Cardiac Arrest During Neuraxial Anesthesia: Frequency and Predisposing Factors Associated with Survival

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The frequency and predisposing factors associated with cardiac arrest during neuraxial anesthesia remain undefined, and the survival outcome data are contradictory. In this retrospective study, we evaluated the frequency of cardiac arrest, as well as the association of preexisting medical conditions and periarrest events with survival after cardiac arrest during neuraxial anesthesia between 1983 and 2002. To assess whether survival after cardiac arrest differs for patients who arrest during neuraxial versus general anesthesia, data were also obtained for patients who experienced cardiac arrest under general anesthesia during similar surgical procedures during the same time interval. Over the 20-yr study period at the Mayo Clinic, there were 26 cardiac arrests during neuraxial blockade and 29 during general anesthesia. The overall frequency of cardiac arrest during neuraxial anesthesia for 1988 to 2002 was 1.8 per 10,000 patients, with more arrests in patients receiving spinal versus epidural anesthesia (2.9 versus 0.9 per 10,000; $P = 0.041$). In 14 (54%) of the 26 patients who arrested during a neuraxial technique, the anesthetic contributed directly to the arrest (high sympathectomy or respiratory depression after sedative administration), whereas in 12 (46%) patients, the arrest was associated with a specific surgical event (cementing of joint components, spermatic cord manipulation, reaming of the femur, and rupture of amniotic membranes). Patients who arrested during general anesthesia had a higher ASA classification than those who arrested during a neuraxial block ($P = 0.031$). Hospital survival was significantly improved for patients who arrested during neuraxial anesthesia versus general anesthesia (65% vs 31%; $P = 0.013$). The association of improved survival with neuraxial anesthesia remained statistically significant after adjusting for all patient/procedural characteristics, with the exception of ASA classification and emergency procedures. We conclude that a cardiac arrest during neuraxial anesthesia is associated with an equal or better likelihood of survival than a cardiac arrest during general anesthesia.

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The incidence of cardiac arrest during neuraxial anesthesia varies between 1.3 and 18 in 10,000 (1–12). However, predisposing factors, as well as short- and long-term survival, remain contradictory. A recent review by Sprung et al. (1) reported the frequency of arrest for patients during regional anesthesia to be 1.5 per 10,000, which was less than the reported frequency of arrest for patients receiving general anesthesia (5.5 per 10,000). Less frequent arrests for patients receiving regional anesthesia do not necessarily imply greater safety. Rather, this may reflect the fact that a wider variety of more complex cases are performed under general anesthesia, including organ transplantation and cardiac and neurosurgical procedures. Likewise, there may be a bias toward general anesthesia in the emergency setting or for patients with significant coexisting medical conditions.

Equally important to the relative frequency of cardiac arrest during neuraxial and general anesthesia are the long-term survival and outcome after such events. Between 1978 and 1986, analysis of the American Society of Anesthesiologists (ASA) Closed Claims database revealed 14 cases of cardiac arrest in young, healthy patients during spinal anesthesia (13). All were resuscitated from the intraoperative cardiac arrest, but six experienced such severe neurologic injury that they died in the hospital. Of the eight survivors, only one had sufficient neurologic recovery to allow independent self-care. The medicolegal basis of the Closed Claims Project makes it difficult to determine whether these cases are characteristic or, rather, represent the worst outcomes of cardiac arrest occurring

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during neuraxial block. These results are contradicted by Auroy et al. (2), who reported 29 cardiac arrests among 40,640 spinal and 30,413 epidural anesthetics, only 6 of which were fatal. Importantly, no neurologic sequelae were observed in the 23 (79%) patients who survived the cardiac arrest. The series by Auroy et al. (2) suggests that cardiac arrest during neuraxial anesthesia is not rare and that survival with good neurologic outcome is common. This study was performed to reconcile the conflicting results of Auroy et al. (2) and Caplan et al. (13) and to evaluate survival and the association of preexisting medical conditions and intraoperative events with neurologic outcome in patients experiencing a cardiac arrest during neuraxial compared with general anesthesia over 20 years.

Methods

After Mayo Foundation IRB approval, all perioperative cardiac arrests in patients undergoing noncardiac surgery during neuraxial anesthesia between January 1, 1983, and December 31, 2002, were identified. As part of the department's performance improvement (PI) initiative, the Mayo Clinic Department of Anesthesiology maintains a database of all perioperative critical events, including cardiac arrest. Reporting of critical events by anesthesia providers is mandatory. The PI Committee, which consists of staff anesthesiologists, anesthesia chief residents, certified nurse anesthetists, and recovery room nurses—meets monthly to review all incidents. This review process was established in 1985, and since then, for each patient who has experienced a cardiac arrest, the PI committee has reviewed anesthetic records, physicians' notes, laboratory findings, and outcomes of the resuscitation. As part of this process, the participants in the resuscitation were interviewed shortly after the event to ensure the completeness and accuracy of the information. The probable cause of arrest was determined shortly after the event by the PI committee and noted in their report. Before 1985, a similar, although less formal, review was completed and filed for each arrest. One of the authors (ABG or MEW) was a member of the PI committee for the entire study period.

For this study, cardiac arrest during neuraxial anesthesia was defined as hemodynamic instability (severe hypotension, bradycardia, or both) that resulted in loss of consciousness that required resuscitation with defibrillation, chest compressions, and/or vasopressors. All cardiac arrests were included that occurred after anesthesia had been initiated and before transfer from the postanesthesia care unit (PACU) or to the intensive care unit (ICU). To ensure that all cases were included, the Mayo Clinic database records of patients identified as experiencing postoperative cardiac arrest, death, unexplained ICU admission, and unexpected intubation were also reviewed.

Patient demographics, including age, sex, preoperative comorbidities, ASA classification, and the urgency of the surgery, were recorded. The type of neuraxial block, the dose and baricity of the local anesthetic, the highest dermatomal level achieved, and the amount of sedation received were examined. The presence of hemodynamic instability before arrest, such as hypotension (systolic blood pressure $<$80 mm Hg), bradycardia (heart rate $<$40 bpm), or vasopressor use within 30 min before the arrest, was noted. The timing of the cardiac arrest (block placement/anesthetic induction, maintenance of anesthesia, or PACU), as well as any associated surgical event (bleeding; cementing of joint components), was recorded. The primary electrocardiogram rhythm recorded at the time of arrest (ventricular fibrillation, asystole, or severe bradycardia) and resuscitative efforts (chest compressions, defibrillation, atropine, epinephrine, or pacemaker placement) were examined. Immediate survival (successful resuscitation allowing discharge from the operating room), long-term survival (discharge from the hospital), and the presence of long-term sequelae related to the arrest were noted.

By using the same PI database, all patients who arrested during general anesthesia in the same time period and during similar surgical procedures were identified. For the purpose of comparison, the surgical procedures were grouped into three categories: 1) total hip arthroplasty (THA)/femur fracture, 2) general surgery/other orthopedic, and 3) transurethral resection of the prostate (TURP)/cystoscopy. Cardiac arrest during general anesthesia was defined as an intraoperative event that required resuscitation with closed-chest compressions. Identical data regarding patient demographics, comorbidities, surgical course, timing of cardiac arrest, resuscitation efforts, and outcomes were recorded.

The frequency of cardiac arrest during neuraxial anesthesia was calculated both overall and according to the type of anesthesia and is presented with point estimates and 95% confidence intervals (CI). Before 1988, data regarding specific numbers of procedures performed during neuraxial anesthesia are not available. Therefore, the frequency of cardiac arrest was calculated only for 1988 through 2002. In an analysis restricted to patients who experienced cardiac arrest during neuraxial anesthesia, factors potentially associated with survival were assessed by using Fisher's exact test for categorical variables and the ranked sum test for continuous variables. To compare survival between patients who experienced arrest during neuraxial versus general anesthesia, data were analyzed with logistic regression. Given the limited number of patients included in this investigation, multivariate analyses were restricted to models that included at most two independent variables. Therefore, to assess the association of other patient or procedural characteristics with survival after cardiac arrest and to determine whether the type of anesthesia

Table 1. Frequency of Cardiac Arrest During Neuraxial Anesthesia According to Calendar Period and Type of Anesthesia

	Type of neuraxial anesthesia											
	Spinal				Epidural				Total			
			Arrests per 10,000 anesthetics				Arrests per 10,000 anesthetics				Arrests per 10,000 anesthetics	
Calendar period	Anesthetics (*n*)	Arrests (*n*)	Estimate	95% CI	Anesthetics (*n*)	Arrests (*n*)	Estimate	95% CI	Anesthetics (*n*)	Arrests (*n*)	Estimate	95% CI
1983–1987	—[a]	10	—[a]	—[a]	—[a]	2	—[a]	—[a]	—[a]	12	—[a]	—[a]
1988–1992	8,934	5	5.6	1.8, 13.1	12,450	2	1.6	0.2, 5.8	21,384	7	3.3	1.3, 6.7
1993–1997	11,023	3	2.7	0.6, 8.0	15,653	1	0.6	<0.1, 3.6	26,676	4	1.5	0.4, 3.8
1998–2002	14,492	2	1.4	0.2, 5.0	15,133	1	0.7	<0.1, 3.7	29,625	3	1.0	0.2, 3.0
1988–2002	34,449	10	2.9	1.4, 5.3	43,236	4	0.9	0.3, 2.4	77,685	14	1.8	1.0, 3.0

CI = confidence interval.
[a] Data regarding the total number of neuraxial blocks performed were not available before 1988.

was independently associated with survival after adjusting for these characteristics, a series of bivariate logistic regression analyses were performed. For these models, the dependent variable was hospital survival, and the independent variables were type of anesthesia and the patient/procedural characteristic of interest. In all cases, two-tailed tests were performed, with *P* values ≤0.05 considered statistically significant.

Results

During the 20-yr study period, 26 patients experienced a cardiac arrest during neuraxial anesthesia at the Mayo Clinic. The frequency of cardiac arrest during the study period is presented in Table 1. The overall frequency of cardiac arrest during neuraxial anesthesia for 1988–2002 was 1.8 per 10,000 patients, with more frequent arrests for patients receiving spinal versus epidural anesthesia (2.9 vs 0.9 per 10,000; $P = 0.041$). The overall frequency declined over time from 3.3 per 10,000 in 1988–1992 to 1.0 per 10,000 in 1998–2002. This decline was most apparent for spinal anesthesia, for which 50% of the arrests occurred during the initial 5 yr of the study period and then declined from 5.6 per 10,000 in 1988–1992 to 1.4 per 10,000 in 1998–2002.

Demographic data and preexisting conditions for the 26 patients who experienced cardiac arrest during neuraxial anesthesia are listed in Table 2. Mean patient age was 66 ± 15 yr (range, 34–89 yr). Twelve patients were listed as ASA physical status I or II, 12 were ASA physical status III, and 2 patients were ASA physical status IV or V. Eight patients arrested during THA/femur fracture repair, 8 patients during TURP/cystoscopy, and 10 patients during general surgery/other orthopedic procedures (Tables 3–5). In 20 patients (77%), the arrest occurred during a spinal anesthetic (including 1 continuous technique); the remaining 6 (23%) arrests were associated with a caudal or continuous epidural technique.

The cardiac arrest occurred at the time of block placement in 1 patient (4%), between block placement and surgical incision in 5 patients (19%), during the surgical procedure in 16 patients (62%), and after surgical closure in 4 patients (15%). The median time to arrest from the last local anesthetic administration (initial intrathecal injection or last epidural/caudal injection before arrest) was 50 min (range, 0–210 min). A sensory level at T6 or above (corresponding to a sympathetic level of T4 or above) was noted in 11 patients. In 12 (46%) patients, the cardiac arrest was associated with a specific surgical event, such as cementing of joint components, spermatic cord manipulation, intramedullary rod placement, rupture of amniotic membranes, hyponatremia secondary to prostatic resection, or reaming of the femur. In two patients, a preexisting cardiac condition was the etiology of the arrest. A vagally mediated response to block placement or postoperative nausea resulted in cardiac arrest in two patients. Sedation leading to respiratory depression was the mechanism of arrest in the remaining three patients (Tables 3–5).

Twelve of the 26 patients had a documented change in mental status or made specific complaints to the caregiver before the arrest, including nausea ($n = 4$), shortness of breath or restlessness ($n = 4$), light-headedness ($n = 1$), and tingling fingers ($n = 1$). One patient became less responsive but remained arousable, whereas another patient stated, "I'm going out." The presenting cardiac rhythm was asystole in 15 (58%) patients, VF in 5 (19%) patients, and severe bradycardia, pulseless electrical activity, or ventricular tachycardia in 6 (23%) patients. Resuscitative efforts included chest compression in 18 (69%) patients and defibrillation in 8 (31%) patients. Atropine and epinephrine were administered to 21 (81%) and 18 (69%) patients, respectively. The median duration of resuscitation was 5 min (range, 0.5–85 min). Patients who survived were resuscitated more quickly than nonsurvivors: 9 ± 20 min versus 34 ± 12 min,

Table 2. Hospital Survival After Cardiac Arrest During Neuraxial Versus General Anesthesia

	Neuraxial		General		Logistic regression *P* values[a]	
Characteristic	*n*	Survival, *n* (%)	*n*	Survival, *n* (%)	Type of anesthesia	Characteristic
Overall	26	17 (65)	29	9 (31)	0.013	
Sex					0.029	0.192
Male	18	13 (72)	13	5 (38)		
Female	8	4 (50)	16	4 (25)		
Age (yr)					0.010	0.192
≥49	4	3 (75)	5	1 (20)		
50–69	8	7 (88)	13	6 (46)		
≥70	14	7 (50)	11	2 (18)		
ASA physical status					0.076	0.043
I or II	12	10 (83)	8	4 (50)		
III	12	7 (58)	12	4 (33)		
IV or V	2	0 (0)	9	1 (11)		
Hypertension					0.012	0.306
No	15	10 (67)	16	3 (19)		
Yes	11	7 (64)	13	6 (46)		
Coronary artery disease[b]					0.013	0.988
No	18	13 (72)	20	5 (25)		
Yes	8	4 (50)	9	4 (44)		
Type of surgery					0.013	0.719
Total hip/femur fracture	8	4 (50)	11	4 (36)		
General/other orthopedic	10	9 (90)	10	2 (20)		
TURP/cystoscopy	8	4 (50)	8	3 (38)		
Emergency					0.053	0.035
No	25	17 (68)	23	9 (39)		
Yes	1	0 (0)	6	0 (0)		
Intraoperative hypotension					0.046	0.102
No	21	15 (71)	15	6 (40)		
Yes	5	2 (40)	14	3 (21)		
Presenting cardiac rhythm					0.008	0.081
Ventricular fibrillation	5	1 (20)	6	2 (33)		
Asystole	15	13 (87)	15	5 (33)		
Other[c]	6	3 (50)	7	1 (14)		
Resuscitation efforts						
Chest compressions					0.034	0.022
No	8	7 (88)	4	3 (75)		
Yes	18	10 (56)	25	6 (24)		
Defibrillation					0.040	0.009
No	17	15 (88)	20	8 (40)		
Yes	9	2 (22)	9	1 (11)		
Epinephrine					0.006	0.002
No	8	8 (100)	4	3 (75)		
Yes	18	9 (50)	25	6 (24)		

TURP = transurethral resection of the prostate.
[a] For each characteristic, a multiple logistic regression analysis was performed in which the dependent variable was hospital survival and the independent variables were type of anesthesia and the given characteristic. For these analyses age was treated as a continuous variable, and all other characteristics were treated as categorical variables by using the categories specified.
[b] Includes previous myocardial infarction.
[c] Includes severe bradycardia, pulseless electrical activity, and ventricular tachycardia.

respectively ($P < 0.001$). Eighteen (69%) patients who arrested during neuraxial anesthesia survived for at least an hour after the arrest. One patient died 25 days later of severe anoxic encephalopathy as a result of his cardiac arrest. The remaining 17 patients were discharged from the hospital without sequelae.

Among the 26 patients who arrested during neuraxial block, the percentage who survived to hospital discharge was not found to differ significantly between those who arrested during spinal versus epidural anesthesia (14 of 20 vs 3 of 6; $P = 0.293$) or according to type of surgery (4 of 8 vs 4 of 8 vs 9 of 10 for hip surgery, TURP, and other orthopedic or general surgical procedures, respectively; $P = 0.115$). However, hospital survival among these 26 patients was significantly associated with presenting cardiac rhythm: patients who experienced asystole had the most frequent hospital survival (13 of 15 vs 1 of 5 vs 3

Table 3. Cardiac Arrest During Neuraxial Anesthesia for Total Hip Arthroplasty/Femur Fracture Repair

Age (yr)/sex, year of surgery	ASA physical status	Procedure	Neuraxial block	Anesthetic dose	Time from injection to arrest (min)	Highest dermatome level	Altered mental status or patient complaint before arrest	Associated perioperative event	Chest compressions	Defibrillation	Length of resuscitation (min)	Outcome
83/M 1984	III	Endoprosthesis femur	Spinal	Procaine 100 mg, tetracaine 10 mg	15	Unknown	No	None	Yes	Yes	21	Death (autopsy: coronary artery disease)
55/F 1984	III	Total hip arthroplasty, removal of endoprosthesis	Spinal	Procaine 100 mg, tetracaine 10 mg	35	T6	No	Sedation	Yes	No	<1	Survived
89/F 1985	III	Hip open reduction/internal fixation	Spinal	Bupivacaine in dextrose 7.5 mg, epinephrine 0.2 mg	90	Unknown	Yes	Cementing of femur	Yes	Yes	55	Death (autopsy: fat and marrow embolus)
89/F 1986	IV E	Total hip arthroplasty	Epidural	Lidocaine 160 mg, epinephrine 1: 200,000	80	T12	Yes	Cementing prosthesis	Yes	No	30	Death
72/F 1991	III	Femur intramedullary rod	Epidural	Lidocaine 320 mg, epinephrine 1: 200,000, bupivacaine 40 mg	10	T6	No	Femoral rod placement	Yes	Yes	25	Death (autopsy: bone marrow embolism)
75/F 1992	III	Total hip arthroplasty	Spinal	Tetracaine 10 mg, epinephrine 0.2 mg	206	T4	No	Cementing prosthesis	Yes	No	5	Survived
72/M 1992	III	Femur intramedullary rod	Spinal	Tetracaine 40 mg, epinephrine 0.2 mg	86	T9	No	Reaming of trochanter	No	No	<5	Survived
73/M 2002	II	Total hip arthroplasty	Spinal	Bupivacaine 16.5 mg, epinephrine 0.2 mg	38	Unknown	No	Sedation	No	No	2	Survived

Table 4. Cardiac Arrests During Neuraxial Anesthesia for General Surgery/Other Orthopedic Procedures

Age (yr)/ sex, year of surgery	ASA physical status	Procedure	Neuraxial block	Anesthetic dose	Time from injection to arrest (min)	Highest dermatome level	Altered mental status or patient complaint before arrest	Associated perioperative event	Chest compressions	Defibrillation	Length of resuscitation (min)	Outcome
75/F 1985	III	Total knee arthroplasty	Spinal	Procaine 100 mg, tetracaine 10 mg	106	T6	Yes	Cementing prosthesis	No	No	<5	Survived
51/M 1985	II	Hemorrhoidectomy	Caudal	Chloroprocaine 720 mg, epinephrine 0.2 mg	25	Unknown	No	Surgical retraction	Yes	No	<5	Survived
34/M 1985	I	Foot procedure	Spinal	Procaine 120 mg, tetracaine 12 mg, epinephrine 0.2 mg	8	T3	No	None	Yes	No	<5	Survived
72/M 1987	II	Inguinal hernia repair	Spinal	Procaine 110 mg, tetracaine 11 mg	149	Unknown	Yes	None	No	Yes	1	Survived: inducible ventricular tachycardia on cardiac evaluation
81/M 1990	III	Hemorrhoidectomy	Caudal	Chloroprocaine 840 mg, epinephrine 0.2 mg	45	T10	No	None	Yes	No	<5	Survived
57/M 1992	III	Distal femur debridement	Spinal	Bupivacaine 15 mg	41	T5	Yes	None	Yes	No	>15	Survived
54/M 1996	II	Anal fistulotomy	Spinal	Lidocaine 75 mg	0	T10	Yes	Vasovagal episode during block	Yes	No	<1	Survived
42/M 1997	I	Groin exploration	Epidural	Lidocaine 610 mg	26	T4	No	Spermatic cord retraction	No	No	3	Survived
38/F 1998	I	Vaginal delivery	Epidural	Lidocaine 60 mg, epinephrine 1:200,000, bupivacaine 94 mg	144	T8	Yes	Rupture of membranes	Yes	No	35	Death (autopsy: Amniotic fluid embolus)
69/F 1998	II	Knee arthroscopy	Spinal	Bupivacaine 12 mg, epinephrine 0.2 mg	18	T1	No	None	Yes	No	<1	Survived

Table 5. Cardiac Arrests During Neuraxial Anesthesia for Transurethral Resection of the Prostate/Cystoscopy

Age (yr)/sex, year of procedure	ASA physical status	Procedure	Neuraxial block	Anesthetic dose	Time from injection to arrest (min)	Highest dermatome level	Altered mental status or patient complaint before arrest	Associated perioperative event	Chest compressions	Defibrillation	Length of resuscitation (min)	Outcome
74/M 1983	IV	TURP	Spinal	Procaine 60 mg, tetracaine 6 mg	55	T10	Yes	Bladder irrigation; sodium 120 mEq/L	Yes	Yes	34	Death (echocardiogram: severe aortic stenosis)
72/M 1986	III	TURP	Spinal	Procaine 80 mg, tetracaine 8 mg	210	T10	No	Spinal regressed, general anesthesia required for last hour of procedure; patient extubated, apnea and arrest during transport	Yes	Yes	20	Severe anoxic brain injury; died 25 after surgery
56/M 1987	II	TURP	Spinal	Procaine 70 mg, tetracaine 7 mg	85	T8	Yes	Vagally mediated after nausea	No	No	<1	Survived
62/M 1987	II	TURP	Spinal	Procaine 70 mg, tetracaine 7 mg	60	T8	Yes	None	No	No	<5	Survived
83/M 1991	III	TURP, inguinal hernia repair	Continuous spinal	Lidocaine 155 mg	15	T2	Yes	Sodium 106 mEq/L	No	Yes	50	Death
75/M 1992	II	TURP	Spinal	Lidocaine 80 mg	64	T5–6	No	Sodium 113 mEq/L	Yes	Yes	85	Survived
66/M 1993	II	TURP, cystoscopy	Spinal	Bupivacaine 13.5 mg	100	T6	No	None	Yes	Yes	38	Death (autopsy: severe coronary artery disease)
46/M 1996	III	TURP	Spinal	Bupivacaine 12 mg	4	C7–8	Yes	None	Yes	No	2	Survived

TURP = transurethral resection of the prostate; GA = general anesthesia.

of 6 for asystole, ventricular fibrillation, and "other" rhythm, respectively; $P = 0.012$).

During the same study period, 29 cardiac arrests occurred during general anesthesia in patients undergoing similar surgical procedures (Table 2). The mean patient age was 63 ± 20 yr (range, 7–94 yr). Eight patients were listed as ASA physical status I or II, 12 patients were ASA physical status III, and 9 patients were ASA physical status IV or V. Seventeen patients arrested because of a cardiac event (including myocardial infarction, high-degree cardiac conduction block, or dysrhythmia), five arrested because of hypoxia, six had a documented thromboembolism, and one experienced significant bleeding. Although there was no significant difference in the frequency of preoperative comorbidities, patients who arrested during general anesthesia had higher ASA classification than those who arrested during a neuraxial block ($P = 0.031$) and were more likely to have experienced hypotension before arrest ($P = 0.045$). The presenting cardiac rhythm at the time of arrest and the resuscitation efforts for patients who experienced a cardiac arrest during general versus neuraxial anesthesia were not statistically different. From univariate analysis, patients who arrested during neuraxial anesthesia had significantly better survival than those who arrested during general anesthesia (immediate survival: 69% vs 38%; $P = 0.023$; odds ratio [OR], 3.7; 95% CI, 1.2–11.2; hospital survival: 65% vs 31%; $P = 0.013$; OR, 4.2; 95% CI, 1.4–13.0).

To assess the influence of other potential patient or procedural characteristics and to determine whether neuraxial anesthesia was independently associated with improved survival after cardiac arrest after adjusting for these characteristics, a series of bivariate logistic regression analyses were performed. From these analyses, higher ASA classification ($P = 0.043$) and emergency surgery ($P = 0.035$) were found to be associated with worse survival, as were intensive resuscitation efforts ($P = 0.022$, $P = 0.002$, and $P = 0.009$ for use of chest compressions, defibrillation, and epinephrine, respectively). The association of neuraxial anesthesia with improved survival was found to remain statistically significant after adjusting for each patient/procedural characteristic, with the exception of ASA classification and emergency procedure. Although not statistically significant, the estimated magnitude of the association between neuraxial anesthesia and hospital survival after adjusting for ASA classification was similar to that found from the unadjusted analysis (OR, 3.0; 95% CI, 0.9–10.3), which is also similar in magnitude to the effect found if the analysis is restricted to nonemergency procedures (OR, 3.3; 95% CI, 1.0–10.9). If the analysis was restricted to neuraxial block patients who required chest compressions (rather than hemodynamic instability accompanied by loss of consciousness, according to the definition of cardiac arrest), patients who arrested during neuraxial anesthesia were still found to have significantly better hospital survival compared with those who arrested during general anesthesia (56% vs 24%; $P = 0.039$; OR, 4.0; 95% CI, 1.1–14.7).

In addition to the 26 arrests during neuraxial anesthesia, we also identified 1 cardiac arrest during the 20-yr study period that occurred during the performance of a peripheral (interscalene) block. Immediately after injection of 20 mL of 1% etidocaine plus 1:200,000 epinephrine, the patient seized and became asystolic. The patient was successfully resuscitated within 5 min without negative long-term sequelae.

Discussion

Initial case reports from the 1940s described cardiac arrest as an inexplicable complication of spinal anesthesia (14–16). The pathophysiology for cardiac collapse was often not considered, despite the patients' young age, healthy medical status, and initially uneventful intraoperative course; neuropsychiatric effects of hypoxic brain injury were of greater interest. Similarly, although large series of spinal anesthesia often included cardiac arrest as an observation, the significance of such a major complication was not discussed (6,10). In the last decade, reports of cardiac arrest associated with epidural block have been reported, although the overall frequency has reportedly decreased (2,7,8). Our study evaluated the association of preexisting medical conditions and intraoperative events with survival in patients experiencing a cardiac arrest during neuraxial compared with general anesthesia over 20 years at a single institution.

Several series have suggested that cardiac arrest during spinal and epidural anesthesia is not uncommon. Auroy et al. (2) reported 32 cardiac arrests among 103,730 regional anesthetics performed over a 5-month period, 7 of which were fatal. The incidence of cardiac arrest was significantly more frequent with spinal (6.4 per 10,000; 95% CI, 3.9–8.9) than with epidural (1.0 per 10,000; 95% CI, 0.2–2.9) anesthesia ($P < 0.05$) or peripheral nerve blocks (1.4 per 10,000; 95% CI, 0.3–4.1) ($P < 0.05$). Twenty (77%) of 26 patients who arrested during spinal anesthesia survived. Importantly, the size of the study by Auroy et al. (2) allowed analysis of potential variables associated with arrest and survival after arrest. For example, significant blood loss was reported at the time of cardiac arrest in nine patients, and three arrests occurred during cementing of the femur during THA. The time between the onset of spinal blockade and the occurrence of cardiac arrest was longer in nonsurvivors than in survivors (42 ± 19 minutes versus 17 ± 16 minutes) ($P < 0.05$). The average age of survivors was 57 ± 20 years, versus 82 ± 7 years for nonsurvivors ($P < 0.05$). In addition, the risk of death after cardiac arrest was increased with ASA classification and THA surgery ($P <$

0.05). Sedation was not noted to be the cause of any cardiac arrests, and bradycardia preceded all events. All patients who survived the cardiac arrest had complete neurologic recovery. In a subsequent investigation, Auroy et al. (3) reviewed 158,083 regional anesthetics, including 78,104 neuraxial blocks performed between August 1998 and May 1999. All 10 cardiac arrests occurred during spinal anesthesia (2.5 per 10,000; 95% CI, 0–5.1). Similar to the previous study, all arrests occurred more than 40 minutes after the intrathecal injection and were preceded by bradycardia. The three deaths occurred in elderly patients (>80 years) who were undergoing hip surgery. Although the most recent series reported less-frequent cardiac arrests, the incidence of death was actually more than the earlier review (30% versus 26%) (2,3).

Our results are similar to those of Auroy et al. (2,3). The overall rates of cardiac arrest are comparable, as is the increased frequency associated with spinal compared with epidural anesthesia. Hip replacement was the most commonly implicated surgical procedure in all series. As with previous surveys, we noted that the arrest often occurred well after establishment of the neuraxial block and was frequently associated with an intraoperative event, such as significant blood loss or cement placement during an orthopedic procedure. The likelihood of survival without neurologic sequelae was high and ranged from 65% to 74%. Although not statistically significant, our results are directionally consistent regarding patient-related variables associated with fatal cardiac arrest—increased age and higher ASA physical status. Contrary to Auroy et al. (2), we did not note a difference in survival when the arrest occurred during hip surgery compared with other surgical procedures. In addition, the presenting cardiac rhythm was asystole (not severe bradycardia) in most of our cases; asystole was associated with improved hospital survival compared with other presenting rhythms. Although, overall, it does not seem unreasonable to predict that elderly patients with multiple comorbidities undergoing a major surgical procedure would be at increased risk for fatal cardiac arrest, these results markedly differ from the cases included in the ASA Closed Claims Project.

During the initial review of the ASA Closed Claims database in 1988, Caplan et al. (13) discovered 14 cases of sudden cardiac arrest in healthy patients who had received spinal anesthesia for relatively minor surgery. The cases were similar in that the patients were young (36 ± 15 years) and healthy (ASA status I and II), the event was unexpected, and the outcome was poor despite apparently appropriate care. Anesthetic care had been in progress for an average of 36 ± 18 minutes at the time of the arrest. Bradycardia, hypotension, and/or cyanosis frequently preceded the arrest. The authors concluded that undiagnosed respiratory insufficiency, high sympathetic blockade, or both may have contributed to occurrence or outcome and recommended 1) that pulse oximetry be used whenever sedatives are administered or the patient's ability to communicate is impaired; 2) that epinephrine be administered early in cases of sudden bradycardia, hypotension, or both; and 3) that a full resuscitative dose of epinephrine be given immediately upon cardiac arrest. The efficacy of early and aggressive pharmacologic intervention has subsequently been confirmed clinically and in animal models (17).

While our series noted a significant decrease in the frequency of cardiac arrests after 1988, particularly during spinal anesthesia, it is unclear whether the outcome has been affected by these recommendations (5,18). In 2001, the Closed Claims database contained 181 claims involving cardiac arrest during spinal or epidural anesthesia.[1] The outcome in 161 (89%) of the claims was brain damage or death. These 161 cases accounted for 14% of all regional anesthesia-related claims in the database. Consistent with the earlier Closed Claims analyses, most cases involved ASA status I or II patients (53%) undergoing nonemergency surgery (70%) with spinal (56%) or epidural (44%) anesthesia. Importantly, prompt resuscitative efforts did not improve outcome; only 16% of cases were considered preventable with better monitoring.

Our review included four cardiac arrests during neuraxial block in patients younger than 50 years of age. Three of these patients were similar demographically to those in the ASA Closed Claims database: healthy and undergoing minor surgery with documented sensory levels above T4 after the initiation of spinal (two patients) or epidural (one patient) block. All three patients were successfully resuscitated without neurologic sequelae. The fourth patient, a healthy 38-year-old parturient with an indwelling epidural catheter and a T8 sensory level, experienced a fatal amniotic fluid embolus during rupture of her amniotic membranes. The survival rate among these patients was similar to the overall rate for our series and suggests that neither the patient population nor the neurologic outcome of patients included in the ASA Closed Claims Project is representative of those who arrest during neuraxial block.

Theories regarding the mechanism by which neuraxial block contributes to cardiac arrest involve a circulatory etiology. The evidence for an underlying respiratory source etiology is sparse. For example, sensory levels up to T4 do not result in hypoventilation. Likewise, although excessive sedation was speculated to have contributed to many of the early arrests during spinal anesthesia that occurred before the widespread use of pulse oximetry, several series report oxygen saturations of >than 90% at the time of arrest; often the patients had

[1] Caplan RA, unpublished data, presented at the ASRA Conference on Local Anesthetic Toxicity, November 18, 2001.

not received sedatives before the event (2,7,8). Although this is speculative, it is likely that the decrease in preload associated with neuraxial block results in a shift in cardiac autonomic balance toward the parasympathetic system. This secondarily results in bradycardia. At least three mechanisms have been proposed, including activation of the low-pressure baroreceptors in the right atrium, the receptors within the myocardial pacemaker cells, and mechanoreceptors in the left ventricle (stimulating a paradoxical Bezold-Jarisch response). In addition, a high sympathetic level may directly favor vagal tone; sedation, hypoxemia, hypercarbia, and chronic medications (such as β-adrenergic antagonists) may contribute to the development and severity of bradycardia (7). Intravascular fluid administration, the administration of mixed α- and β-agonists, and vagolytic therapy have all been advocated to decrease the frequency of and improve the survival associated with cardiac arrest during neuraxial block (5). Among the 17 patients in our series who arrested during neuraxial block and were successfully resuscitated, restoration of hemodynamic stability was accomplished early after diagnosing the cardiac arrest. Only two patients required more than five minutes of resuscitative efforts; intensive and prolonged resuscitations were less likely to be successful.

The physiologic factors that contribute to cardiac arrest during neuraxial block remain incompletely defined. More relevant is patient survival after cardiac arrest under neuraxial versus general anesthesia. Laboratory and clinical series report conflicting outcomes with respect to anesthetic technique. In a canine model, animals under spinal anesthesia did not exhibit normal increases in catecholamine release after cardiac arrest. As a result, the coronary perfusion pressure was less than that needed for successful resuscitation. Only the administration of exogenous epinephrine increased coronary perfusion pressure above the critical threshold (19). Likewise, clinical studies have reported conflicting rates of immediate survival related to anesthetic technique. Biboulet et al. (20) reported 11 cardiac arrests among 101,769 anesthetics. The incidence of cardiac arrest was more frequent during neuraxial (6 per 10,000) compared with general (0.8 per 10,000) anesthesia; 4 of 6 patients survived cardiac arrest in the general anesthesia group, compared with only 1 of 5 in the spinal anesthesia group. In a more recent study involving 518,294 anesthetics over an 11-year period, Sprung et al. (1) reported 223 cardiac arrests, noting a decreased frequency of cardiac arrests during regional compared with general anesthesia (1.5 per 10,000 and 5.5 per 10,000, respectively). The relatively low frequency among the regional anesthesia group precluded meaningful comparisons with the general anesthesia group with respect to predictors of survival.

Our series, conducted over a 20-year period, controlled for surgical procedure to compare survival after cardiac arrest during neuraxial versus general anesthesia. Univariately, patients who arrested during neuraxial block were more likely to survive than those who arrested during general anesthesia: 69% vs 38% for immediate survival and 65% vs 31% for hospital survival, respectively. The ORs corresponded to approximately a fourfold increase in the likelihood of surviving if the arrest occurred during a neuraxial block. The increased likelihood of survival persisted after adjusting for all patient/procedural characteristics, with the exception of ASA physical status and emergency surgery. However, after adjusting for ASA classification and emergency status, the magnitude of the association between improved survival and neuraxial anesthesia was similar but no longer statistically significant. Conservatively, this suggests that the likelihood of survival after cardiac arrest during neuraxial anesthesia is equal to or more than the likelihood of survival after cardiac arrest during general anesthesia.

In any study involving perioperative mortality, it is important to consider the source and integrity of the database. Our institution is a tertiary referral center. However, 90% of patients live within a 500-mile radius and receive their primary care here. Despite the advantage of consistent data collection, the results may not be applicable to the general population. Likewise, the statistical power for assessing the association of a specific patient or procedural factor with survival is dependent on the prevalence of the risk factor among patients who experienced an arrest. As a result, nonstatistically significant findings should be interpreted with caution when the number of patients with and without the risk factor is small.

In summary, this retrospective study evaluated the frequency of cardiac arrest and predisposing factors associated with survival between 1983 and 2002. The frequency of cardiac arrest during neuraxial anesthesia decreased significantly over the study interval and was more frequent with a spinal compared with an epidural technique. Importantly, 65% of patients in our series who arrested during neuraxial anesthesia were resuscitated without neurologic sequelae; few cases resembled the cardiac arrests included in the ASA Closed Claims Project with respect to demographics or outcome. After controlling for patient and procedural variables, we conclude that a cardiac arrest during neuraxial anesthesia is associated with an equal or greater likelihood of survival compared with cardiac arrest during general anesthesia.

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