Anesthesia-related Cardiac Arrest

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ABSTRACT

Background: Much is still unknown about the actual incidence of anesthesia-related cardiac arrest in the United States.

Methods: The authors identified all of the cases of cardiac arrest from their quality improvement database from 1999 to 2009 and submitted them for review by an independent study commission to give them the best estimate of anesthesia-related cardiac arrest at their institution. One hundred sixty perioperative cardiac arrests within 24 h of surgery were identified from an anesthesia database of 217,365 anesthetics. An independent study commission reviewed all case abstracts to determine which cardiac arrests were anesthesia-attributable or anesthesia-contributory. Anesthesia-attributable cardiac arrests were those cases in which anesthesia was determined to be the primary cause of cardiac arrest. Anesthesia-contributory cardiac arrests were those cases where anesthesia was determined to have contributed to the cardiac arrest.

Results: Fourteen cardiac arrests were anesthesia-attributable, resulting in an incidence of 0.6 per 10,000 anesthetics (95% CI, 0.4 to 1.1). Twenty-three cardiac arrests were found to be anesthesia-contributory resulting in an incidence of 1.1 per 10,000 anesthetics (95% CI, 0.7 to 1.6). Sixty-four percent of anesthesia-attributable cardiac arrests were caused by airway complications that occurred primarily with induction, emergence, or in the postanesthesia care unit, and mortality was 29%. Anesthesia-contributory cardiac arrest occurred during all phases of the anesthesia, and mortality was 70%.

Conclusion: As judged by an independent study commission, anesthesia-related cardiac arrest occurred in 37 of 160 cardiac arrests within the 24-h perioperative period. **(ANESTHESIOLOGY 2014; 120:829-38)**

MUCH is still unknown about the incidence of anesthesia-related cardiac arrest in the United States. Since our original report was published in 2002, there have been a number of articles and editorials exploring the topic of anesthesia-related cardiac arrest.[1–5] A review article published in 2002 suggested that the overall perioperative mortality rate for patients having American Society of Anesthesiologists (ASA) physical status I to V is approximately 1 per 500 anesthetics.[2] The data further suggest that the anesthesia-related perioperative mortality rate is approximately 1 death per 13,000 anesthetics.

Another report found an overall frequency of perioperative cardiac arrests of 4.3 per 10,000 anesthetics. Cardiac arrests primarily attributable to anesthesia were estimated to be approximately 0.5 per 10,000 anesthetics. Mortality attributable to anesthesia was approximately 1 in 100,000 anesthetics.[4] This article was accompanied by an editorial noting that without standardized methods of data collection and analysis, it is difficult to compare results between institutions.[5]

Beginning in 2005, there were additional publications on this topic.[6–10] In 2008, a report looked at an unanticipated day of surgery deaths in Department of Veterans Affairs Hospitals.[11] After review of 88 unanticipated day of surgery deaths, the authors concluded that improved anesthesia care may have prevented fatality in approximately 1 of 13,900 cases. Another study using data from the American College of Surgeons National Surgical Quality Improvement Program database from 2005 to 2007 (n = 362,767) found that an intraoperative cardiac arrest occurs at a rate of approximately 7 per 10,000 noncardiac surgeries with a 30-day mortality rate of 63%.[12] In 2012, a review of 87 articles selected from the world literature on anesthesia-related mortality over the

What We Already Know about This Topic

- Much is still unknown about the actual incidence of anesthesia-related cardiac arrest in the United States
- Using a single institution's quality improvement database, all cases of cardiac arrest from 1999 through 2009 were identified and submitted for review by an independent study commission to estimate the incidence of anesthesia-related cardiac arrest

What This Article Tells Us That Is New

- As judged by an independent study commission, anesthesia-related cardiac arrest occurred in 37 out of 160 cardiac arrests within a 24-h perioperative period

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past 60 yr found considerable differences in mortality related to both economic development and ASA physical status with ASA physical status from III to V having markedly increased mortality rates.[13]

In 2013, a study looked at predictors of survival from perioperative cardiopulmonary arrests. The authors used a national in-hospital resuscitation registry to identify patients 18 yr or older who had a cardiac arrest in the operating room or within 24 h postoperatively. Out of a total of 2,524 perioperative cardiac arrests reported from 234 hospitals, they found 1,458 intraoperative cardiac arrests and 536 that occurred in the postanesthesia care unit (PACU). The remainder occurred in telemetry, critical care areas, or general inpatient areas. Those arrests in the operating room and PACU had better survival compared with the survival in other perioperative locations.[14]

To address this lack of information about anesthesia-related cardiac arrests, we asked an independent study commission, comprised of three anesthesiologists, an internist and critical care specialist, and a surgeon, to review all of the cases of cardiac arrest occurring within the 24-h perioperative period at our institution, to determine the incidence and outcome of anesthesia-attributable and anesthesia-contributory cardiac arrests.

Materials and Methods

After obtaining approval from the University of Nebraska Medical Center Institutional Review Board, Omaha, Nebraska, we identified all cardiac arrests that occurred within 24 h after anesthesia that were reported to our anesthesia database at The Nebraska Medical Center from August 15, 1999 to December 31, 2009. We used the same methodology as in our first report in that after we identified all cases of cardiac arrest from our anesthesia database, we prepared an abstract of each case from anesthesia and medical records. (See appendix 1 for details extracted from the records to prepare the abstract.) We then submitted the abstracts to an independent study commission representing anesthesiology, internal medicine, and surgery. The use of an independent study commission for review of deaths related to anesthesia in the perioperative period was proposed by Henry S. Ruth, M.D. (1899–1956; Professor, Department of Anesthesiology, Hahnemann Hospital and Medical College, Philadelphia, Pennsylvania) in 1945.[15] The independent study commissions would be modeled after maternal mortality study commissions. It was thought that there would be an insufficient number of deaths in Philadelphia to warrant the use of a commission. The independent study commission we created was asked to determine which cases were anesthesia-attributable and which cases were anesthesia-contributory to the cardiac arrest.[1] From these values, we calculated an anesthesia-attributable cardiac arrest rate and an anesthesia-contributory cardiac arrest rate. Cardiac arrests were identified from the anesthesia database that was developed from a quality assurance (QA) form included as mandatory documentation with each anesthetic record. The anesthesiology faculty member, anesthesiology resident, or nurse anesthetist providing the anesthetic completed the QA form. Required data on the QA form contained patient demographics, anesthesia provider information, date, location, ASA physical status classification, and a 60-item checklist of airway, cardiovascular, respiratory, neurologic, regional, and miscellaneous events. Providers were encouraged to describe the event, treatment, and outcome, and make any comments as to the cause or causes. Cardiac arrest was defined as an event requiring cardiopulmonary resuscitation, which may include closed or open-chest cardiac compressions. All QA forms were collected daily with a copy of the anesthesia record and reviewed for completeness by one of the authors (M.C.N.) throughout the review period covered by this study. During the study period, a weekly mortality and morbidity conference was held as part of our quality improvement process in which challenging cases or perioperative complications were discussed. Providers were expected to complete a 24-h follow-up of all cases. This allowed documentation of early postoperative complications that may have occurred in the PACU, the intensive care unit, or in the patient's room. For outpatients, a designated nurse called the patient within 24 h to determine whether the patient had any concerns. Any problems identified in the postoperative period were added to the database.

Each case of cardiac arrest was matched by a "proximal convenience" method to four other cases receiving anesthesia on the same date and in a similar operating suite. During the study period, all anesthetic records were kept in files maintained by the Department of Anesthesiology. Two cases randomly filed by billing personnel immediately preceding the cardiac arrest case and two immediately after the cardiac arrest case were identified as controls. For each study case and each control case, data were obtained on patient demographics (including age and sex), ASA physical status, operative status (emergency or elective), surgical procedure performed, time of day, and outcome. A copy of this data collection form is provided in appendix 2. A case was considered an emergency if it was designated as such by the ASA physical status classification. Additional pertinent information related to preoperative assessment, intraoperative course, and anesthetic management was recorded. Surgical procedures were classified by major categories according to the Physician's Current Procedural Terminology, 4th edition, as found in the ASA Relative Value Guide.[16]

The medical and anesthesia records of each patient who had a cardiac arrest during anesthesia or in the 24-h perioperative period were reviewed by at least one of the authors (S.J.E., M.C.N., J.A.S., or K.R.P.) from our Department of Anesthesiology. Abstracts were prepared without assigning responsibility for the cardiac arrest. Each abstract was assigned a three-digit code and submitted anonymously to an independent study commission formed for this analysis.

Members of the independent study commission included the Chairman of the Department of Anesthesiology at The Ohio State University Wexner Medical Center, Columbus, Ohio, a Professor of Anesthesiology and Director of Liver Transplant Anesthesiology at the University of Kansas Medical Center, Kansas City, Kansas, the former Chairman of the Department of Anesthesiology and now Professor Emeritus at the University of Nebraska Medical Center, Omaha, Nebraska, the Chairman of the Department of Surgery at the University of Nebraska Medical Center, Omaha, Nebraska, who was not at this institution during the period of this study, and a Professor of Internal Medicine and Critical Care at the Veterans Affairs Nebraska Western-Iowa Healthcare System, Omaha, Nebraska, and the University of Nebraska Medical Center, Omaha, Nebraska with no direct involvement in the care of these patients. Commission members from outside the institution may provide a more unbiased evaluation of these cases than if we used faculty exclusively within our institution.

Commission members were asked to review abstracts of all cases of cardiac arrest and were asked on their initial review to provide their assessment of the primary cause of cardiac arrest or death as due to (1) anesthesia, (2) surgery, (3) patient disease or condition, (4) other, for example, serendipity, electrical malfunction, fall, catastrophic failure of equipment, or (5) unable to decide from information provided. Commission members were also asked to determine which of the following, anesthesia, surgery, patient disease or condition, or other contributing cause, appeared to be a contributing cause of cardiac arrest or death. Consensus was determined when at least three of the five commission members agreed on a cause of the cardiac arrest or death.

The cases identified as anesthesia-attributable or anesthesia-contributory on the first review were resubmitted to the commission for a second, more restrictive review. The commission members were asked to make a choice of the role of anesthesia in these cases using the following scale, briefly summarized from our previous publication:

1. Anesthesia was the primary cause of the adverse event (certainty >90%)
2. Anesthesia was the primary cause of the adverse event (certainty 51 to 90%)
3. Anesthesia was an important contributing cause of the adverse event (certainty >90%)
4. Anesthesia was an important contributing cause of the adverse event (certainty 51 to 90%)
5. Anesthesia was neither the primary nor an important contributing cause of the adverse event.

After the second review by the commission, cases were assigned as anesthesia-attributable if the majority of the members judged them to have anesthesia as the primary cause (1 or 2 on the review scale) or anesthesia-contributory if the majority of the members judged them to have anesthesia as an important contributing cause (numbers 3 and 4 on the review scale) of the cardiac arrest.

Statistical Analysis

The incidence, cause, and mortality of anesthesia-related cardiac arrests were summarized. Matching of cases and controls was based on the anesthesia time and location. The characteristics of case and control groups were summarized using means and SDs for continuous variables, and frequencies and percentages for categorical variables. A P value of less than 0.05 was considered to be statistically significant.

Results

There were 217,365 anesthetics administered during the slightly more than 10-yr period of this study, from August 15, 1999 to December 31, 2009. A total of 160 cardiac arrests within the 24-h perioperative period were identified from an anesthesia QA database. The incidence of cardiac arrest from all causes was 1 per 1358, or 7.4 per 10,000 anesthetics (95% CI, 6.3 to 8.6). To provide a comparison group, cases experiencing cardiac arrest were matched with four other cases that underwent anesthesia on the same day and in the same location by a proximal convenience method. The characteristics of the cases that had a cardiac arrest and the controls are reported in table 1.

Differences were found between cases and controls with regard to age, sex, ASA physical status, emergency surgery status, surgical procedure, length of operation, time of day, and anesthetic technique by univariate analysis (all $P < 0.05$). The cardiac arrest group was older (53.5 ± 22.6 *vs.* 45.7 ± 22.7 for controls), had a higher proportion of males (61.3 *vs.* 46.3%), greater percentages of patients with higher ASA physical status (ASA ≥IV, 68.6 *vs.* 7.6%), greater percentage of patients having emergency surgery (51.9 *vs.* 12.0%), more patients with thoracic or spine procedures (35.0 *vs.* 14.7%), more patients with upper abdominal procedures (16.9 *vs.* 4.7%), longer length of operation (3.2 ± 2.9 *vs.* 1.6 ± 1.7 h), more evening surgery (37.5 *vs.* 22.7%), and a greater percentage had general anesthesia compared with the control group (93.8 *vs.* 86.6%).

In the cardiac arrest group, there were only four cases less than 1 yr of age and only 12 cases between 1 and 20 yr. The largest group of cases, 59 (37.8%), was between 51 and 70 yr of age. Controls were evenly distributed in the 31 to 50 and 51 to 70 yr old age groups. Males comprised 61% of the cardiac arrest cases. Three patients with ASA I and eight patients ASA II experienced a cardiac arrest. Seventy-three percent of cardiac arrests occurred in patients with ASA physical status III and IV. A little over 60% of cases with cardiac arrest occurred during regular working hours from 07:00 to 15:00 and the remainder took place in late afternoon and evening/nighttime hours. General anesthesia was the predominant anesthetic technique used in cases with cardiac arrest.

Table 1. Characteristics of Cases and Comparison Group for Cardiac Arrest

Characteristics	Cases (n = 160)	Controls (n = 640)	*P* Value
Age (yr)	53.5 ± 22.6	45.7 ± 22.7	<0.0001
<1	4 (2.6)	18 (2.8)	
1–10	7 (4.5)	38 (6.0)	
11–20	5 (3.2)	37 (5.8)	
21–30	10 (6.4)	77 (12.1)	
31–50	35 (22.4)	185 (29.1)	
51–70	59 (37.8)	184 (29.0)	
71–90	36 (23.1)	96 (15.1)	
Sex			
Female	62 (38.8)	344 (53.8)	0.0008
Male	98 (61.3)	296 (46.3)	
ASA physical status*			
I	3 (1.9)	86 (13.5)	<0.0001
II	8 (5.0)	237 (37.3)	
III	39 (24.5)	264 (41.6)	
IV	77 (48.4)	48 (7.6)	
V	32 (20.1)	0 (0.0)	
Emergency *vs.* scheduled	83 (51.9)	77 (12.0)	<0.0001
Surgical procedures			
Head/neck	11 (6.9)	144 (22.5)	<0.0001
Thoracic/spine	56 (35.0)	94 (14.7)	
Upper abdomen	27 (16.9)	30 (4.7)	
Extremity	18 (11.3)	129 (20.2)	
Other	6 (3.8)	116 (18.1)	
Lower abdomen	42 (26.3)	127 (19.8)	
Length of operation (h)	3.2 ± 2.9	1.6 ± 1.7	<0.0001
≤1.5	66 (41.3)	442 (69.1)	
1.5–3	41 (25.6)	117 (18.3)	
>3	53 (33.1)	81 (12.7)	
Time of day (24-h clock)			
Day (07:00–15:00)	100 (62.5)	495 (77.3)	0.0001
Evening/night (15:00–07:00)	60 (37.5)	145 (22.7)	
Anesthetic technique, general *vs.* other	150 (93.8)	554 (86.6)	0.02

* The reference level of ASA physical status in the univariate conditional logistic regression analysis was level ≥IV.
ASA = American Society of Anesthesiologists.

Figure 1 is a flow diagram illustrating the results of the review process used by the independent study commission in reviewing the 160 cardiac arrest case abstracts. All 160 abstracts were sent to the commission members for the initial review. After the initial review, 12 cases received at least three of five votes for anesthesia-attributable and nine cases had three of five votes for anesthesia-contributory. All were included in the cases sent back to the reviewers for the second review. An additional 24 cases had at least one vote for anesthesia-attributable and 17 cases had at least two votes for anesthesia-contributory. Many cases qualified in both categories because they had both one vote for anesthesia-attributable and two votes for anesthesia-contributory. A total of 53 abstracts were sent back to the reviewers for a second, more restrictive review. Reviewers were asked not to consult any notes from the first review but make a single judgment as outlined in the Materials and Methods. After this second review, there were now 14 cases determined to be anesthesia-attributable. Two of the original anesthesia-attributable cases were moved to the anesthesia-contributory category. An additional four cases were added to the anesthesia-attributable category making a total of 14. One case had been in the anesthesia-contributable group and moved to anesthesia-attributable. Three cases had previously had two votes for anesthesia-attributable and one case had previously only had one vote for anesthesia-attributable, but now, all three cases moved to the anesthesia-attributable group after the second review. The original nine cases in the anesthesia-contributory group changed to eight after the second review because one case moved from anesthesia-contributory to anesthesia-attributable. An additional 15 cases were added to the anesthesia-contributory group of 8 after the second review giving a total of 23 cases in the anesthesia-contributory group. Sixteen cases of the 53 in the second review were judged to be neither anesthesia-contributory nor anesthesia-attributable.

After the more restrictive second review, a total of 14 cases were identified as anesthesia-attributable with a mortality rate of 29% (95% CI, 8 to 58%), 4 of 14. These are listed in table 2. The adverse event leading to the arrest, the period of the anesthetic in which it occurred, the anesthetic technique

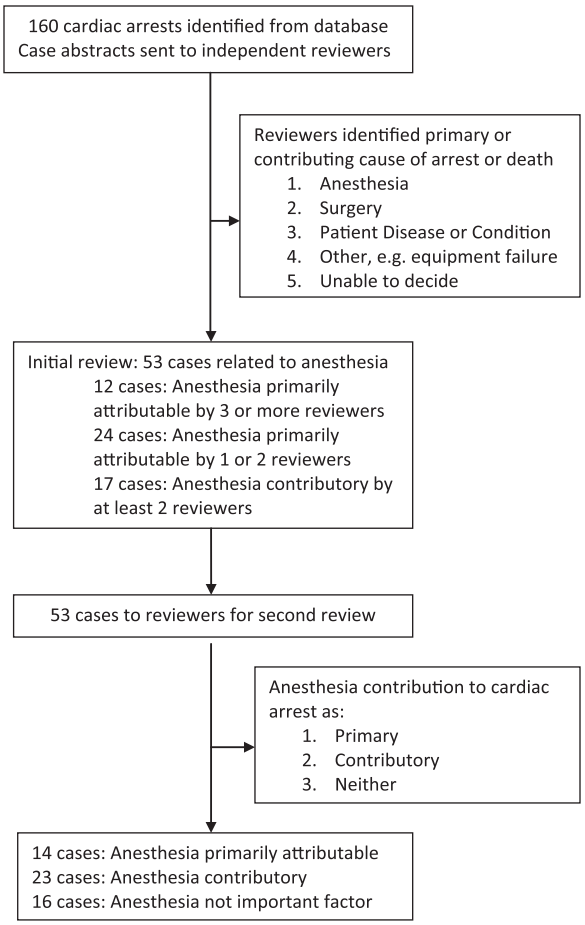

Fig. 1. Flow diagram of review process to identify anesthesia-attributable and anesthesia-contributory cases from 160 cases of perioperative cardiac arrest.

used, and the outcomes are also found in table 2. The 14 cardiac arrests attributable to anesthesia result in a cardiac arrest rate attributable to anesthesia of 1 per 15,526 anesthetics or 0.6 per 10,000 anesthetics (95% CI, 0.4 to 1.1). Risk of death due to anesthesia-attributable cardiac arrest was 1 in 54,341 or 0.2 per 10,000 anesthetics (95% CI, 0.1 to 0.5).

Mortality in the anesthesia-attributable cardiac arrest group was 29% compared with a mortality rate of 70% in cases of patient disease or condition or surgical/technical factors causing cardiac arrest. Nine of the 14 cases involved airway management either at induction or with extubation of the trachea at the end of the case followed by inability to mask ventilate or loss of airway on transport to or after arrival in the PACU (two cases). Several problems with placement of double-lumen tubes were noted. There were two cases of cardiac arrest involving central venous access and one case of hypotension after a small dose of intravenous narcotic. The patient with bradycardia during subarachnoid block ultimately required insertion of an intravenous pacemaker. The patient with a seizure after interscalene block had multiple medical problems and on another occasion had experienced a cardiac arrest during general anesthesia.

Cases were considered by the independent study commission to have anesthesia as an important contributory cause of cardiac arrest for an anesthesia-contributory cardiac arrest of 1 case per 9,450 or 1.1 per 10,000 anesthetics (95% CI, 0.7 to 1.6).

Table 3 lists the adverse events in the 23 cases of anesthesia-contributory cardiac arrests. Seventy percent had cardiac or cardiovascular complications which included myocardial infarction, hypotension, ST segment depression, bradycardia, ventricular fibrillation, and myocarditis. There were three cases (13%) of airway complications, all of which had a cardiac arrest in the PACU. Two cases (9%) of anesthesia-contributory cardiac arrest had pulmonary edema. There was one case of a type III protamine reaction and one case that underwent surgery after an intracranial hemorrhage. Five of the 23 anesthesia-contributory cardiac arrests occurred in patients having emergency surgery and four of those five patients died. Overall, 16 of the 23 cases of anesthesia-contributory cardiac arrests died resulting in a mortality of 70% (95% CI, 47 to 87%). This is the same mortality rate found for perioperative cardiac arrests not related to anesthesia which are listed in table 4.

Comments from the reviewers as to why anesthesia was considered contributory to the cardiac arrest focused on four areas: inadequate preoperative evaluation, issues with intraoperative management, inadequate volume resuscitation during the case, and postoperative respiratory depression from narcotics administered during the case. In several cases, the reviewers noted that the patient should have been assigned an ASA physical status IV instead of an ASA physical status III.

Table 4 lists cardiac arrests that were not anesthesia-related but attributable to patient disease/condition or attributable to surgical/technical factors. Technical factors include complications during cardiac catheterization, interventional radiology, or attempts at central venous access. Mortality in these 123 cardiac arrests was 70% with approximately 50% of patients in three categories: trauma, complications associated with liver transplantation, and inability to wean from cardiopulmonary bypass. The next most common categories were surgery on the thoracic or abdominal aorta (mortality 100%) and technical complications with 50% mortality. Two cases with perioperative myocardial infarction as well as two cases with pulmonary embolus died. There was one perioperative mortality in which no definitive cause was determined.

Discussion

This report is similar to our previous study[1] in that it describes the findings of an independent study commission that reviewed 160 cases of cardiac arrest in 217,365 anesthetics over a slightly more than 10-yr period of time from August 15, 1999 to December 31, 2009. The denominator in this current study contains over 144,000 cases more than the previous study. During this time period, a merger

Table 2. Adverse Events in Anesthesia-attributable Cardiac Arrests (n = 14)

No.	Age (yr)	ASA PS	Location	Adverse Event Leading to Cardiac Arrest	Period	Outcome	Anesthesia Technique
1	78	III	IP	Hypotension after intravenous narcotic. Multiple comorbidities.	Maintenance	Recovered	General
2	70	IV	IP	CL pulled out during patient move to PACU bed. Cardiac arrest during attempted replacement of CL.	Emergence	Died	General
3	33	IVE	IP	Hemothorax after CL attempt by anesthesia. Thoracotomy performed to control bleeding.	Preinduction	Recovered	None
4	67	IV	IP	Loss of airway on transport to PACU after early extubation.	PACU	Recovered	General
5	42	I	OP	Loss of airway on emergence due to bleeding and laryngospasm after nasal trumpet placed.	Emergence	Recovered	General
6	76	III	IP	Attempted DLT placement for thoracotomy after laparotomy.	Maintenance	Recovered	General
7	67	II	OP	Loss of airway in patient with known cancer of larynx. Unable to ventilate.	Induction	Recovered	General
8	76	III	IP	Breathing circuit misconnected after position change. Unable to ventilate using circuit. Successful with self-inflating bag.	Induction	Recovered	General
9	70	IV	IP	Extubated at end of long intra-abdominal operation. Apneic on arrival in PACU. Reintubation.	PACU	Died	General
10	53	IV	IP	Loss of airway with induction drugs. Difficult ventilation, bradycardia.	Induction	Recovered	General
11	26	III	IP	Difficulty in ventilating with DLT. DLT replaced with single-lumen endotracheal tube.	Induction	Recovered	General
12	91	III	IP	Bradycardia and dysrhythmia. Ejection fraction 20%.	Maintenance	Recovered	SAB
13	27	IV	IP	Seizure after interscalene block. Multiple comorbidities, previous cardiac arrest during general anesthesia.	Induction	Died	Regional
14	59	II	IP	Known difficult airway but extubated at end of case. Loss of airway. Unable to ventilate. Tracheostomy done.	Emergence	Died	General

ASA PS = American Society of Anesthesiologists physical status score; CL = central line; DLT = double-lumen tube; IP = inpatient operating rooms; OP = outpatient operating rooms; PACU = postanesthesia care unit; SAB = subarachnoid block.

between the University Hospital and a neighboring community hospital was completed with a significant increase in total numbers of cases attended by the Department of Anesthesiology. The study commission found that 37 of 160 cardiac arrests were related to anesthesia. Fourteen cases were judged to be anesthesia-attributable. This compares with the anesthesia-attributable cardiac arrest rate of 1 per 14,591 anesthetics or 0.69 per 10,000 (95% CI 0.085 to 1.29) in our first study. Nine of 14 (64%) of anesthesia-attributable cases were related to airway management compared with 2 of 5 (40%) in our previous study. Airway problems included difficulties either placing or ventilating through a double-lumen endotracheal tube, extubation and loss of airway on emergence or in the PACU, or difficulty ventilating on induction of anesthesia. Two of the four deaths in this group were related to airway management. Mortality in this group was 29%. This improved mortality rate contrasts with an 80% mortality rate in our first study. The improved mortality rate may be related to early recognition of the airway problem contributing to the cardiac arrest and having sufficient help available to "rescue" the patient. Other than one case of drug reaction after an interscalene block and complications with central venous access, all other patients in this category were rescued successfully.

The study commission found that 23 patients were in the anesthesia-contributory group. This compares with a somewhat higher anesthesia-contributory cardiac arrest rate of 1.37 per 10,000 anesthetics (95% CI, 0.52 to 2.22) in our first study. This could be related to a smaller denominator in the first study while having significant numbers of trauma, complex surgeries, and other high-risk patients. All of the patients in the anesthesia-contributory group in the current study were with ASA physical status III or IV and presented challenges with predominantly cardiovascular problems such as recent myocardial infarctions, dysrhythmias, hypotension, and pulmonary edema that were not easily correctable. Mortality was 70% in the anesthesia-contributory group. This is in contrast to our previous study, where 70% of the patients with anesthesia-contributory cardiac arrest survived. Their complications were less life threatening and more easily reversible problems of adverse drug events, vagal reactions, and easily correctible dysrhythmias.

A recently published review article on quality and safety in pediatric anesthesia discusses several institutions where

Table 3. Adverse Events in Anesthesia-Contributory Cardiac Arrests (n = 23)

No.	Age (yr)	ASA PS	Adverse Events and Issues Leading to Cardiac Arrest	Period	Outcome	Anesthesia Technique
1	47	III	Intraoperative hemorrhage and MI with inadequate volume resuscitation during the case.	Maintenance	Died	General
2	92	IVE	Bowel obstruction with recent MI. Etomidate used for induction and probable inadequate volume resuscitation.	Maintenance	Died	General
3	75	IV	Surgery postintracranial hemorrhage and problems with intraoperative management.	Maintenance	Died	General
4	20	III	Respiratory arrest in PACU. Likely an ASA IV with metastatic cancer and bowel obstruction. Respiratory depression after morphine administration.	PACU	Died	General
5	68	IV	Severe type III reaction to protamine. Unanticipated reaction to 1/3 dose of protamine.	Maintenance	Died	General
6	86	IVE	Non Q-wave MI and unstable angina. Cardiac arrest after induction dose of etomidate.	Induction	Died	General
7	44	III	Hypotension during AICD change. Problems with intraoperative management.	Maintenance	Recovered	General
8	41	III	Acute MI after superior laryngeal nerve block in morbidly obese patient. Inadequate preoperative evaluation. ASA IV.	Induction	Died	General
9	70	IVE	Sudden back pain and reintubation after off-pump CABG. Cause uncertain.	ICU	Died	General
10	64	III	Sudden bradycardia and hypotension. Active myocarditis. Inadequate preoperative evaluation and of resting pulse of 107 beats/min before elective hip replacement.	Maintenance	Died	General
11	57	IV	Dysrhythmia, desaturation, and hypotension at the end of insertion of intravenous port during MAC anesthesia. Postoperative respiratory depression secondary to narcotics.	Emergence	Died	MAC
12	91	III	Hypotension and bradycardia. Problems with intraoperative management.	Maintenance	Died	General
13	67	IV	Hypotension and bradycardia. Case cancelled after induction due to discovery of skin lesion. Inadequate preoperative evaluation. Complete heart block developed while emerging from anesthesia.	Emergence	Died	General
14	74	III	Septic arthritis and hypotension. Inadequate volume replacement after intraoperative loss of 3,000 ml of blood.	Maintenance	Died	General
15	49	III	Sudden onset pulmonary edema in patient with multiple comorbidities and ejection fraction of 25% scheduled for esophagogastroduodenoscopy. Induction with etomidate and propofol. Inadequate preoperative evaluation.	Maintenance	Recovered	General
16	38	IIIE	Respiratory arrest within 15 min of arrival in PACU. Postoperative respiratory depression secondary to narcotics administered throughout case and within 30 min of extubation in the operating room.	PACU	Recovered	General
17	46	IV	Recurrent episodes of hypotension. Attempted intravenous sedation for placement of hemodialysis catheter and AV fistula. Problems with intraoperative management.	Maintenance	Died	General
18	86	III	Bradycardia and hypotension after extubation in OR. Reintubated in OR. Problems with intraoperative management of elective total hip replacement.	Emergence	Recovered	General
19	3	IV	Respiratory arrest 30 min after arrival in PACU. Likely cause respiratory arrest secondary to narcotics.	PACU	Recovered	General
20	84 d	IVE	Pulmonary edema during case resulted in occluded endotracheal tube. Difficulties encountered during attempts at replacing. Problems with intraoperative management.	Maintenance	Died	General
21	67	III	Hypotension and bradycardia 15 min after induction of anesthesia. ST depression in lead II. Cardiology found stenotic lesion in anomalous RCA. Successful CABG 9 days later.	Induction	Recovered	General
22	55	III	Cardiac arrest 15 min after induction of anesthesia for placement of permanent pacemaker. Sudden VF in patient with sick sinus syndrome.	Maintenance	Recovered	General
23	87	IV	Sudden onset of hypotension and severe ST segment depression after administration of neostigmine and glycopyrrolate for reversal of muscle relaxants. Patient had undergone repair of femoral neck fracture. Multiple medical problems.	Emergence	Died	General

AICD = automatic implantable cardiac defibrillator; ASA PS = American Society of Anesthesiologists physical status score; AV = arteriovenous; CABG = coronary artery bypass grafting; ICU = intensive care unit; MAC = minimal alveolar concentration; MI = myocardial infarction; OR = operating room; PACU = postanesthesia care unit; RCA = right coronary artery; VF = ventricular fibrillation.

Table 4. Cardiac Arrests Attributable to Patient Disease/Condition, or Surgical/Technical Factors

	Number n (%)	Mortality (%)
Causes of Arrest	123	70
Trauma: motor vehicle, gunshot wound, fall, pedestrian, other	24 (19.5)	100
End-stage liver disease and complications associated with liver transplantation	18 (14.6)	61
Inability to wean from cardiopulmonary bypass	18 (14.6)	100
Complications associated with cardiac surgery	6 (4.9)	67
Thoracic or abdominal aortic aneurysm surgery (seven ruptured)	10 (8.0)	100
Technical complications: surgical, special procedures, cardiac catheterization laboratory, central venous access	14 (11.4)	50
Sepsis and/or multiple organ failure	6 (4.9)	83
Exsanguinating hemorrhage at operation associated with primary disease process	5 (4.0)	80
Complications associated with small bowel or kidney transplant	4 (3.2)	75
Complications associated with radical cancer surgery	4 (3.2)	100
Vagal reaction	3 (2.4)	0
Perioperative myocardial infarction	2 (1.6)	100
Pulmonary embolus	2 (1.6)	100
Pacemaker or implantable cardiac defibrillator related	2 (1.6)	0
Miscellaneous: drug reaction and cause undetermined	3 (2.4)	33

adverse event data are gathered from self-report, department quality improvement review, and other sources.[17] Cases are then peer-reviewed by at least three anesthesiologists who were not involved in the case. Demographic data on patients with anesthesia are provided by the institutions so that estimates of incidence can be determined. An editorial discussing this article points out the opportunity of using quality, patient safety, and process improvement as an area of study.[18] Clark also noted in his editorial that collecting significant events is a problem and may require manual tracking and analysis by experienced clinicians.

An analysis of factors associated with unanticipated day of surgery deaths in Department of Veterans Affairs Hospitals was reported in 2008.[11] The authors analyzed 815,077 elective surgical patients with ASA physical status I, II, or III in the National Surgical Quality Improvement Program database to identify patients who died on the day of surgery. They found that 0.08% or 646 patients died on the day of surgery with the type of surgery the strongest predictor and aortic surgery the most risky. The authors did a chart review of 88 deaths and found that opportunities for improved anesthesia care were present in 13 of the 88 (15%). They also found that the time between the conclusion of surgery and final transfer of care into recovery was a time in which many of the deaths occurred. We noted this time period to be a factor in several of our anesthesia-attributable cardiac arrests. They suggested that a death might have been prevented by improved anesthesia care in approximately 1 per 13,900 cases. This number is similar to that previously reported in a study of anesthesia-related perioperative mortality.[2]

In comparison with our previous study of perioperative cardiac arrests, there are more airway-related complications in this latest 10-yr review compared with the previous 10 yr and a lower number of medication-related complications. We have observed an increase in the number of airway complications on emergence from anesthesia or in the PACU. Three of 23 (13%) of anesthesia-contributory cardiac arrests occurred from respiratory arrests in the PACU. A report on perioperative cardiac arrest in 53,718 anesthetics over 9 yr from a Brazilian teaching hospital found that all anesthesia-related cardiac arrests were related to airway management and medication administration.[19]

In our current study, the overall incidence of cardiac arrest was 7.4 per 10,000 anesthetics. This compares with our previous study in which the overall incidence of cardiac arrest was 19.7 per 10,000 anesthetics. The distribution and numbers of cardiac arrests attributable to patient disease/condition or surgical/technical factors remained fairly similar between the two studies, but we had a much larger denominator in the current study. This may explain the change in incidence. The distribution of patients in the ASA physical status groups has stayed approximately the same in the two time periods. The top three categories for causes of cardiac arrest remained the same: trauma, end-stage liver disease and complications associated with liver transplantation, and inability to wean from cardiopulmonary bypass. Technical complications including surgical and special procedures increased from 7 to 11.4%.

Limitations to this study include its representation of perioperative cardiac arrests from a single institution. The Nebraska Medical Center is a 600-bed tertiary referral center with approximately 20,000 surgical cases per year. It includes a level 1 trauma center, an active solid organ transplantation program including both adult and pediatric liver, small bowel, and kidney transplants, adult heart transplants, high-risk obstetrical care, and neonatal and pediatric intensive care units. Patient mix is local and referral as well as

some national/international patients. Our experience may not be the same as other institutions.

We have maintained our database of adverse events for more than 20 yr by reporting from providers including faculty, residents, and certified registered nurse anesthetists. This is part of our QA and improvement program. During the study period, adverse events were reviewed weekly as part of our morbidity and mortality program. It is always possible that not all events were captured. The independent study commission did not have access to original records. It is possible that this could have introduced unrecognized bias into the commission's interpretation of perioperative events.

A total of 37 cases of anesthesia-related cardiac arrest were identified from 217,365 anesthetics over a 10-yr period in an academic medical center. Fourteen cases were determined to be anesthesia-attributable with an anesthesia-attributable cardiac arrest rate of 0.6 per 10,000 anesthetics (95% CI, 0.4 to 1.1) which is comparable with a rate of 0.69 per 10,000 anesthetics (95% CI, 0.085 to 1.29) in the previous 10 yr. Twenty-three cases were determined to be anesthesia-contributory for a risk of anesthesia-contributory cardiac arrest of 1.1 per 10,000 anesthetics (95% CI 0.7 to 1.6) compared with a rate of 1.37 per 10,000 anesthetics in the previous 10 yr. The anesthesia-related cardiac arrest rate has not changed significantly over a 10-yr period. Many of the events occurred in the operating room after the patient was emerging from anesthesia, during or after transport to the PACU, and in the PACU. Airway management decisions, complications associated with vascular access, preoperative patient assessment, and intraoperative cardiovascular events are the areas where improvements should be directed.

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Competing Interests

The authors declare no competing interests.

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Appendix 1. Data Collection Form for Items to Be Included in Preparation of Abstracts

Case identification code:
Patient demographics:

- Age
- Sex
- American Society of Anesthesiologists physical status score
- Emergency or scheduled operation
- Surgical procedure
- Length of operation (if helpful)
- Time of day (day: 07:00 to 15:00, evening/night: 15:00 to 07:00)
- Comorbid conditions
  - Obesity
  - Smoking
  - Hypertension
  - Diabetes mellitus
  - Coronary artery disease
  - Chronic obstructive pulmonary disease
  - End-stage renal disease
  - End-stage hepatic disease
  - Congestive heart failure
  - Myocardial infarction in past 6 months

Pertinent facts related to preoperative assessment, intraoperative course, management of anesthetic, and resuscitation:
Outcome, if known:
Autopsy findings, if known:

Appendix 2. Data Collection Form for Cases and Controls

1. Registration No. Case or Control Identifier No.
2. Date of operation
3. Time of operation
4. Sex
5. Age in
   a. Days
   b. Months
   c. Years
6. ASA physical status
7. Operation
   a. Scheduled
   b. Urgent
   c. Emergency
8. Length of operation in
   a. Minutes <60
   b. Hours
9. Anesthetic
   a. Local only
   b. MAC
   c. Regional
   d. General
   e. Regional and general
10. If cardiac arrest, was
    a. Resuscitation successful
    b. Resuscitation unsuccessful

ASA = American Society of Anesthesiologists; MAC = minimal alveolar concentration.