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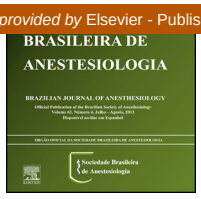

REVIEW ARTICLE

Perioperative cardiac arrest: an evolutionary analysis of the intra-operative cardiac arrest incidence in tertiary centers in Brazil

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KEYWORDS
Intra-operative complications;
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Abstract
Background: Great changes in medicine have taken place over the last 25 years worldwide. These changes in technologies, patient risks, patient profile, and laws regulating the medicine have impacted the incidence of cardiac arrest. It has been postulated that the incidence of intraoperative cardiac arrest has decreased over the years, especially in developed countries. The authors hypothesized that, as in the rest of the world, the incidence of intraoperative cardiac arrest is decreasing in Brazil, a developing country.
Objectives: The aim of this study was to search the literature to evaluate the publications that relate the incidence of intraoperative cardiac arrest in Brazil and analyze the trend in the incidence of intraoperative cardiac arrest.
Contents: There were 4 articles that met our inclusion criteria, resulting in 204,072 patients undergoing regional or general anesthesia in two tertiary and academic hospitals, totalizing 627 cases of intraoperative cardiac arrest. The mean intraoperative cardiac arrest incidence for the 25 years period was 30.72:10,000 anesthesias. There was a decrease from 39:10,000 anesthesias to 13:10,000 anesthesias in the analyzed period, with the related lethality from 48.3% to 30.8%. Also, the main causes of anesthesia-related cause of mortality changed from machine malfunction and drug overdose to hypovolemia and respiratory causes.
Conclusions: There was a clear reduction in the incidence of intraoperative cardiac arrest in the last 25 years in Brazil. This reduction is seen worldwide and might be a result of multiple

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factors, including new laws regulating the medicine in Brazil, incorporation of technologies, better human development level of the country, and better patient care.

PALAVRAS-CHAVE
Complicações intraoperatórias;
Parada cardíaca;
Reanimação cardiopulmonar;
Anestesia

Parada cardíaca perioperatória: uma análise evolutiva da incidência de parada cardíaca intraoperatória em centros terciários no Brasil

Resumo
Justificativa: Nos últimos 25 anos ocorreram grandes mudanças na medicina em todo o mundo. Essas mudanças de tecnologias, riscos do paciente, perfil do paciente e leis que regulam medicamentos tiveram impacto na incidência de parada cardíaca (PC). Postula-se que a incidência de parada cardíaca intraoperatória (PCI) tem diminuído ao longo dos anos, especialmente em países desenvolvidos. A nossa hipótes foi que, como no resto do mundo, a incidência de PCI está diminuindo no Brasil, um país em desenvolvimento.
Objetivos: O objetivo deste estudo foi pesquisar e avaliar na literatura as publicações que relacionam a incidência de PCI no Brasil e analisar a tendência na incidência de PCI.
Conteúdo: Descobrimos quatro artigos que atenderam os critérios de inclusão, resultando em 204.072 pacientes submetidos à anestesia regional ou geral em dois hospitais terciários e acadêmicos, totalizando 627 casos de PCI. A média de incidência de PCI para o período de 25 anos foi de 30,72:10.000 anestesias. Houve uma diminuição de 39:10.000 anestesias para 13:10.000 anestesias no período analisado, com letalidade relacionada de 48,3% para 30,8%. Além disso, as principais causas de mortalidade relacionadas à anestesia mudaram de mau funcionamento de máquinas e overdose de medicamentos para hipovolemia e causas respiratórias.
Conclusões: Houve uma clara redução na incidência de PCI nos últimos 25 anos no Brasil. Essa redução é observada em todo o mundo e pode ser o resultado de vários fatores, incluindo novas leis que regulam medicamentos no Brasil, incorporação de tecnologias, melhor nível de desenvolvimento humano do país e melhor assistência ao paciente.

Introduction

Cardiac arrest (CA) is the most serious potentially reversible adverse event that can be present in the perioperative period setting. It is assumed that in-hospital arrest is an event that has greater chance of survival than in patients admitted for other medical conditions, with a survival rate of about 15%, while out-hospital arrests have positive outcomes of 2–5% in most studies.[1,2] Usually, in-hospital CAs are preceded by hypotension, metabolic or electrolyte disturbances, and respiratory insufficiency, and are potentially preventable or modifiable, making a greater survival rate for in-hospital CA.[3–6]

Regarding intraoperative cardiac arrest (ICA), its incidence varies from 2.56 to 44 cases per 10,000 procedures, with a 30-day mortality that can reach up to 70%.[3,7–11] These differences in incidence may vary greatly mainly because the studied period varies significantly from 2 to 10 years and there is a lack of adequate epidemiological recording.[12] The importance of the length of the study time is crucial, since improvements in technologies and in clinical practices may have impacted the study period.[13] Also, with the emphasis on patient safety in anesthesia since the early 1980s, and with more concentrated efforts toward patient safety since the 1990s, a reduction of the incidence of perioperative mortality was observed.[9,13,14]

The patient risks and profile have also changed over the years, as there is a trend in submitting patients with greater age and comorbidities to surgery.[15–17] Patients with ASA III or greater are responsible for 92–96% of the patients that presented ICA.[18,19] Anesthetic-related and perioperative-related mortalities have decreased over the past 50 years consistently, despite the increase in baseline ASA status and patient complexity.

Also, the studied country has an impact in the incidence of ICA. The greatest and most consistent decline was seen in developed countries, as can be seen by some studies in Sweden and in the United States.[9,13,14,20] In developing countries, there is a lack of studies analyzing the trends in ICA.

The authors hypothesized that, as in the rest of the world, the incidence of ICA is decreasing in Brazil. The aim of this study was to search the literature to evaluate the publications that relate the incidence of ICA in Brazil and compare with those seen in other countries.

Methods

In our study, ICA was defined as the cardiac arrest present at the operating room.

We reviewed the scientific literature from MEDLINE, OVID, SCIELO and PubMed databases since 1980 using the

search terms: Intra-operative, perioperative, CA, Brazil, tertiary hospitals, anesthesia complications, anesthesia outcomes, cardiopulmonary resuscitation and anesthetic death. The terms were used combined and isolated. Articles reporting ICA cases in tertiary Brazilian hospitals were included and analyzed. Also, the references on the found texts were evaluated for possible relevant papers. Data were analyzed descriptively.

Inclusion criteria

Since the goal of this study was to evaluate the trend of ICA in Brazil, only Brazilian papers were considered for analysis, including both retrospective and prospective studies. All of the studies were needed to mention the ICA incidence in the operating rooms (ORs) or diagnostic procedure rooms, from all patients submitted to regional or general anesthesia. Also, the mortality rates, causes, and outcomes of CPR had to be present.

All articles found were read and classified according to the duration period, number of patients, number and incidence of arrests, mortality, etiology and outcomes.

Exclusion criteria

Since the aim of this review was to analyze ICA, studies that present only anesthesia-related and intraoperative-related mortalities were not included.

Results

There were only 4 studies that met the inclusion criteria (Table 1). The first study was performed by Ruiz Neto et al., which analyzed the incidence of ICA over the years 1982–1984, among 51,422 patients undergoing general or regional anesthesia. The second and third studies were conducted by Braz et al., which analyzed the incidence of ICA during the years 1988–1996 and 1996–2005, reviewing the incidence of ICA in 58,553 and 53,718 patients, respectively. The fourth study was performed by Sebbag et al., during the year 2007, which included 40,437 patients.[21] Together, these studies analyzed the incidence of 204,072 patients undergoing regional or general anesthesia in two tertiary and academic hospitals, which resulted in 627 cases of ICA. The mean ICA incidence for the 25 years period was 30.72:10,000 anesthesias (Table 2).

As presented in Table 2, the incidence of ICA decreased along the years, mainly after 2005. In the period of 1982–1984, the incidence of ICA had its greatest value for both overall and emergency arrests. During 1988–2005, the overall incidence of ICA decreased when compared to the study performed by Ruiz-Neto et al., mainly due to a fall in the emergency incidence of ICA. In 2007, a great decrease in the incidence of ICA and lethality was noticed, having an incidence of 13 ICA per 10,000 anesthetics, with an immediate lethality of 30.8%.[21] Although the two studies performed by Braz et al. included cardiac surgery and PACU arrests, the study done by Sebbag et al. did not. Cardiac surgery ICA and PACU arrests were responsible, respectively, for 14.8% and 5.4% of the total arrests during the years 1996–2005; 3.85% and 6.52% in the years 1988–1996.[18,21,22] Recalculating the incidence of ICA, excluding cardiac surgery and PACU arrests, there was an incidence of 21.9:10,000 anesthetics for the years 1988–1996, 28.1:10,000 anesthetics for the years 1996–2005, and 13:10,000 in 2007, again showing a reduction of ICA in the last years.[7,18,21,22]

During the first years of the analyzed period (1982–1984), 76.7% of ICA that occurred during elective surgeries was related to anesthesia and the comorbidities were responsible for only 5.9%. In the following years (1988–2007), ASA physical status gained great importance, being more important than surgical or anesthetic causes of ICA. Anesthesia, after the year 1984, greatly decreased its importance as the cause of ICA, being less important that surgical causes and ASA status.[7,18,21,22] The incidence of the event during all of the analyzed periods was higher during general anesthesia than with subdural, epidural, sacral or regional anesthesia.

The mean age of ICA showed an increase during the period of 1982–2007. The age group that had the greatest incidence of ICA in the years 1982–1984 was between 20 and 49 years (27.4%), while in the following years, the age groups greater than 40 years had the greatest incidence of ICA.

The main causes of ICA also varied along the analyzed years. During the years 1982–1984, the main factors that led to ICA were related to the surgery. Those related to anesthesia were mainly anesthetic overdose, hypoxemia, cardiocirculatory collapse after regional anesthesia, and anesthesia machine malfunction. In the years 1988–1996, hypoxia and hypoventilation were the leading cause of anesthesia-related ICA. These causes resulted mainly from vomit aspiration, though no difficult airway was mentioned. The second main cause of ICA during this same period was cardiocirculatory collapse after regional anesthesia.[22] In the years 1996–2005, the leading cause of anesthesia-related ICA was also hypoventilation, but mainly due to difficult airway. Hypoventilation was followed by medication-related problems, which included anesthetic over dosage and fluid overload. During the year 2007, the most common cause of the studied adverse events was hypovolemia (42%), followed by respiratory (21%) and metabolic (21%) disturbances and the ICA mainly occurred during the maintenance period of general or combined anesthesia.[18,21,22]

When analyzing the lethality of the CA (calculated dividing the number of deaths by the total CAs), in the years 1982–1984, it was 12% for anesthesia, 76.3% for surgery and 46.4% for comorbidities. In the study of Braz et al. during the period of 1988–1996, the anesthetic lethality of ICA was 24% with an overall lethality of 67.3%. In the years 1996–2005, the anesthesia-related lethality kept on raising to 33%, with an overall lethality of 63.4%. The study performed by Sebbag et al. does not provide enough data to calculate anesthesia-related lethality, but 40% of the ICA was at least partially attributable to anesthesia. The overall immediate lethality was 30.8%, which is a pronounced reduction from the last studied period (1996–2005).[18,21,22]

The proportion of anesthesia-related CA to the total number of anesthesia also presented with changes along the studied period. In the years 1982–1984, this proportion was 14.39:10,000 (7), while from 1988 to 1996, it reduced to 0.85:10,000. After this nadir, the proportion of anesthesia-related CA to the total number of anesthesia kept on raising on all of the following studies (3.35:10,000 in the years

Table 1 Summary of the studies and respective results.

Author	Period	Location of data collection	Design	*n*	ICA	Monitor
Ruiz Neto, RBA 1986 (REF)	1982–1984	Hospital das Clínicas, Faculty of Medicine, University of Sao Paulo, Sao Paulo, Sao Paulo State, Brazil (Tertiary Academic Hospital)	Retrospective	51,422 (38,652 electives and 12,770 emergencies)	- 205 cases - Incidence: 39: 10,000 - 75.1% urgencies - 24.9% electives	NIBP ECG
Braz, RBA 1999	1988–1996	Botucatu School of Medicine University Hospital, Sao Paulo State University, Botucatu, Sao Paulo State, Brazil	Retrospective	58,553	- 184 cases - Incidence: 31.42:10,000 - 68% urgencies - 32% electives	Not Specified
Braz, BJA 2006	1996–2005	Botucatu School of Medicine University Hospital, Sao Paulo State University, Botucatu, Sao Paulo State, Brazil	- Prospective with mandatory quality check	53,718 – includes cardiac surgeries	186 cases 34.6:10,000 - 68% urg - 32% electives	NIBP EKG SpO_2 Et CO_2 Conc O_2 Gas analysis Ventilometer
Sebbag, SPMJ 2013	2007	Hospital das Clínicas, Faculty of Medicine, University of Sao Paulo, Sao Paulo, Sao Paulo State, Brazil (Tertiary Academic Hospital)	- Prospective	40,379	52 cases (13:10,000) - 29% electives - 71% urgencies	NIBP EKG SpO_2 Et CO_2 Conc O_2 Gas analysis Ventilometer

Author	Mortality (:10,000)	Lethality (deaths divided by CA)	CPR and OR outcome	Causes of ICA	Results
Ruiz Neto, RBA 1986 (REF)	- Electives 2: 10,000 - Urgency 70:10,000	Anesthetic: 12% Surgical: 76.3% Physical Status: 46.4%	ROSC electives: 83.4% Urgency ROSC: 41.6%. After ROSC: 59.4% Bad overall status (OS), 40.6% Good and Regular OS. Those with anesthetic cause: 47% good and regular OS.	- Elective surgeries: mostly anesthesia-related (76.5%) - Urgency mostly surgical-related (59.7%)	- Urgencies > electives - Related factors: Gender (male), age (elder), clinic (general surgery), moment (maint),
Braz, RBA 1999	- 21.17:10,000 - Cause: Physical status: 15.71:10,000 - Surgical: 4.61:10,000 - Anesthetic: 0.85:10,000	Anesthetic 23.8% Surgical 58.7% Physical status 78.6%	After ROSC: 55% Bad OS, 20% regular OS and 25% in good OS. Those with anesthetic cause: 71% good OS.	- Physical Status 19.98 CPA: 10,000 (anesthetics) - Anesthetics: 3.59:10,000 Surgical: 7.86:10,000	- 88.59% in the OR - Factors: age (elder), gender (male), Physical Status 3 or higher, urgency, general anest.
Braz, BJA 2006	-21.97:10,000 - Cause: Physical status: 14.89:10,000 - Surgical: 5.96:10,000 - Anesthetic: 1.12:10,000	Anesthetic: 33.3% Surgical 68.1% Physical status 66.1%	Not specified	- Defined by CPAs commission: - Anesthetics: 3.35:10,000 - Surgical patient: 8.75:10,000 - Physical status: 22.52:10,000 Anesthetic: 1 – respiratory (55.6%) 2 – drugs (44.4%)	- OR > PACU (RPA) - Related factors: gender (male), age (newborns, <1 y, 51–64 y), ASA (III or +), urgency, general anest

Table 1 (*Continued*)

Author	Mortality (:10,000)	Lethality (deaths divided by CA)	CPR and OR outcome	Causes of ICA	Results
Sebbag, SPMJ 2013	Up to 30 days – 10:10,000	- Overall immediate lethality: 30.8% - 30-days lethality was 75%	- 69% successful CPRs Survivors: - 39% in 24 h - 25% in 30 d - elect 53% - emerg 14%	- Defined retrospectively - Physical status (52%) - Surgical (8%) - Anesthetic (40%)	- Related factors: gender (male) - Physical status (ASA III or +) - Emergency (71%) - General anest (90%)

ECG, continuous electrocardiogram; NIBP, non-invasive blood pressure; SpO_2, pulse oximeter; OS, overall status; OR, operating room; CPA, cardio-pulmonary arrest; ROSC, return of spontaneous circulation; PACU, post-anesthesia care unit.

1996–2005 and 5:10,000 in 2007).[18] Although the number of ICA and the overall lethality greatly decreased in 2007, the proportion of anesthesia-related CA to the total number of anesthesia increased.[18,21,22]

Discussion

Along the 25 years analyzed by this review, the incidence of ICA presented with changes. There was observed a decrease in ICA in Brazil, especially in the last decade.

In the 1980s, other studies around the world showed that ICA ranged from 1 to 23 arrests/10,000 anesthesias while, in Brazil, in the years 1982–1984, the incidence of ICA was higher than the worldwide incidence, with 39:10,000 anesthesias.[7,9,10,13,23,24] This worldwide incidence was found in studies performed in developed countries, which included France, United States of America, Sweden and Netherlands. The French study, which presented with the highest ICA incidence among the developed countries, reported that the main anesthesia-related cause had an important relationship with medication use, which was in agreement with the main cause found in Brazil, which was anesthetic overdose.[7] In the USA, which had the lowest incidence of ICA, enhanced intraoperative monitoring, the introduction of pulse oximetry and capnometry, the routine use of disconnect alarms, and a general awareness of the reported mishap were pointed as important steps to reduce the overall incidence of ICA, resulting in the lowest incidence of the reported studies.[13] At this period, pulse oximetry, monitored end-tidal CO_2, and defibrillators were not obligated by any legislation to be present inside the operating room in Brazil, which could have had a negative impact in the ICA, since it can help detect situations that can lead to CA, such as ventilator failures and disconnection. Anesthesia machine failure was listed among the top causes of ICA in Brazil and was not cited as an expressive cause of ICA by other articles during this decade.[24] Since the study done by Ruiz-Neto et al. does not provide further details on the type of machine failure nor it specifies the anesthesia machine used, we can speculate that the incorporation of capnographs or alarms could have reduced the incidence of ICA as expected by Keenan and Boyan, but since machine failure is a vast term, we cannot affirm this statement.[13] Also, the descriptive study of Ruiz Neto et al. was performed in a tertiary teaching hospital, in which patients have more comorbidities, with a great number of urgent and emergency surgeries, in patients ASA P IV and V, which could have an important role in increasing the ICA during this period.[7]

In the following decade, ASA physical status was the main factor related to ICA, followed by hypoxemia because of vomit aspiration. During this period, anesthetic overdose was not listed as one of the most important factors that could lead ICA. The most noticeable change was that anesthesia was no longer the main factor related to ICA in elective surgeries. Also, there was a noticeable reduction in the number of ICA related to anesthesia and surgery, but an increase in those related to the patient physical status, especially those patients categorized as ASA P III, IV and V. The number of CA related to anesthesia over all of the anesthetic procedures performed and anesthesia-related mortality suffered a great decrease. Part of these results may be related to the introduction of a Brazilian legislation in 1993, which included as mandatory the monitoring of blood pressure, the use of precordial stethoscope, and the presence of defibrillators and rescue drugs in

Table 2 Incidence of cardiac arrest (elective, emergency and overall), overall lethality along the years. Values of incidence of cardiac arrest and mortality are presented per 10,000 anesthetics. Lethality is presented in percentages.

Years	Overall incidence of cardiac arrest (:10,000)	Incidence of cardiac arrest in emergency cases (:10,000)	Incidence of cardiac arrest in elective cases (:10,000)	Overall lethality
1982–1984	39.0	120.0	13.0	48.3%
1988–1996	31.4	45.4	19.2	67.3%
1996–2005	34.6	55.4	19.4	63.4%
2007	13.0	15.0	5.0	30.8%

the operating theater (Federal Medicine Council Resolution Number 1363/93).[25] The monitoring of end tidal CO_2 was still reserved for certain procedures and pulse oximetry was mandatory only in hospitals that used oxygen concentration plants. Although this legislation increased patient safety and could theoretically reduce the incidence and the lethality of ICA, an increase in overall- and anesthetic-related lethalities and a decrease in the incidence of ICA were found during these years. The incorporation of these technologies might have an impact in preventable and promptly reversible causes of ICA, such as hypoxia that could be prevented by the use of oxymeters or by disconnection alarms. But, some causes of ICA (i.e. cardiac infarction) could not be prevented by the presence of monitors or alarms. Usually, theses causes have more difficult return to the spontaneous circulation, which could explain why the lethality increased along the analysed years: less preventable causes of ICA. Also, during this decade, as reported by other studies, a noticeable increase in the number of high-risk surgical elderly patients was reported, which might explain the increase in the lethality.[9,26,27]

In 2007, a great decrease in the incidence of ICA and lethality was noticed, having an incidence of 13 ICA per 10,000 anesthetics, with an immediate lethality of 30.8%. Although few studies have analyzed the ICA incidence from 2005 up to now, this incidence lies in the middle of the worldwide average for this period, which varied from 7 to 44 CAs per 10,000 anesthetics.[11,28] The decrease in the incidence of ICA maybe partially explained by a new legislation directed to anesthesia approved in the year 2006 (Federal Council of Medicine Resolution n° 1.802/2006).[29] This legislation required that all patients had a pre-anesthetic consult before hospital admission and established the minimum working conditions to perform anesthesia, which must include, at least, non-invasive blood pressure measurements, continuous ECG, pulse oximetry and capnography for all patients. Also, this new legislation included minimum monitors for post-anesthesia care unit, which included non-invasive blood pressure and pulse oximetry. This legislation was a step toward an increase in patient safety, which has been a world focus since early 1980s and with more efforts in the 1990s. This focus has been particularly adopted by all countries, but mainly in high human development indexed countries.[20]

One fact to consider when analyzing ICA in Brazil is that it is a developing country, which has a universal health system. The country's human development index (HDI) is related to the rate of improvement in perioperative mortality overtime, and this might be a result of the ability of wealthier countries to increase health-care investment in technologies, techniques, and training necessary to improve patient safety.[20] As seen by another review, there is a worldwide trend to reduce the incidence of ICA, especially in developed countries.[20] Brazil is no exception to this rule, decreasing from 39 ICA per 10,000 anesthetics to 13 ICA per 10,000 anesthetics along these 25 years studied. Although Brazil had, during the 1980s–1990s, a mean HDI of 0.56, which was close to the world average (0.58) and far from very high (0.82) HDI countries, its incidence of ICA was closer to those countries with low HDI, being more than 30 CAs per 10,000 anesthetics.[20] After the year 2000, especially in the year 2007, Brazil had an increase in the HDI (0.71) and sat closer to high HDI (0.74) countries, but its incidence of ICA was still far from high HDI countries.[20,30] This might be indicative of a relationship between countries' HDI and the incidence of ICA, even suggesting that the incidence of ICA might reflect the country's health care system. This is also supported by the fact that, in 2011, only 4.1% of the gross national product of Brazil was spent in the health system, which is less than half of what the USA spent for public health.[30] One fact to consider is that Brazil has a universal health system, while USA does not.

Although there were almost 204,072 patients analyzed, which resulted in 627 cases of ICA, with an incidence of 30.72:10,000 anesthesia during the 25 years period, this review showed a decrease in ICA from 39:10,000 to 13:10,000. All of the four studies were performed in tertiary teaching hospitals, which might have resulted in a higher incidence of ICA. Also, these hospitals were located in the wealthier part of Brazil, in one specific state of the country, which also is a limitation of this review.

Summary

There was a reduction in the incidence of ICA in the last 25 years in Brazil. This reduction is seen worldwide and might be a result of multiple factors, including new laws regulating the medicine in Brazil, incorporation of technologies, better human development level of the country, and better patient care.

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Conflicts of interest

The authors declare no conflicts of interest.

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