Perioperative cardiac arrest: a study of 53 718 anaesthetics over 9 yr from a Brazilian teaching hospital

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Background. Little information exists regarding factors influencing perioperative cardiac arrests and their outcome. This survey evaluated the incidence, causes and outcome of perioperative cardiac arrests in a Brazilian tertiary general teaching hospital between April 1996 and March 2005.

Methods. The incidence of cardiac arrest during anaesthesia was prospectively identified from an anaesthesia database. There were 53 718 anaesthetics during the study period. Data collected included patient characteristics, surgical procedures (elective, urgent or emergency), ASA physical status classification, anaesthesia provider information, type of surgery, surgical areas and outcome. All cardiac arrests were retrospectively reviewed and grouped by cause of arrest and death into one of four groups: totally anaesthesia related, partially anaesthesia related, totally surgery related or totally patient disease or condition related.

Results. One hundred and eighty-six cardiac arrests (34.6:10 000) and 118 deaths (21.97:10 000) were found. Major risk factors for cardiac arrest were neonates, children under 1 yr and the elderly (P<0.05), male patients with ASA III or poorer physical status (P<0.05), in emergency surgery (P<0.05) and under general anaesthesia (P<0.05). Patient disease/condition was the major cause of cardiac arrest or death (P<0.05). There were 18 anaesthesia-related cardiac arrests (3.35:10 000)—10 totally attributed (1.86:10 000) and 8 partially related to anaesthesia (1.49:10 000). There were 6 anaesthesia-related deaths (1.12:10 000)—3 totally attributable and 3 partially related to anaesthesia (0.56:10 000 in both cases). The main causes of anaesthesia-related cardiac arrest were respiratory events (55.5%) and medication-related events (44.5%).

Conclusions. Perioperative cardiac arrests were relatively higher in neonates, infants, the elderly and in males with severe underlying disease and under emergency surgery. All anaesthesia-related cardiac arrests were related to airway management and medication administration which is important for prevention strategies.

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The incidence and causes of cardiac arrests related to anaesthesia in the perioperative period have been studied over the last two decades by many authors from the USA,¹–⁴ Canada,⁵ France,⁶,⁷ Sweden,⁸ The Netherlands,⁹ Japan,¹⁰,¹¹ Taiwan,¹² Thailand¹³ and Australia.¹⁴ Literature on perioperative cardiac arrests are scarce in Brazil.¹⁵,¹⁶ In addition, these Brazilian publications are unknown in the international community because they were published in journals not indexed by the Medline and HealthStar databases.

Many improvements have been seen in monitoring techniques, the widespread adoption of medical practice guidelines and patient care over the last two decades. So, many authors believe that the frequency of
anaesthesia-related cardiac arrest and its mortality have declined over recent decades. However, a recent review questioned whether these have in fact changed over the last few decades.

Although much attention has rightly been focused on issues surrounding the incidence of perioperative cardiac arrests, there is relatively little information on factors influencing its outcome. This study reports all cardiac arrests that occurred in a surgical population during anaesthesia and in the postanaesthesia care unit (PACU) over a 9-yr period in a Brazilian general tertiary teaching hospital and determines incidence, causes and outcome.

Methods
After obtaining approval from Medical Ethics Committee of School of Medicine, UNESP, Botucatu, Brazil, we analysed all reported cardiac arrests in 53 718 consecutive anaesthetics given to all patients requiring anaesthesia services at Botucatu School of Medicine University Hospital, UNESP, São Paulo State, Brazil, a public tertiary teaching hospital, from April 1, 1996 to March 31, 2005. UNESP hospital is a 450-bed tertiary care referral centre performing 6500 surgeries per year to all ages and is a trauma centre. It provides care to the population of Botucatu and the surrounding areas. Patient mix includes all surgical areas, high-risk obstetric and newborn patients with 15-bed neonatal, 10-bed paediatric and 25-bed adult intensive care units. Anaesthesia care is provided by full-time academic faculty and residents.

All patients were examined by an anaesthetist immediately before emergency and urgent surgical procedures, or the day before for elective procedures. Basic safety monitoring in the operating room (OR) during regional and neuraxial anaesthesia and sedation, consisted of continuous ECG display, automatic non-invasive blood pressure and pulse oximetry. For general anaesthesia, oxygen concentration, capnography, delivered anaesthetic vapour concentration and ventilation parameters were also measured. Since 1996, adult laryngeal mask airway (LMA) devices have been progressively used, while LMA for neonates and children was only introduced in 1998 in our institution.

Cardiac arrests and deaths during anaesthesia in the OR and PACU were prospectively identified from an anaesthesia database which is developed using a quality assessment form as part of the mandatory documentation for each anaesthetic procedure. The forms were completed by the anaesthesia staff and residents responsible for each anaesthetic. The form contains date and location, patient characteristics, surgical procedures (elective, urgent or emergency surgery), surgical area, ASA physical status classification, anaesthesia provider information and a 95-item checklist of airway, respiratory, cardiocirculatory, neurological, renal and miscellaneous events related to the operation room or post-anaesthetic care unit stay. When regional and general anaesthesia were combined, only general anaesthesia was considered according to anaesthetic technique. Cardiac arrest was defined as an event requiring cardiopulmonary resuscitation, which may include closed-chest cardiac compressions. The anaesthetist responsible for each case was asked to review the case and provide a written summary for peer review. This procedure avoided the situation that data collection forms were found to be incomplete. Cases meeting autopsy quality review criteria, including any unanticipated or unexplained intraoperative death, were referred to our Mortality Review Committee.

The medical and anaesthesia records, written summary and when applicable, the autopsy report were analysed by the Anaesthesia Cardiac Arrest Study Commission composed of three of the authors who are faculty members at the Department of Anaesthesia (J.R.C.B., N.S.P.M. and P.N.Jr). The cardiac arrests were jointly analysed by all three members. There was unanimity on the event cause in the majority of the cardiac arrests. Disagreements among the three members were resolved by discussion and, in all cases, agreement or consensus was determined as when at least two out of three members agreed on the event cause. The causes of cardiac arrest and death were retrospectively assigned to one of four groups: (i) totally related to anaesthesia when anaesthesia was the only or the major contributory factor; (ii) partially related to anaesthesia when patient disease/condition or surgical procedure were contributory factors, but anaesthesia represented an additional factor; (iii) totally related to surgery; or (iv) totally related to patient disease or condition.

Event incidences are expressed per 10 000 anaesthetics. Incidence of causes of cardiac arrest and death and cardiac arrest incidence according to gender were compared using χ²-test with actual number of patients or events. The Tukey-type test for multiple comparisons among proportions was used for incidence of cardiac arrests in the perioperative period, modelled as a function of various patient characteristics, including age, ASA physical status, surgical procedures, anaesthetic technique and surgical area. \( P<0.05 \) was considered statistically significant.

Results
Over the 9 yr of the study, 53 718 patients received anaesthesia care. A total of 186 cardiac arrests were identified from the anaesthesia database within the perioperative period (OR and PACU). Overall cardiac arrest incidence from all causes was 34.6:10 000 anaesthetic cases. The majority of cardiac arrests were in the OR (94.6%) in relation to PACU (5.4%). Major risk factors were neonates, children below 1 yr, adults between 51 and 64 yr and the elderly (\( P<0.05 \)) (Table 1); male adult patients (2.4:1 compared with female) (\( P<0.05 \)) (Table 1); patients with ASA

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The adverse events in anaesthesia-related cardiac arrests are summarized in Table 6. Respiratory events accounted for 55.5% of all cases; the most common aetiology was loss of airway/difficult intubation. In these cases all patients had significant underlying disease and consisted mostly of ASA physical status III or IV. Two cases of pulmonary aspiration of stomach contents during general anaesthesia induction in adults with underlying diseases who died in the OR were found.

Medication-related problems accounted for 8 (44.5%) anaesthesia-related cardiac arrests being cardiovascular depression in 7 cases and fluid overload in 1 case. Cardiovascular depression was associated with the use of sevoflurane in two children. In both cases, the children recovered. One case of cardiac arrest in an ASA physical status III adult patient was associated with cardiovascular depression after metoprolol 5 mg i.v. administration for therapy of reentrant tachyarrhythmia during anaesthesia; the patient died in the OR. Another one was associated with relative propofol overdose (2 mg kg\(^{-1}\)) during anaesthesia induction. This patient suffered from significant underlying disease that could have contributed to the cardiac arrest. Fortunately, he was successfully resuscitated and went to complete recovery. In three cases of cardiac arrest, cardiovascular collapse occurred after epidural anaesthesia. Out of these three, two ASA physical status IV elderly patients died in the operating theatre. In the third patient, the incident occurred after a spinal anaesthesia in an obstetric patient with double mitral valve lesion. She recovered completely. There was one case of fluid overload followed by acute lung oedema during the recovery period in an ASA physical status III or IV patient.

The incidence of cardiac arrest and mortality in 53,718 anaesthetics is shown in Table 1. The incidence of cardiac arrest was highest in the age group 18 to <30 years (21.52%), followed by the age group 31 to <40 years (18.84%). The incidence of cardiac arrest was lowest in the age group 65 to <80 years (11.82%). The incidence of cardiac arrest was highest in the gender group male (24.86%), followed by the gender group female (23.83%). The incidence of cardiac arrest was lowest in the gender group male (57.12%), followed by the gender group female (51.74%). The incidence of cardiac arrest was highest in the gender group male (24.86%), followed by the gender group female (23.83%). The incidence of cardiac arrest was lowest in the gender group male (57.12%), followed by the gender group female (51.74%).

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status III patient with medical history of chronic renal failure. This patient died.

**Discussion**

This report provides insight into the origins and outcomes of 186 cardiac arrests in 53,718 anaesthetic cases under current practices and conditions in a Brazilian university teaching hospital over a 9-year period. Our intraoperative cardiac arrest incidence (34.6:10,000 anaesthetics) is higher than other recent studies, which have reported incidences from 0.50 to 2.10 per 10,000 anaesthetics. This is also higher than other studies, which have reported incidences from 0.50 to 2.10 per 10,000 anaesthetics. 2-4 7 9-13 On the other hand, our anaesthesia-related mortality rate (1.12:10,000) is similar to other studies from the last decade, which range from 0.12 to 1.40 per 10,000 anaesthetics. 2-4 7 9-13 A survey reported the anaesthesia-related mortality rate in our institution from 1988 to 1996 as 0.85:10,000. So, anaesthesia-related mortality rate has been stable over the past decade at approximately 1 death per 13,000 anaesthetics.

It is difficult to compare the intraoperative cardiac arrest and mortality rates reported in this work with previous studies, as methods substantially differ. 1-15 Many were based on case series, of which only seven were prospective studies, others on voluntary declarations of critical incidents. Some only include cardiac arrests totally related to anaesthesia. The patient populations differ considerably between studies; many studies examine all types of surgery, while others exclude cardiac surgery, obstetrical surgery or ASA V physical status patients. Perioperative cardiac arrest incidence also depends on how the perioperative period was defined: intraoperative only, intraoperative and recovery from anaesthesia, first 24 h postoperative, or first 2 days postoperative. However, the inclusion of all types of surgery and of patients of all ages and ASA physical III or higher, as a result of certain pre-existing morbidity (e.g., traumatic injury, sepsis and multiple organ failure), which seems to occur with high incidence at Brazil, certainly influenced our cardiac arrest incidence.

The analysis of these cardiac arrests seems instructive. In our study, as in other studies, the highest number of cardiac arrests in the paediatric patients was observed in neonates and children under 1 yr, with ratios of 8.5:1 and 5.7:1, respectively compared with older children. Prematurity and congenital diseases place neonates and children under 1 yr at higher anaesthetic risk than older children and adults.

Advanced age also increases the risk of cardiac arrest during anaesthesia. Anaesthesia-related cardiac arrests and deaths in 70–80-yr-old patients seem to be increasing, especially during hip arthroplasty surgery. In France anaesthetic procedures increased from 6.6 in 1980 to 13.5 per 100 people in 1999. The increases were greater in the elderly and those with higher ASA physical status.

The higher incidence of intraoperative arrest in adult males seen in our study is similar to other studies. Adult males are more predisposed to trauma, violence and vascular disease than females. ASA physical status and emergency surgery have been reported as risk factors for anaesthesia-related cardiac arrest and are the only predictive factors of mortality after cardiac arrest. Our study also observed a 11.27-fold higher incidence of cardiac arrests in emergency surgery than elective surgery and a 25.5-fold higher incidence in ASA IV than ASA I patients.

Cardiac arrest frequency was 8.3-fold higher in general than neuraxial anaesthesia. Studies suggest that cardiac arrest incidence is higher during general anaesthesia, however, this may be because many high-risk surgeries are performed under general anaesthesia, including cardiac, thoracic and neurosurgical procedures. Likewise, there may be a bias towards general anaesthesia in emergency settings or in patients with coexisting medical conditions. The most comprehensive recent survey of cardiac arrest incidence during neuraxial anaesthesia reported 2.7 cardiac arrests per 10,000 anaesthetics, which is lower than an earlier study by the same authors and our study. Improved knowledge of neuraxial block physiology and the use of new local anaesthetics with fewer side-effects, associated with more routinely used oxygen monitoring through pulse oximetry, has substantially decreased the possibility of major complications during neuraxial anaesthesia. In contrast, no cardiac arrests were observed during plexus...
Table 6 Adverse events in cardiac arrests related to anaesthesia. *Totally related to anaesthesia; #partially related to anaesthesia; ARDS, acute respiratory distress syndrome; ARF, acute renal failure; COPD, chronic obstructive pulmonary disease; H, hypertension; MI, myocardial infarction; DM, diabetes mellitus; CRF, chronic renal failure; AOP, arterial obliteration peripheral; PACU, postanaesthesia care unit

<table>
<thead>
<tr>
<th>No.</th>
<th>Age</th>
<th>Sex</th>
<th>ASA status</th>
<th>Surgical procedure</th>
<th>Surgery</th>
<th>Anaesthetics technique</th>
<th>Patient’s medical history</th>
<th>Event leading cardiac arrest</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>5 days</td>
<td>M</td>
<td>IV</td>
<td>Emergency</td>
<td>Exploratory laparotomy</td>
<td>General</td>
<td>Intestinal perforation, ARF, ARDS</td>
<td>Loss of airway/unable to ventilate</td>
<td>Full recovery</td>
</tr>
<tr>
<td>2*</td>
<td>2 months</td>
<td>F</td>
<td>IV</td>
<td>Urgency</td>
<td>Ventriculoperitoneal shunt</td>
<td>General</td>
<td>Liver failure, hydrocephaly</td>
<td>Failure to intubate and ventilate after induction</td>
<td>Full recovery</td>
</tr>
<tr>
<td>3*</td>
<td>3 months</td>
<td>M</td>
<td>III</td>
<td>Elective</td>
<td>Exploratory laparotomy</td>
<td>General</td>
<td>Pulmonary failure, intestinal perforation</td>
<td>Loss of airway/unable to ventilate</td>
<td>Full recovery</td>
</tr>
<tr>
<td>4*</td>
<td>6 yr</td>
<td>F</td>
<td>IV</td>
<td>Elective</td>
<td>Hiatal hernia</td>
<td>General</td>
<td>ARDS, ARF, COPD, gastric reflux</td>
<td>Failure to intubate and bronchoscopy after induction</td>
<td>Full recovery</td>
</tr>
<tr>
<td>5*</td>
<td>25 yr</td>
<td>F</td>
<td>II</td>
<td>Elective</td>
<td>Caesarean</td>
<td>Spinal</td>
<td>Mitral stenosis-regurgitation</td>
<td>Cardiovascular depression after induction</td>
<td>Full recovery</td>
</tr>
<tr>
<td>6*</td>
<td>27 yr</td>
<td>F</td>
<td>III</td>
<td>Elective</td>
<td>Vertebral column metastasis resection</td>
<td>General</td>
<td>Breast cancer, vertebral column metastasis, re-entrant tachyarrhythmia</td>
<td>Cardiovascular depression after metoprolol</td>
<td>Death</td>
</tr>
<tr>
<td>7*</td>
<td>37 yr</td>
<td>M</td>
<td>III</td>
<td>Elective</td>
<td>Cerebral abscess drainage</td>
<td>General</td>
<td>Ethylism, abscess cerebral</td>
<td>Cardiovascular depression after induction with propofol</td>
<td>Full recovery</td>
</tr>
<tr>
<td>8*</td>
<td>47 yr</td>
<td>M</td>
<td>IV</td>
<td>Urgency</td>
<td>Cholecystectomy</td>
<td>General</td>
<td>ARF, DM, acute cholecystitis</td>
<td>Pulmonary aspiration after induction</td>
<td>Death</td>
</tr>
<tr>
<td>9*</td>
<td>57 yr</td>
<td>M</td>
<td>III</td>
<td>Emergency</td>
<td>Appendicectomy</td>
<td>General</td>
<td>Acute appendicitis, obesity</td>
<td>Failure to intubate and ventilate after induction after pulmonary aspiration</td>
<td>Death</td>
</tr>
<tr>
<td>10*</td>
<td>59 yr</td>
<td>M</td>
<td>IV</td>
<td>Urgency</td>
<td>Hip abscess drainage</td>
<td>General</td>
<td>DM, H, kidney transplantation, hip arthritis suppurative</td>
<td>Failure to intubate and ventilate after induction</td>
<td>Recovered with pneumonae</td>
</tr>
<tr>
<td>11*</td>
<td>30 days</td>
<td>F</td>
<td>III</td>
<td>Urgency</td>
<td>Laryngoscopy + tracheotomy</td>
<td>General</td>
<td>Face and airway congenital defects</td>
<td>Failure to intubate and ventilate after induction</td>
<td>Full recovery</td>
</tr>
<tr>
<td>12*</td>
<td>1 yr</td>
<td>F</td>
<td>I</td>
<td>Elective</td>
<td>Dacryocystorhinostomy</td>
<td>General</td>
<td>Dacryocystorhinostenosis</td>
<td>Vagal response followed by cardiovascular depression</td>
<td>Recovered with injury</td>
</tr>
<tr>
<td>13*</td>
<td>7 yr</td>
<td>M</td>
<td>III</td>
<td>Elective</td>
<td>Percardiostomy</td>
<td>General</td>
<td>Pericardial tamponade, ventricular septal defect</td>
<td>Cardiovascular depression after induction</td>
<td>Full recovery</td>
</tr>
<tr>
<td>14*</td>
<td>63 yr</td>
<td>F</td>
<td>IV</td>
<td>Urgency</td>
<td>Lower limb amputation</td>
<td>Epidural</td>
<td>Thromboangiitis obliterans, H, MI</td>
<td>Cardiovascular depression after induction</td>
<td>Death</td>
</tr>
<tr>
<td>15*</td>
<td>68 yr</td>
<td>M</td>
<td>III</td>
<td>Urgency</td>
<td>Cervical abscess drainage</td>
<td>General</td>
<td>DM, COPD, cervical abscess</td>
<td>Failure to intubate and ventilate after induction</td>
<td>Full recovery</td>
</tr>
<tr>
<td>16*</td>
<td>71 yr</td>
<td>F</td>
<td>IV</td>
<td>Urgency</td>
<td>Lower limb amputation</td>
<td>Epidural</td>
<td>DM, AOP, MI</td>
<td>Cardiovascular depression after induction</td>
<td>Death</td>
</tr>
<tr>
<td>17*</td>
<td>75 yr</td>
<td>M</td>
<td>IV</td>
<td>Urgency</td>
<td>Thoracoscopy</td>
<td>General</td>
<td>Atrial fibrillation, plural effusion</td>
<td>Hypoxaeia + cardiovascular depression after tracheal extubation in the PACU</td>
<td>Recovered with MI</td>
</tr>
<tr>
<td>18*</td>
<td>82 yr</td>
<td>F</td>
<td>III</td>
<td>Elective</td>
<td>Cholecystectomy</td>
<td>General</td>
<td>CRF, acute cholecystisis</td>
<td>Fluid overload followed by acute lung oedema in the PACU</td>
<td>Death</td>
</tr>
</tbody>
</table>
block. Studies have shown that, because there are no major respiratory and cardiocirculatory changes in plexus block, especially after the introduction of newer local anaesthetics, with low myocardial toxicity, cardiac arrest incidence is almost null.7 16 31

In our study, respiratory causes of anaesthesia related cardiac arrest in patients were still more frequent (55.6%) than medication cases (44.4%). Respiratory event incidence was high in younger children. This is possibly because of the relatively narrow infant airway and the higher incidence of respiratory tract infections in young children.26 32 In our study, in all cases of cardiac arrest by respiratory event, the children had significant underlying disease that could have contributed to the cardiac arrest. In addition, three of the five respiratory cases of anaesthesia related cardiac arrest in children occurred in the first 2 yr of this study (1996 and 1997), a period in which our institution did not have the LMA for children yet.

The predominant mechanism in medication-related cardiac arrests was cardiovascular depression. No medication-related case in our study involved the use of this incorrect drug, but rather a relative overdose administered to the patient or an unusual response to standard doses. In two children, cardiac arrest was associated with cardiovascular depression after inhalation of sevoflurane. This halogenated when compared with halothane causes less myocardial contractility depression in children.25 Even so, cardiac arrest associated with sevoflurane can occur as seen in our and other studies.25

Many studies have demonstrated equal proportions of cardiac arrest from respiratory and cardiovascular causes during anaesthesia.13 4 In other reports and in this study, respiratory causes of cardiac arrest were more frequent than cardiovascular.8 16 35 Other studies have shown cardiovascular causes being more frequent than respiratory causes.3 25 36 Murray and colleagues25 suggested that the predominance of cardiovascular events in anaesthesia-related cardiac arrest may be related to the frequent use of pulse oximetry and capnography, which may be more effective in preventing respiratory rather than cardiovascular events.

Improvements need to focus on these more important areas which may help to reduce the number of perioperative cardiac arrests. Continued education for anaesthesia practitioners is pivotal; however one study demonstrated that poor practical application rather than lack of knowledge leads to critical incidents.37 Our anaesthetists are experienced and have continuous practice in anaesthesia. All trainees are closely supervised by a staff of anaesthetists.

There may have been some methodological weakness associated with our study. Firstly, it depends on adverse events being reported by faculty and residents. Underreporting is likely in this situation even though filling the form out for each case was mandatory. On the other hand, it seems that the anaesthetists report more accurately major adverse events rather than minor events.26 In order to minimize the risk of underreporting cardiac arrests, the information was cross-checked with operating theatre records and hospital administration files. Secondly, this study is representative for the experience in one institution only. Our institution is relatively small and had low faculty staff turnover rate during the study period. The single-institution database offered a reporting consistency that would not have been available from a multicentre study.3 However, practices peculiar to our institution might have influenced our statistics.

In conclusion, there were 186 perioperative cardiac arrests (34.5:10,000) over a 9-yr period in a public tertiary teaching hospital. The risk of anaesthesia-related cardiac arrest was 3.35:10,000, while the risk of cardiac arrest totally attributable to anaesthesia was 1.86:10,000 and the risk of anaesthesia contributory to cardiac arrest was 1.49:10,000. There were 118 perioperative deaths (21.97:10,000). The risk of anaesthesia-related death was 1.12:10,000 anaesthetics, while the risk of death totally attributable or contributory to anaesthesia was 0.56:10,000 in both cases. Major risk factors for cardiac arrest were neonates, children under 1 yr, the elderly, male gender in adults, ASA III or poorer physical status, emergency surgery and general anaesthesia in multiclinal, cardiac or thoracic surgery. The fact that all anaesthesia-attributable cardiac arrests were related to airway management and medication administration is important in prevention strategies.

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