014–2019 (12/25, 48%) did not significantly decrease from that in 2008–2013 (57.1%, 4/24/2; mean difference, –9.1%; 95% CI, –34.4 to 17.2%; P = 0.640). Among them, cardiac arrests caused by human factor-related respiratory events appeared to decrease from 19% (8/42) in 2008–2013 to 4% (1/25) in 2014–2019, although without significant differences (mean difference, –15%; 95% CI, –29.6 to 3.0%; P = 0.080).

DISCUSSION

This study updated the data regarding critical incidents associated with pediatric anesthesia at a single tertiary teaching children’s hospital in 2014–2019, and compared it
Table 4. Human Factor-related Critical Incidents

| Major classification | Detailed classification | Cardiac surgery | Non-cardiac surgery | Total |
|----------------------|-------------------------|-----------------|---------------------|-------|
| Respiratory (n = 95)  | Tracheal tube related*  | 0 (0)           | 48 (26.7)           | 48 (26.7) |
|                      | Laryngospasm            | 0 (0)           | 26 (14.4)           | 26 (14.4) |
|                      | Ventilatory failure     | 0 (0)           | 13 (7.2)            | 13 (7.2) |
|                      | Supraglottic device – unfitting | 0 (0) | 7 (3.9) | 7 (3.9) |
|                      | Pneumothorax            | 0 (0)           | 1 (0.6)             | 1 (0.6) |
|                      | Total                   | 0 (0)           | 95 (52.8)           | 95 (52.8) |
| Cardiovascular (n = 19) | Cardiopulmonary bypass related | 2 (1.1) | 0 (0) | 2 (1.1) |
|                      | Hemorrhage/hypotension  | 2 (1.1)         | 2 (1.1)             | 4 (2.2) |
|                      | Air embolism            | 1 (0.6)         | 0 (0)               | 1 (0.6) |
|                      | Arrhythmia              | 3 (1.7)         | 0 (0)               | 3 (1.7) |
|                      | Cardiogenic shock       | 1 (0.6)         | 2 (1.1)             | 3 (1.7) |
|                      | Hemothorax              | 0 (0)           | 0 (0)               | 0 (0) |
|                      | Hypovolemia             | 0 (0)           | 2 (1.1)             | 2 (1.1) |
|                      | Fluid overloading       | 0 (0)           | 1 (0.6)             | 1 (0.6) |
|                      | error of surgeon        | 1 (0.6)         | 0 (0)               | 1 (0.6) |
|                      | Electrolyte imbalance   | 0 (0)           | 2 (1.1)             | 2 (1.1) |
|                      | Total                   | 10 (5.6)        | 9 (5.0)             | 19 (10.6) |
| Pharmacological (n = 20) | Medication error       | 0 (0)           | 20 (11.1)           | 20 (11.1) |
|                      | Total                   | 0 (0)           | 20 (10.6)           | 20 (10.6) |
| Equipment (n = 19)   | Disconnection           | 1 (0.6)         | 18 (10)             | 19 (10.6) |
|                      | Total                   | 1 (0.6)         | 18 (10)             | 19 (10.6) |
| Others (n = 27)      | Central catheter-related† | 1 (0.6) | 2 (1.1) | 3 (1.7) |
|                      | Complication during catheterization | 2 (1.1) | 2 (1.1) | 4 (2.2) |
|                      | Burn                    | 0 (0)           | 3 (1.7)             | 3 (1.7) |
|                      | IV disconnection/malfunction | 0 (0) | 6 (3.3) | 6 (3.3) |
|                      | Inadequate anesthetic depth | 0 (0) | 2 (1.1) | 2 (1.1) |
|                      | Tooth extraction        | 0 (0)           | 6 (3.4)             | 6 (3.4) |
|                      | Fall down               | 0 (0)           | 1 (0.6)             | 1 (0.6) |
|                      | Fire hazard             | 0 (0)           | 1 (0.6)             | 1 (0.6) |
|                      | Sore                    | 0 (0)           | 1 (0.6)             | 1 (0.6) |
|                      | Total                   | 3 (1.7)         | 24 (13.3)           | 27 (15) |
| Total human factor-related critical incidents (n = 180) | 14 (7.8) | 166 (92.2) | 180 (100) |

Values are presented as number (%). IV: intravenous. *Both endotracheal and tracheal tube related, it includes accidental extubation, tracheal tube obstruction, endobronchial intubation or intubation failure. †Accidental withdrawal, malfunction or abnormal position of central catheter.

...with previous data obtained in 2008–2013 [5]. Despite the increase in manpower and improvement in monitoring systems, the incidence rate and patterns of total critical incidents did not change significantly over 6 years.

We hypothesized that the rate of total and human-related critical incidents would be lower than that in 2008–2013 [5], given the increase in the number of pediatric anesthesia specialists and their experience. According to the multicenter APRICOT (Anaesthesia Practice In Children Observational Trial) study conducted in Europe, the anesthesiologist’s experience reduces the incidence of severe respiratory and cardiovascular critical events [8], and may affect the patients’ outcome [11]. However, we found that the rate of total critical incidents did not change considerably. Actually, the rate of critical incidents changed differently for each event (increased rate of critical incidents such as laryngospasm, circuit disconnection, IV disconnection, and medication error, whereas, a decreased rate of critical incidents such as cardiovascular events). In addition, the proportion of cardiac surgery in human factor related critical incidents decreased compared to the previous data. For pediatric patients undergoing cardiac surgery, interdisciplinary co-work...
is important in terms of clinical outcome and patient safety compared to noncardiac surgery [12]. Our pediatric cardiac anesthesiologists’ team member has not changed since 2008 and the experience has accumulated. In addition, multidisciplinary team collaboration among cardiac anesthesiologists, surgeons, pediatricians and nurses have been well established. These factors may contribute the decreased incidence of human error in cardiac surgery.

The possible reasons for minimal changes in the critical incidents rate are as follows: An increase in the number and experience of specialists could decrease the incidence of more serious events such as cardiovascular events including cardiac arrest. On the other hand, this factor would also allow for faster and more sensitive detection of critical incidents. The threshold for calling for help and reporting the case could have been lower in 2014–2019 than in 2008–2013. Based on the new categorization, the total incidence of near miss and no-harm events increased from 1.8% in 2008–2013 to 6.1% in 2014–2019, meaning that the detection rate increased and early management was done to avoid these events from progressing to adverse events.

Another reason may be that quality improvement efforts might have been insufficient during the study period, considering that medication error and communication error can be significantly improved by quality improvement efforts. Medication error was an important human error in pediatric anesthesia and drug overdose and miscalculation was the most common error [13]. The Wake Up Safe for Quality Improvement Initiative in pediatric anesthesia reported that medication error was the third most common critical incident, with 97% of these errors being preventable [14]. The communication failures are also preventable and account for a significant number of errors in the operating theater [15].

Even though the incidence of overall critical events did not reduce, there was a significant decrease in the incidence of cardiac arrest. This suggests that severe complications may be prevented through early detection of critical incidents, as well as prompt and appropriate treatment on their occurrence. In particular, there was a decrease in respiratory events induced-cardiac arrest, compared to those in 2008–2013. The proportion of cardiac arrests with a respiratory cause was 23.8% (10/42) in 2008–2013; this declined to 12% (3/25) in 2014–2019. We speculated that inclusion of regular education on pediatric difficult airway algorithms in the resident training program after 2013, could have contributed to the reduced incidence of respiratory arrests in the operating room. Additionally, there has been an increase in the accessibility and use of supraglottic airway devices, videolaryngoscopes, and high flow nasal cannula. It can be presumed that appropriate use of these resources has contributed to the reduction in the number of cases of cardiac arrest induced by respiratory causes.

After reviewing our data, we found some points that can improve the quality of pediatric anesthetic care. First, we need to reduce preventable human errors such as medication error to decrease critical incidents; many strategies have been reported to improve these errors [14,16,17]. Second, education program should be further strengthened, especially at the beginning of each training year. Bringing attention to frequently occurring accidents as well as recognizing of complications will reduce the chances of the same events occurring again [18]. Third, it is also important to maintain constant resources and interest in what is well maintained in terms of quality management. Lastly, it is essential to create an environment that encourages voluntary reporting and gives constructive feedback to maintain quality control.

This study has several limitations. First, this was a single-center study and may not represent the circumstances of all hospitals. Even though we applied the patient safety policy of the JCI to complement this limitation of the single-center study, it is not enough to know the real situation depending on hospital’s situation or prevent critical incident of other hospital. Therefore, it is necessary to create a nation-wide registry related to critical incidents in perioperative care. Second, since the study objective was the comparison of data between 2014–2019 and 2008–2013, data regarding gender, anesthetic management protocols, anesthetic agents used, anesthesia duration, and events related to regional anesthesia were not analyzed as before. Finally, thresholds for calling for help and reporting the cases may have varied depending on the attending anesthesiologists; furthermore, there could have been under-reporting, especially in cases of near miss or no-harm events.

In conclusion, our findings suggest that the incidence of pediatric perioperative critical incidents did not change significantly over 6 years. However, the incidence of adverse events and cardiac arrests from critical incidents decreased. The majority of critical incidents were associated with human error. The implementation of strategies for reducing various errors should therefore be continued to maximize children’s safety during the perioperative period.
SUPPLEMENTARY MATERIALS

Supplementary data including a "comparison of incidence of critical events between 2008–2013 and 2014–2019" can be found online at https://doi.org/10.17085/apm.22164.

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None.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

DATA AVAILABILITY STATEMENT

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

Conceptualization: Jin-Tae Kim. Methodology: Ji-Hyun Lee, Sung-Ae Cho. Formal analysis and investigation: Sang-Hwan Ji, Young-Eun Jang, Eun-Hee Kim. Writing-original draft preparation: Ji-Hyun Lee, Sung-Ae Cho. Writing-review and editing: Hee-Soo Kim. Supervision: Jin-Tae Kim.

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