Perioperative cardiac arrest and its mortality in children. A 9-year survey in a Brazilian tertiary teaching hospital

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Summary

Background: The incidence of perioperative cardiac arrest and mortality in children is higher than in adults. This survey evaluated the incidence, causes, and outcome of perioperative cardiac arrests in a pediatric surgical population in a tertiary teaching hospital between 1996 and 2004.

Methods: The incidence of cardiac arrest during anesthesia was identified from an anesthesia database. During the study period, 15,253 anesthetics were performed in children. Data collected included patient demographics, surgical procedures (elective, urgent, or emergency), ASA physical status classification, anesthesia provider information, type of surgery, surgical areas, and outcome. All cardiac arrests were reviewed and grouped by the cause of arrest and death into one of four groups: totally anesthesia-related, partially anesthesia-related, totally surgery-related, or totally child disease or condition-related.

Results: There were 35 cardiac arrests (22.9 : 10 000) and 15 deaths (9.8 : 10 000). Major risk factors for cardiac arrest were neonates and children under 1 year of age (P < 0.05) with ASA III or poorer physical status (P < 0.05), in emergency surgery (P < 0.05), and general anesthesia (P < 0.05). Child disease/condition was the major cause of cardiac arrest or death (P < 0.05). There were seven cardiac arrests because of anesthesia (4.58 : 10 000) – four totally (2.62 : 10 000) and three partially related to anesthesia (1.96 : 10 000). There were no anesthesia attributable deaths reported. The main causes of anesthesia attributable cardiac arrest were respiratory events (71.5%) and medication-related events (28.5%).

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Conclusions: Perioperative cardiac arrests were relatively higher in neonates and infants than in older children with severe underlying disease and during emergency surgery. The fact that all anesthesia attributable cardiac arrests were related to airway management and medication administration is important in prevention strategies.

Keywords: cardiac arrest; outcomes; anesthesia

Introduction

A higher incidence of perioperative cardiac arrest and mortality has been recognized in children than in adults (1–8). A number of studies have identified children <1 month and under 1 year old as at higher risk than older children (6–11 years). However, recent literature on pediatric cardiac arrests and mortality is scarce (10,11) and many improvements in the monitoring and care of pediatric patients have been seen over the last 10 years. This study reports all cardiac arrests that occurred in a pediatric surgical population during anesthesia and in the postanesthesia care unit (PACU) over 9 years at our institution, and determines their incidence, causes, and outcome.

Methods

After obtaining approval from our institution’s Medical Ethics Committee, we analyzed all reported cardiac arrests in 15,253 consecutive anesthetics given to all pediatric patients who required anesthesia services at the University Hospital, School of Medicine, UNESP, Botucatu, São Paulo State, Brazil, a public tertiary teaching hospital from January 1, 1996 to December 31, 2004. All children were examined by an anesthesiologist immediately before emergency and urgent surgical procedures, and the day before elective procedures. Basic safety monitoring in the operating room (OR) during regional and neuraxial anesthesia and sedation included continuous ECG display, NIBP, and pulse oximetry. For general anesthesia, oxygen concentration, capnography, delivered anesthetic vapor concentration, and ventilation parameters were also measured.

Fatal and nonfatal cardiac arrests during anesthesia and in the PACU were identified from our anesthesia database; this was developed from a quality assessment form included with each anesthesia record for mandatory documentation of each anesthetic. The forms were completed by the anesthesia staff and residents responsible for each anesthetic. The form contains date and location, patient demographics, surgical procedures (elective, urgent, or emergency surgery), ASA physical status classification, anesthesia provider information, and a 95-item checklist of airway, respiratory, hemodynamic, neurologic, renal and miscellaneous events in OR and PACU. Cardiac arrest was defined as an event requiring cardiopulmonary resuscitation, which may include closed-chest cardiac compressions. The anesthesiologist responsible for each case was asked to review the case and provide a written summary for peer review. Cases meeting autopsy quality review criteria were referred to our Mortality Review Committee.

The medical and anesthesia records, the written summary, and, when applicable, the autopsy report were analyzed by the Anesthesia Cardiac Arrest Study Commission composed of three of the authors who are faculty members in the Department of Anesthesiology. The causes of cardiac arrest and death were jointly analyzed by the three members and they were assigned to one of four groups: (1) totally related to anesthesia when anesthesia was the only or the major contributory factor, (2) partially related to anesthesia when child disease/condition or surgical procedures were contributory factors, but anesthesia represented an additional factor, (3) totally related to surgery, or (4) totally related to child disease or condition. Agreement of opinion or consensus was determined when at least two of the three commission members agreed on the cause of event.

Children were divided into four groups according to age: neonates (up to 30 days), infants from 31 days to under 12 months of age, children aged 1–12 years, and older children aged 13–17 years.
Event incidences are expressed per 10 000 anesthetics. Causes of cardiac arrest and death and its incidence and gender were compared using chi-squared test with actual number of patients or events. The Tukey test was used for incidence of cardiac arrests in the perioperative period, modeled as a function of various child characteristics, including age, ASA physical status, surgical procedures, anesthetic technique, and surgical area (12). \( P < 0.05 \) was considered statistically significant.

**Results**

Over the 9 years of the study, 15 253 anesthetics were given to children. A total of 35 cardiac arrests were identified within the perioperative period (OR and PACU) from the anesthesia database. Overall incidence of cardiac arrest from all causes was 22.9 : 10 000 anesthetics. All cardiac arrests were observed in the OR. Major risk factors for cardiac arrest were neonates and children <1 year old (\( P < 0.05 \)), children with ASA III physical status or higher (\( P < 0.05 \)), emergency surgery (\( P < 0.05 \)) (Table 1), general anesthesia (\( P < 0.05 \)) (Table 2), and cardiac (33.4 : 10 000), thoracic (67 : 10 000), gastroenterological (54 : 10 000), neurological (38 : 10 000), general (36 : 10 000), ophthalmological (7.5 : 10 000), and otorhinolaryngological (5 : 10 000) surgery (\( P < 0.05 \)). Gender was not a risk factor (\( P > 0.05 \)).

Child disease/condition was the most significant cause of cardiac arrest (\( P < 0.05 \)). There were seven cardiac arrests because of anesthesia (4.58 : 10 000 anesthetics), four totally and three partially attributed to anesthesia (Figure 1).

There were 15 deaths (9.8 : 10 000 anesthetics). Child disease/condition was the most significant cause of death (\( P < 0.05 \)). There were no anesthesia attributable deaths reported (Figure 1).

Of the 28 cardiac arrest cases attributable to child disease/condition, the more important factors were sepsis and organ failure with nine (32.1\%) cases, and complications associated with cardiac surgery also with nine (32.1\%) cases, followed by exsanguination at surgery associated with primary disease, and other surgical complications, with four (14.28\%) cases each, and

**Table 1**

Cardiac arrest incidence in 15 253 anesthetics according to age, ASA physical status, and surgical procedures

<table>
<thead>
<tr>
<th>Cardiac arrests</th>
<th>Anesthetics</th>
<th>n (%)</th>
<th>Incidence (per 10 000)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–30 days</td>
<td>697 (4.57)</td>
<td>14</td>
<td>200.86(^a)</td>
</tr>
<tr>
<td>31 days to &lt;1 year</td>
<td>2368 (15.52)</td>
<td>10</td>
<td>42.22(^b)</td>
</tr>
<tr>
<td>1 to ≤12 years</td>
<td>8856 (58.06)</td>
<td>8</td>
<td>9.03</td>
</tr>
<tr>
<td>13 to ≤17 years</td>
<td>3332 (21.85)</td>
<td>3</td>
<td>9.00</td>
</tr>
<tr>
<td><strong>ASA physical status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>9800 (64.24)</td>
<td>2</td>
<td>2.04</td>
</tr>
<tr>
<td>II</td>
<td>3910 (25.63)</td>
<td>2</td>
<td>5.11</td>
</tr>
<tr>
<td>III</td>
<td>1193 (7.82)</td>
<td>11</td>
<td>92.20(^c)</td>
</tr>
<tr>
<td>IV</td>
<td>312 (2.04)</td>
<td>15</td>
<td>480.76(^d)</td>
</tr>
<tr>
<td>V</td>
<td>41 (0.27)</td>
<td>5</td>
<td>1219.51(^e)</td>
</tr>
<tr>
<td><strong>Surgical procedures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elective</td>
<td>8612 (56.46)</td>
<td>13</td>
<td>15.09</td>
</tr>
<tr>
<td>Urgent</td>
<td>5585 (36.62)</td>
<td>9</td>
<td>16.11</td>
</tr>
<tr>
<td>Emergency</td>
<td>1056 (6.92)</td>
<td>13</td>
<td>123.10(^f)</td>
</tr>
</tbody>
</table>

\(^a\)\( P < 0.05 \) compared with 31 days to <1 year, 1 to ≤12 years, and 13 to ≤17 years.

\(^b\)\( P < 0.05 \) compared with 0–30 days, 1 to ≤12 years, and 13 to ≤17 years.

\(^c\)\( P < 0.05 \) compared with I, II, IV, and V ASA.

\(^d\)\( P < 0.05 \) compared with I, II, III, and V ASA.

\(^e\)\( P < 0.05 \) compared with I, II, III, and IV ASA.

\(^f\)\( P < 0.05 \) compared with elective and urgent surgery.

**Table 2**

Cardiac arrest incidence in 15 253 anesthetics according to anesthetic technique

<table>
<thead>
<tr>
<th>Anesthetic technique</th>
<th>Anesthetics</th>
<th>n (%)</th>
<th>Incidence (per 10 000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General anesthesia</td>
<td>11 844 (77.65)</td>
<td>35</td>
<td>29.55(^a)</td>
</tr>
<tr>
<td>Regional anesthesia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epidural/spinal/caudal</td>
<td>2455 (16.09)</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Plexus blocks</td>
<td>235 (1.54)</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>General + epidural/spinal/caudal</td>
<td>190 (1.25)</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>General + nerve blocks</td>
<td>224 (1.47)</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Sedation</td>
<td>305 (2.00)</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

\(^a\)\( P < 0.05 \) compared with other anesthetic techniques data.
hepatic trauma during childhood with two (7.14%) cases.

The adverse events in anesthesia-related cardiac arrests are summarized in Table 3. The four cardiac arrests totally related to anesthesia are listed as numbers 1–4, and the three partially related to anesthesia as 5–7. Age, gender, ASA physical status, surgical procedure, surgery, surgical area, child’s medical history, anesthetic technique, event leading to cardiac arrest, and outcome are noted. General anesthesia alone was administered in all cases of cardiac arrest related to anesthesia. Most anesthesia-related cardiac arrest in children occurred during induction (71%). Respiratory events accounted for 71.5% of all cases; the most common etiology was loss of airway/difficult intubation. In these cases, all children had significant underlying disease and most were 3 months or younger with ASA physical status III or IV. All children were successfully resuscitated.

Medication-related problems accounted for two (28.5%) anesthesia-related cardiac arrests. Cardiovascular depression was associated with sevoflurane administration in all medication cases. One cardiac arrest occurred during induction of anesthesia in a child with ASA physical status III and congenital heart disease, and was preceded by hypotension and bradycardia. The other occurred during anesthesia maintenance in an ASA physical status I child, and was preceded by a vagal response following by cardiovascular depression during dacryocystorhinostomy. Both children were successfully resuscitated.
Discussion

This report provides insight into the origins and outcomes of 35 cardiac arrests in 15,253 pediatric anesthetics (22.9 : 10,000 anaesthetics) under current practice conditions in a single Brazilian academic medical center over a 9 year period.

Seven cardiac arrests were judged to be related to anesthesia (4.58 : 10,000). Four of which were totally related to anesthesia (2.62 : 10,000) and three partially related to anesthesia (1.96 : 10,000). There was no anesthesia related mortality.

It is not possible to compare our incidence of cardiac arrest in children during anesthesia with previous studies, as methods differ substantially (6–11). However, analyzing the causes of these arrests seems instructive (13).

In our study, the highest number of cardiac arrests was observed in neonates and children under 1 year in a ratio of 22 : 1 and 4.6 : 1, respectively, compared with older children. Several authors have reported an increased incidence of perioperative cardiac arrest in neonates and infants (2,6–11,13,14). Prematurity, congenital heart disease, congenital neurological disease, and other congenital defects place neonates and infants at higher anesthesia risk than older children and adults (10). Additionally, most recent studies from Australia (15), France (13), the Netherlands (16), the USA (10,17), and Brazil (18) have shown a lower incidence of cardiac arrests and deaths in children between 1 and 12 years old.

American Society of Anesthesiologists physical status and emergency surgery have been reported as risk factors for anesthesia-related cardiac arrest in children (7,9,10) and are the only predictive factors of mortality following the cardiac arrest (10). Our study also observed an eightfold higher incidence of cardiac arrests in emergency surgery compared with elective surgery and a 236-fold higher incidence in ASA IV compared with ASA I children.

General anesthesia alone was administered in all cases of cardiac arrest. Morray et al. (10) in their initial findings of the Pediatric Perioperative Cardiac Arrest (POCA) Registry observed that in anesthesia-related cardiac arrest, general anesthesia alone was administered in most cases (88%); local techniques were used alone or with general anesthesia in 1% and 9%, respectively.

The lower frequency of cardiac arrests in patients receiving neuraxial anesthesia does not necessarily imply its greater safety. Rather, this may reflect the fact that a wider variety of more complex cases are performed under general anesthesia, including cardiac, thoracic, and neurosurgical procedures. Likewise, there may be a bias toward general anesthesia in emergency settings or for patients with coexisting medical conditions (19). However, improved knowledge of neuraxial block physiology and safer local anesthetics, such as ropivacaine and L-bupivacaine, with less myocardial toxicity than racemic bupivacaine, together with improved monitoring of oxygenation by pulse oximetry, has substantially decreased the possibility of major complications during neuraxial anesthesia.

We observed that respiratory causes of anesthesia-related cardiac arrest in children were still the most important, eclipsing hemodynamic changes. Not surprisingly, the incidence of respiratory events was higher in younger children. This may be because of the relatively narrow infant airway and the higher incidence of respiratory tract infections in young children (20). The type of procedures associated with a higher incidence of cardiac arrest in our study seems to be different from the POCA Registry results (10). In this study, cardiac arrest incidence from otorhinolaryngological surgery seemed to be high. This association does not exist in our study despite a similar high incidence of respiratory events. However, in both studies most children who arrested from anatomic airway obstruction or difficult intubation had significant underlying or congenital disease.

Medication-related cardiac arrests accounted for 28% of anesthesia-related cardiac arrest in children. In these cardiac arrests, sevoflurane was the halogenated anesthetic utilized. No medication-related case in our study involved halogenated anesthetic misuse, but rather anesthetic overdose or unusual responses to standard doses.

In 2000, the POCA Registry collated and published data on 150 anesthesia-related cardiac arrests for the years 1994–1997 (10). In this study, medication-related problems were most frequent accounting for 37% of all arrests. The predominant mechanism in this category was cardiovascular depression from the inhalation agents, usually halothane alone (46%) or in combination with an i.v.
medication (20%). There were two arrests (4%) relating to cardiovascular depression from sevoflurane. Because denominators were not available, the incidence for halothane and sevoflurane-related cardiac arrests could not be calculated. In 2005, the POCA Registry collated and published data on 163 anesthesia-related cardiac arrests for the years 1998–2003 (21). Medication-related problems accounted for 20% of all arrests due primarily to the decline of cases of cardiovascular depression from the inhalation agents. Nowadays, sevoflurane is the halogenated anesthetic most utilized by pediatric anesthesiologists. Sevoflurane when compared with halothane is less depressant of myocardial contractility in infants (22) and children (23). In addition, sevoflurane maintains heart rate, which is decreased with halothane, in infants and children (24). However, cardiac arrest associated with the use of sevoflurane may occur as demonstrated in our study and others (10,21), but always associated with ASA II physical status or higher (case # 6, Table 3). In our study, there was one cardiac arrest during anesthesia with sevoflurane in an ASA I child (case # 7, Table 3), preceded by a vagal response followed by cardiovascular depression during dacryocystorhinostomy surgery. In both cases (cases # 6 and 7, Table 3), the cardiac arrests were assigned to partially related to anesthesia as the disease and surgical procedure, respectively, were contributory factors, but anesthesia represented an additional factor.

Many studies have demonstrated equal proportions of cardiac arrest from respiratory and cardiovascular causes in children during anesthesia (25,26). In another report, respiratory causes of cardiac arrest were more frequent (43%) than cardiovascular (13%) (27). Yet, other studies showed cardiovascular causes being more frequent (32–36%) than respiratory causes (20–27%) (10,21); they suggested that the predominance of cardiovascular events in anesthesia-related cardiac arrest may be related to the frequent use of pulse oximetry and capnography, and monitors that may be more effective in preventing respiratory rather than cardiovascular events (10). In our study, all cardiac arrest cases during general anesthesia were monitored with pulse oximetry and capnography. Our anesthesiologists are experienced and have continuous practice in pediatric anesthesia. All trainees are closely supervised by an experienced anesthetist.

Improvements should focus on these two most important areas which may help reduce the incidence and outcome of cardiac arrest in children. Continued education of anesthesia practitioners is fundamental; however, one study demonstrated that it is poor practical application rather than lack of knowledge that leads to critical incidents (28). Major effects on perioperative morbidity and mortality seem to be possible with simple anesthesia management principles such as: routine use of an equipment checklist, direct availability of an anesthesiologist to lend a hand or troubleshoot when needed, and the use of full-time rather than part-time anesthesia team members; the presence of two anesthesia team members at emergencies; monitoring neuromuscular blockade and, when necessary, muscle relaxant reversal at the end of anesthesia had dramatic, positive effects associated with reduced perioperative mortality in the 48h after surgery and anesthesia (28).

There may have been some methodology weaknesses associated with our study. Firstly, it depends on the reporting of adverse events by faculty and residents. Under-reporting is likely in this situation even though filling the form out for each case was mandatory. Secondly, it is representative of the experience from a single institution. The UNESP hospital is a 450-bed, including 65 pediatric beds, tertiary care referral center performing approximately 6500 procedures per year. It provides care to the population of Botucatu and the surrounding areas. Patient mix includes high-risk obstetric and newborn patients with 15-bed neonatal and a 10-bed pediatric intensive care unit. Anesthesia care is provided by full-time academic faculty and residents. Our institution is relatively small, with 1500–2000 pediatric anesthesiologists per year and with low faculty staff turnover rate during the study period. The single-institution database offered reporting consistency that would not have been available from a multicenter study (7). However, practices peculiar to our institution might have influenced our results.

In conclusion, 35 cardiac arrests within the perioperative period were identified from a total of 15 253 pediatric anesthetics (22.9 : 10 000) over a 9-year period in a public tertiary teaching hospital. The risk of cardiac arrest related to anesthesia was 4.58 : 10 000, while the risk of cardiac arrest totally attributable to anesthesia was 2.62 : 10 000, and the
risk of anesthesia contributory to cardiac arrest was 1.96 : 10 000. There were no deaths related to anesthesia. Major risk factors for cardiac arrest were neonates and children under 1 year old, ASA III or poorer physical status, emergency surgery, and general anaesthesia in cardiac, thoracic, or gastroenterological surgery. Airway management and medication-related events accounted for all anesthesia-related cardiac arrests.

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