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Perioperative cardiac arrests in children at a university teaching hospital of a developing country over 15 years

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Summary
Objective/Aim: To study the incidence, causes, and outcome of perioperative cardiac arrests in children at a university teaching hospital with an aim of improving quality of care.
Background: Analysis of anesthesia-related complications is routinely performed by most anesthesia departments to make prevention strategies.
Methods: All perioperative cardiac arrests in children up to 18 years from induction of anesthesia to postanesthesia care unit discharge or ICU admission during noncardiac surgery from January 1992 to December 2006 were analyzed. Outcome variable was noted as survival to discharge. Anesthesia-related cardiac arrests were identified and their causes analyzed.
Results: Ten cardiac arrests occurred among 20216 patients. Overall incidence was 4.95 per 10000 (95% CI: 1.88–8.01). Six (6.53/10000) were females. Seven (19.44/10000) patients belonged to the classification III–IV of ASA physical status, eight (18.28/10000) were below 1 year, and two (1.26/10000) above 1 year. Three patients (6.53/10000) were undergoing emergency surgery. Anesthesia was primarily responsible in four cases. The causes of anesthesia-related arrests were medication-related (two), airway-related (one), and under-replacement of fluids (one). Seven patients died during the arrest and three were discharged home. The event was considered avoidable in seven (70%) cases.
Conclusion: Perioperative cardiac arrests were higher in patients with poor physical status, in those under 1 year of age, and in female patients. Anesthesia-related cardiac arrests were mainly due to medication- or airway-related causes. The majority of arrests were avoidable indicating the importance of prevention strategies.
Keywords: perioperative complications: cardiac arrest; pediatric anesthesia

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Introduction

Analysis of anesthesia-related complications should be routinely performed by all anesthesia departments with an aim of improving quality of care. It is important to identify the preventable causes and to make prevention strategies. Studies and updates on perioperative cardiac arrests in children (1–5) have shown that many arrests are due to potentially preventable causes. Deliberation and appropriate actions taken to prevent these causes may lead to improvements in practice (2) which in turn would result in improved outcomes. Thus, the analysis of perioperative cardiac arrests is a valuable method with a potential to decrease perioperative morbidity and mortality.

No published data on frequency and causes of perioperative cardiac arrests in children were available from Pakistan. The objective of this study was to determine the incidence and outcome of perioperative cardiac arrests in children aged <18 years, undergoing noncardiac surgery between the years 1992 and 2006, in a tertiary care university teaching hospital of a developing country.

Methods

After obtaining approval from our institutional ethical review committee, we analyzed all reported perioperative cardiac arrests occurring in patients below 18 years of age, undergoing noncardiac surgery at the Aga Khan University Hospital from January 1, 1992 to December 31, 2006. Cardiac arrests that occurred during cardiac surgery were not included.

The Aga Khan University Hospital is a 500-bed hospital in the southern part of the country. The anesthesia department provides an average of 10000 anesthetics per year for surgeries such as pediatric, vascular, orthopedic, general, neurosurgery, ear–nose–throat surgery, urology, gynecology, and plastic surgery. All operating rooms were equipped according to the ASA recommended standards for monitoring. Anesthesia services were also provided for radiology procedures.

Two designated anesthesia consultants were responsible for obtaining data on all anesthesia-related morbidity and mortality. They received feedback, in this regard, from anesthesia residents, recovery room staff, and anesthesia technicians. A form was filled out for each morbidity which included information on patient’s demographic information, preoperative condition, type of surgery, and sequence of events. All these cases were discussed in depth at the morbidity and mortality meetings of the department. Two independent consultants gave their written opinions as regards to the possible cause of arrest, role of anesthesia, and whether it was avoidable. Suggestions were given for improvements in practice. This system has been in place since 1992. Cases of perioperative cardiac arrests in children were identified from these records.

A comprehensive form was developed and completed after going through the patient’s medical records as well as the departmental files. Cardiac arrest was defined as an event that required cardiopulmonary resuscitation (CPR) which included closed chest cardiac compressions. Perioperative period was defined as the time starting from the induction of anesthesia to PACU discharge or ICU admission. Patient’s demographic data were recorded. Surgical specialty, type of anesthesia, senior-most anesthetist presence, and monitoring used were noted. The main outcome variable observed was survival to discharge.

Statistical analysis

This study was part of the quality improvement audits of our department. The overall incidence of cardiac arrest was calculated per 10000 cases with 95% CI. Incidence related to demographic and clinical variables was also calculated in a similar way. Outcome in terms of death and survival to discharge for the different demographic variables was calculated as actual numbers.

Results

Over the 15 years of the study, 20216 pediatric patients received anesthetic care for noncardiac surgeries at our hospital. A total of 10 cardiac arrests occurred in the defined perioperative period. The incidence was 4.95 per 10000 cases (95%CI: 1.88–8.01). Five patients died during the arrest, two survived for more than 1 h but died later, and three were discharged home without any residual
complications. Incidence in terms of age, gender, urgency of surgery, and ASA physical status and outcome in terms of death and survival is given in Table 1. There was no survival in patients falling into ASA physical status classification of IV and V (Table 2).

Five patients were undergoing neurosurgical procedures, two were having general surgical procedures, one was undergoing a cleft palate repair, one patient had an arrest during magnetic resonance imaging (MRI) of the brain, and one during sclerotherapy of esophageal varices. All these patients had received general anesthesia. Seven arrests occurred during the routine working hours of 8:00 AM–5:00 PM, two occurred between 5:00 PM and midnight, and one between midnight and 8:00 AM. All three patients who survived to discharge had arrest during routine working hours. Cardiac arrests were deemed primarily anesthesia-related in four cases. The patient’s primary condition was considered the cause in three, hemorrhage in two, and surgical complications in one patient. The cause of primarily anesthesia-related arrests was medication-related in two cases, airway related in one patient, and underreplacement of fluids in one patient (Table 3). Three of the four patients with primarily anesthesia-related arrests survived to discharge, whereas there were no survivors after arrests due to other causes. The event was considered avoidable in 7 of the 10 cardiac arrests. A consultant anesthesiologist was present at the time of the arrest in seven cases and three of these seven patients survived to discharge. Two

### Table 1
Incidence of cardiac arrests and their outcome according to age, gender, urgency of surgery, and ASA physical status

<table>
<thead>
<tr>
<th>Age group</th>
<th>Incidence (per 10000)</th>
<th>95% CI</th>
<th>Died, n</th>
<th>Discharged, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1 year</td>
<td>8</td>
<td>18.28</td>
<td>12.39–24.17</td>
<td>5</td>
</tr>
<tr>
<td>&gt;1–18 years</td>
<td>2</td>
<td>1.26</td>
<td>–2.07–4.59</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 2
Frequency of cardiac arrests according to each classification of ASA physical status (number) and their outcome in terms of death and survival

<table>
<thead>
<tr>
<th>ASA status</th>
<th>Cardiac arrests</th>
<th>Death</th>
<th>Survival to discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>III</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 3
Cardiac arrests attributed primarily to anesthesia: ASA status, cause, survival, and preventability

<table>
<thead>
<tr>
<th>No</th>
<th>Age</th>
<th>ASA status</th>
<th>Event (probable cause of arrest)</th>
<th>Survival to discharge</th>
<th>Preventable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 days</td>
<td>III</td>
<td>Under replacement of fluid during surgery of a large sacrococcygeal teratoma</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>8 months</td>
<td>II</td>
<td>Inadequate ventilation after extubation following cleft palate repair (airway related)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>6 days</td>
<td>II</td>
<td>Bradycardiac arrest after succinylcholine (medication related)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>1 year</td>
<td>I</td>
<td>Two vaporizers were opened simultaneously during MRI (medication related)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

MRI, magnetic resonance imaging.
arrests occurred at induction of anesthesia, six during maintenance, and two at or soon after emergence.

**Discussion**

Intra-operative cardiac arrest is likely to be diagnosed much earlier than that occurring in other situations because of the close monitoring of patient’s vital signs by the anesthesiologist. It is reasonable to believe that survival after cardiac arrest would be improved with quick diagnosis and prompt management. Over the 15 years of our study, 10 perioperative cardiac arrests occurred in 20216 pediatric patients (4.95 per 10000 cases) who received anesthetic care for noncardiac surgeries at our university teaching hospital. A recent study by Braz et al. (3) reported an incidence of 22.9 per 10000 cases over a 9-year period. Their study cannot be compared with ours as they had included children undergoing cardiac as well as noncardiac surgery. Due to substantial differences in methodology, it is not possible to compare our results directly with the results of other reports on the incidence of perioperative cardiac arrests in children (1–4). However, analyzing the causes of these arrests and sharing such data from different centers were informative and had a potential to improve outcomes.

Recent reports from the pediatric perioperative cardiac arrest registry in the United States (1,4) include data from nearly 80 North American institutions, whereas our data are from a single center; hence, the small number of cases prevents the application of statistical tests for univariate and multivariate analysis. Seven of the ten patients died and three were discharged home. Braz et al. (3) reported 15 deaths from a cohort of 35 (43%) patients with perioperative cardiac arrests. The relatively higher number in our study could be due to sicker patients presenting at advanced stages of disease. We do not have an effective primary and secondary health care system resulting in tertiary care hospitals dealing with poorly optimized sick patients requiring emergency surgeries. The incidence of perioperative cardiac arrest was higher in females (6.53 per 10000 cases vs 3.62 per 10000 in males). We could not pinpoint a specific reason for this difference, as we hope that we are past the era of prioritization of the male offspring for all available facilities including medical attention.

Seven patients (70%) were graded as ASA physical status III–V (19.44 per 10000 vs 1.81/10000 in ASA I and II), six of whom died during or following the event. Braz et al. (3) found ASA physical status III and above as a major risk factor for perioperative cardiac arrests in children. A recent update from the perioperative cardiac arrest registry (1) also reported that 75% of the anesthesia-related arrests occurred in patients of ASA physical status III–V. Eight of the ten children were aged 1 year or less. This has been observed by several other authors (2,4,6–9). Flick et al. (2) have reported that the incidence of cardiac arrest in children undergoing noncardiac procedures was very high for neonates (39.4 per 10000) and much lower for all other age groups. However, Bhananker et al. (1), in their recent update, reported fewer incidents in patients under 1 year of age compared with 6–18 year age group. They have ascribed this to the declining use of halothane as halothane-induced cardiovascular depression tended to occur in previously healthy children under 1 year. They suggest that changes in pediatric anesthesia practice in recent years may have altered the causes of perioperative cardiac arrests in children. The use of halothane has also become almost nonexistent at our institute over the last year, and sevoflurane has replaced it for inhalational inductions in children.

The incidence of cardiac arrest was higher in emergency cases (8.43 vs 4.20 per 10000 cases) and there was no survival to discharge in these patients. Flick et al. (2) also found a lower survival in emergency cases. The reason for this may be a lack of appropriate preoperative optimization in patients presenting for emergency surgeries when compared with those scheduled for elective procedures. Five of the patients were undergoing neurosurgical procedures. We could not identify a specific reason for this except for the fact that these were major procedures being performed in advanced stages of disease. All the three patients who survived to hospital discharge had their surgery performed during routine working hours of 8:00 AM–5:00 PM. Similar findings were reported by Sprung et al. (10). Increased availability of personnel and a more comprehensive response to cardiac arrest could well be the reason for this.
Four of the ten patients were deemed primarily anesthesia-related by the reviewers, three of whom survived to discharge. The patient who did not survive among the primarily anesthesia-related arrests had shown poor respiratory efforts after extubation following cleft palate repair, with rapid desaturation and bradycardic arrest. The most likely cause was inadequate reversal of neuromuscular blockade. One patient, a two-day-old neonate, became hypotensive and had arrest during the surgery of a large sacrococcygeal teratoma. This patient responded to rapid fluid replacement along with a short period of CPR. Two of the anesthesia-related arrests were medication-related; one patient having a hypotensive arrest when two vaporizers were opened simultaneously during an MRI scan and the other, a neonate, experienced a bradycardic arrest after the administration of succinylcholine. The chance of simultaneously opening two vaporizers has become a thing of the past since the incorporation of a locking mechanism in the vaporizers. In infants who have not been given atropine, there was a significant potential for bradycardia with succinylcholine (5). The use of succinylcholine for intubation in neonates and infants had declined significantly at our institute since the introduction of sevoflurane.

In his article on anesthesia-related cardiac arrest in children, Morray (11) concludes that the improvement in mortality rates for anesthetized children over the past 50 years reflects the many improvements that have been made in pediatric perioperative care. He comments that the modern pediatric anesthesiologist is better trained and has an improved arsenal of monitoring devices and anesthetic agents from which to choose.

A consultant anesthesiologist was present in all of the three patients who survived the arrest. This highlights the importance of the presence of an experienced anesthesiologist for all pediatric cases. The event was considered avoidable by the reviewing consultants in 7 of the 10 cardiac arrests. Preventable factors associated with poor outcomes include inadequate preoperative assessment, faulty anesthetic technique (12), inadequate monitoring, failure in the application of existing knowledge, neglecting to consult more experienced colleagues (13), postoperative respiratory and circulatory failure, and inadequate postoperative care (12).

The limitations of the study must be mentioned for a better understanding of the results. Our department has collected data prospectively for all morbidities since 1992, but some data were missing in the department files and had to be retrieved from patients’ medical records. The completeness of the information obtained was limited by the amount of documentation available in old medical records. The long period (15 years) of data collection is a major limitation of our study as many drugs and equipment have been improved considerably over this period. There have also been changes in the recommendations for CPR during the period of data collection (14). CPR is now recommended for even brief bradycardia because bradycardia is the most common antecedent of cardiac arrest during anesthesia in children (15). Thus, for improving the outcome, cardiac arrest should really be defined as an impending cessation of circulation rather than a complete one, and the warning signs should be heeded quickly and steps for resuscitation initiated at the earliest.

The small number of cases in our study prevented the application of statistical tests for further analyses. A narrow window of time from the induction of anesthesia to PACU discharge or ICU admission was considered in this study. We specified this period because we wanted to analyze the arrests during the time when the patient is under the direct care of the anesthesiology team and when the anesthesiologist has immediate control of the situation. Many anesthetic complications, including anesthesia-related cardiac arrests and mortality, are likely to occur in the time immediately following this period. Therefore, our use of the term ‘anesthesia-related’ cardiac arrests does not fully correlate with the usually accepted definition of anesthesia-related complications. There is limited availability of standard monitoring equipment in most medical centers in Pakistan. In contrast, ours is a private university hospital with adequate facilities and even in 1992, we had provision for monitoring peripheral oxygen saturation, endtidal carbondioxide, electrocardiogram, and non-invasive blood pressure at all areas of anesthesia provision. Facilities for invasive hemodynamic monitoring were also available. Therefore, our study does not really reflect the level of care in other parts of our country. Our results are also not directly comparable with other similar studies, including
Braz’s comprehensive prospective study of this topic (3) because of the differences in methodology. We believe that adherence to methodology and collection of data from a single center are strengths of this study.

Despite the fact that the coordinators of the morbidity and mortality meetings are very vigilant in collecting information regarding all perioperative morbidities, there is a possibility that some events will be missed leading to an underestimation of the incidence. Reliable voluntary reporting of untoward events in health care is very hard to achieve (16,17), and only a fraction of the total number of adverse events are likely to be picked up if voluntary reporting is the only source of data collection. Therefore, quality improvement programs often use multiple data reporting sources like structured record review and incident reporting to identify perioperative adverse events (18–20).

In conclusion, incidence of perioperative cardiac arrests in children was found to be higher in patients with poor physical status in those below 1 year of age and in female patients. Majority of the cases were considered avoidable indicating the importance of prevention strategies.

Acknowledgement

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