ORIGINAL ARTICLE

SURGICAL CARE OF THE AGING POPULATION

Cardiac Arrest Among Surgical Patients

An Analysis of Incidence, Patient Characteristics, and Outcomes in ACS-NSQIP

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Objectives: To describe the incidence, characteristics, and outcomes of surgical patients who experience cardiac arrest requiring cardiopulmonary resuscitation (CPR).

Design: Retrospective cohort study.

Setting: American College of Surgeons–National Surgical Quality Improvement Program (ACS-NSQIP), 2005-2010.

Main Outcome Measures: Incidence of CPR, complications, mortality, and survival to hospital discharge at 30 days or less after surgery.

Results: A total of 6382 nontrauma patients (mean age, 68 years) underwent CPR; 85.9% of events occurred postoperatively, of which 49.8% occurred within 5 days after surgery. Overall incidence of CPR was 1 in 203 surgical cases but varied by specialty (1 in 33 for cardiac surgery vs 1 in 258 for general surgery). The mortality rates varied by specialty (45.0%-74.5%) and were associated with comorbidity burden (58.7% for no comorbidity, 63.1% for 1 comorbidity, and 72.8% for $\geq$2 comorbidities; $P < .001$). A total of 77.6% of CPR patients experienced a complication; approximately 75.0% occurred before or on the day of CPR, and septicemia (26.7%), ventilator dependence (22.1%), significant bleeding (13.9%), and renal impairment (11.9%) were the most common. The overall 30-day mortality was 71.6%. Survival to discharge in 30 postoperative days or less was 19.2%; 9.2% of CPR patients were alive but hospitalized at postoperative day 30. Older age, a preexisting do-not-resuscitate order, renal impairment, disseminated cancer, preoperative sepsis, and postoperative arrest were among the factors independently associated with worse survival.

Conclusions: One in 203 surgical patients undergoes CPR, and more than 70.0% of patients die in 30 postoperative days or less. Complications commonly precede arrest; prevention or aggressive treatment of these complications may potentially prevent CPR and improve outcomes. These data could aid discussions regarding advance directives among surgical patients.

JAMA Surg. 2013;148(1):14-21

CARDIAC ARREST REQUIRING cardiopulmonary resuscitation (CPR) is a major public health problem[1,2]; 1 event occurs every 90 seconds.[3] An estimated 200 000 to 750 000 cardiac arrests occur annually among hospitalized patients.[2,4,5] Not all cardiac arrests have the same origin[6]: out-of-hospital arrest usually results from an acute onset of cardiac arrhythmia,[7,8] whereas up to 14% of in-hospital arrests are preceded by complications, such as hypotension, metabolic or electrolyte disturbances, and respiratory insufficiency, and are potentially preventable or modifiable.[1,2,9-11]

See Invited Critique at end of article

Before the introduction of closed-chest cardiac massage in 1960,[12] results of resuscitation after cardiac arrest were reported mainly in surgical patient populations and surgical journals. At that time, the only method of resuscitation available was internal cardiac massage through a thoracotomy performed in the operating room. Introduction of closed-chest CPR redirected scholarly attention to patients who experienced cardiac arrest outside the operating room.[13] Currently, most studies[1,2,5,14,15] of CPR outcomes are based on data derived from the medical population. The most commonly reported outcome of in-hospital CPR is the rate of survival to hos-

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pital discharge, which has remained at 15% to 18% for the past 3 decades.

Most studies of CPR among surgical patients were conducted more than a decade ago[16] and were single-institution studies that either excluded or were restricted to cardiac surgery patients.[13,16-19] Their focus was often intraoperative arrests examined from the anesthesia perspective.[13,17,18] As such, the overall incidence, characteristics, and outcomes of surgical patients who receive CPR are largely unknown.

Using a multi-institutional database, we performed a retrospective analysis of surgical patients who received intraoperative and/or postoperative CPR to determine the incidence of CPR, patient characteristics, and 30-day outcomes. Our aim was to identify factors associated with 30-day mortality that could be targeted to improve patient outcomes.

METHODS

DATA SOURCE

We used data collected from up to 250 US hospitals participating in the American College of Surgeons–National Surgical Quality Improvement Program (ACS-NSQIP) that were included in the Participant Use Data File (2005-2010). In ACS-NSQIP, *cardiac arrest requiring CPR* is defined as the "absence of cardiac rhythm or the presence of chaotic cardiac rhythm that results in loss of consciousness requiring the initiation of any component of basic and/or advanced cardiac life support within 30 days of the operation. Patients with automatic implantable cardioverter defibrillators that fire but the patient has no loss of consciousness should be excluded." Through medical record review and patient follow-up, trained nurses prospectively collected data regarding preoperative and operative characteristics, as well as 30-day postoperative outcomes of surgical, nontrauma patients captured in the database.

INCIDENCE OF CPR

Overall incidence of CPR was calculated as the ratio of (intraoperative and postoperative) CPR occurrences to the total number of surgical cases in the entire ACS-NSQIP Participant Use Data File (2005-2010). The ACS-NSQIP collects data for more than 40 comorbidities. On the basis of a calculated mean of 1.6 comorbidities per surgical case in the database, CPR incidence also was stratified by the presence of 0, 1, or 2 or more comorbidities. The database includes a variable that specifies the primary specialty of the attending surgeon. Incidence of CPR by specialty of the attending surgeon was calculated as the ratio of CPR occurrence in each specialty to the total number of cases for that specialty in the database. Primary operative procedures were abstracted using the *Current Procedural Terminology* variable included in the ACS-NSQIP.

BASELINE CHARACTERISTICS OF CPR PATIENTS

Demographic characteristics included age, sex, race, preexisting do-not-resuscitate (DNR) orders instituted within the month before surgery, residence, and functional status before surgery. Clinical characteristics included emergency vs nonemergency surgery, American Society of Anesthesiologists (ASA) classification, and operative wound classification as defined by the primary surgeon.

Preexisting conditions included hypertension requiring medication; diabetes mellitus; ventilator dependence; history of chronic obstructive pulmonary disease; current pneumonia; newly diagnosed or worsening congestive heart failure 30 days or less after surgery; myocardial infarction 6 months before surgery; history of cardiac surgery or percutaneous coronary intervention; peripheral vascular disease, including revascularization and rest pain; ascites 30 days or less before surgery; acute renal failure 24 hours or less before surgery; dialysis dependence (≤2 weeks before surgery); history of paralysis (hemiplegia, paraplegia, or quadriplegia); impaired sensorium 48 hours or less before surgery; non–drug-induced preoperative coma; disseminated cancer; presence of an open wound before surgery; preoperative sepsis; and preoperative blood transfusion of 5 U or more in the 72 hours before surgery.

OUTCOMES

Clinical outcomes of interest were occurrence of 1 or more postoperative complications, survival to hospital discharge, and mortality at 30 days or less after surgery. Complications included (re)intubation, prolonged ventilator use (failure to wean from ventilator at >48 hours), pneumonia, venous thromboembolism (pulmonary embolism, deep venous thrombosis, or thrombophlebitis), myocardial infarction, stroke, coma lasting longer than 24 hours, wound infections (superficial, deep, and organ space) and dehiscence, severe sepsis or shock, bleeding requiring 5 U or more of blood, acute renal failure or insufficiency, and urinary tract infection. The timing of the occurrence of complication(s) was categorized into 4 occurrence intervals: (1) more than 1 day before CPR, (2) 1 day before CPR, (3) on the day of CPR, and (4) 1 or more days after CPR.

STATISTICAL ANALYSIS

Bivariate analyses of categorical variables were performed using a 2-tailed χ^2 test. A multivariate stepwise logistic regression model was generated to determine risk factors for 30-day postoperative mortality among CPR patients; $P < .10$ was used as the initial entry criterion. Odds ratios with 95% CIs were calculated. $P < .05$ was considered statistically significant.

Data analyses and management were performed using SPSS statistical software for Windows, version 19.0 (SPSS, Inc). Definitions of variables used in this study are available from the ACS-NSQIP Participant Use Data File user guide.[20] The ACS-NSQIP Participant Use Data File is a public database with deidentified data; therefore, this study was granted exemption by our institutional review board.

RESULTS

OVERALL INCIDENCE AND OUTCOMES

Among more than 1.3 million surgical cases captured in the ACS-NSQIP data set, 6382 patients experienced cardiac arrest requiring CPR. The overall incidence was 1 event per 203 cases. The incidence of CPR among patients with 0, 1, or 2 or more comorbidities was 1 in 2174, 1 in 699, and 1 in 95, respectively. Do-not-resuscitate orders were present in 0.6% of all cases in the ACS-NSQIP Participant Use Data File; 1.9% of patients who received CPR had a DNR order.

The overall 30-day mortality in the ACS-NSQIP data set was 1.7%; patients who received CPR had a mortality of 71.6% ($P < .001$). The mortality on the day of CPR

Table 1. Baseline Characteristics and 30-Day Outcomes of CPR Patients, ACS-NSQIP (2005-2010)

Characteristic	No. (%) of Patients[a]	Mortality, %	*P* Value	Survival to Discharge, %	*P* Value
Age, y					
<55	1052 (16.5)	66.0		22.0	
55-65	1399 (21.9)	70.7		19.3	
66-75	1690 (26.5)	71.4	<.001	20.0	.002
76-85	1708 (26.8)	74.2		18.2	
>85	533 (8.4)	80.6		14.0	
Sex					
Male	3687 (57.9)	72.3	.11	18.1	.009
Female	2680 (42.1)	70.5		20.7	
Race					
White	4464 (69.9)	70.8		20.3	
Black	1106 (17.3)	72.9	.09	16.3	.003
Other or unknown	812 (12.7)	74.1		17.1	
Residence before hospitalization					
Home	5158 (80.8)	70.6		20.0	
Acute care facility	737 (11.5)	73.4	<.001	17.1	.002
Chronic care facility	351 (5.5)	80.3		13.5	
Other or unknown	136 (2.1)	76.5		13.0	
Do-not-resuscite order					
No	6260 (98.1)	71.3	.002	19.3	.02
Yes	120 (1.9)	84.2		10.9	
Functional status before surgery					
Independent	3673 (57.6)	66.6		23.9	
Partially dependent	1247 (19.6)	75.8	<.001	14.7	<.001
Totally dependent	1453 (22.8)	80.5		11.1	
Emergency surgery					
No	3788 (59.4)	67.6	<.001	22.5	<.001
Yes	2594 (40.6)	77.4		14.3	
Prior surgery within 30 days					
No	5602 (87.8)	71.1	.02	20.0	<.001
Yes	779 (12.2)	75.0		13.5	
ASA classification					
1-2	422 (6.7)	58.5		30.8	
3	2624 (41.6)	68.1	<.001	21.8	<.001
4	2693 (42.6)	73.7		17.3	
5	580 (9.2)	87.1		7.8	
Intraoperative transfusion					
None	2930 (45.9)	71.8		19.1	
One unit	353 (5.5)	69.7	.71	22.1	.36
Multiple units	3099 (48.6)	71.6		18.8	
Operative wound classification					
Clean	2538 (39.8)	67.1		23.0	
Clean-contaminated	1872 (29.4)	72.8	<.001	18.8	<.001
Contaminated	686 (10.7)	77.6		14.4	
Dirty	1286 (20.1)	75.5		14.7	

Abbreviations: ACS-NSQIP, American College of Surgeons–National Surgical Quality Improvement Program; ASA, American Society of Anesthesiologists; CPR, cardiopulmonary resuscitation.
[a] Percentages were rounded and may not total 100.

was 51.5%; 1 day after CPR, it was 59.4%. Mortality in the interval between the day of CPR and postoperative day 30 increased by 39%. The overall rate of survival to discharge at 30 postoperative days or less was 19.2%; 9.2% of patients who received CPR were alive but hospitalized at postoperative day 30.

PATIENT CHARACTERISTICS AND OUTCOMES

The mean age of the CPR patients was 68.2 years (range, 17-90 years), which was higher than the mean age of patients in the entire ACS-NSQIP (55.5 years; $P < .001$). As indicated in **Table 1**, CPR patients were more often male and assigned an ASA classification of 4 to 5. A total of 39.5% of CPR patients had systemic sepsis preoperatively (**Table 2**). The mean number of comorbidities was approximately 5, which was higher than the approximate mean of 2 comorbidities for the entire ACS-NSQIP data set ($P < .001$); 8.8% of CPR patients had 1 preexisting condition, and 2.8% had none. Mortality rates of CPR patients increased with more comorbidities (58.7%, 63.1%, and 72.8% for patients with 0, 1, and ≥2 conditions captured in the data set; $P < .001$).

Approximately 86.0% of cardiac arrests occurred postoperatively. The overall incidences of postoperative ar-

Table 2. Comorbidities and 30-Day Outcomes of CPR Patients, ACS-NSQIP (2005-2010)

Preexisting Condition	No. (%) of Patients[a]	Mortality, %	*P* Value	Survival to Discharge, %	*P* Value
CHF					
No	5751 (90.1)	71.4	.26	19.3	.40
Yes	630 (9.9)	73.5		17.9	
Peripheral vascular disease					
No	5395 (84.6)	71.5	.65	19.5	.08
Yes	985 (15.4)	72.2		17.2	
Pneumonia					
No	6038 (94.6)	71.2	.002	19.7	<.001
Yes	342 (5.4)	78.9		10.6	
Ventilator dependent					
No	5344 (83.7)	69.7	<.001	21.0	<.001
Yes	1037 (16.3)	81.5		9.8	
COPD					
No	5281 (82.8)	70.7	<.001	19.9	.001
Yes	1100 (17.2)	75.9		15.7	
Coma					
No	6268 (98.2)	71.3	<.001	19.4	.003
Yes	112 (1.8)	88.4		8.0	
Impaired sensorium					
No	5747 (90.1)	70.5	<.001	20.0	<.001
Yes	633 (9.9)	81.8		11.4	
Paralysis					
No	6106 (95.7)	71.4	.07	19.5	.01
Yes	276 (4.3)	76.4		13.2	
Acute renal failure					
No	5963 (93.4)	70.8	<.001	19.8	<.001
Yes	418 (6.6)	82.5		9.8	
Dialysis					
No	5515 (86.4)	70.7	<.001	20.4	<.001
Yes	866 (13.6)	77.4		11.3	
Ascites					
No	5998 (94.0)	71.0	<.001	19.6	<.001
Yes	383 (6.0)	80.9		11.8	
Disseminated cancer					
No	6100 (95.6)	71.2	.005	19.3	.10
Yes	281 (4.4)	79.0		15.4	
Open wound					
No	5245 (82.2)	71.0	.03	20.3	<.001
Yes	1136 (17.8)	74.2		13.9	
Systemic sepsis					
No	3864 (60.5)	67.8	<.001	22.8	<.001
Yes	2518 (39.5)	77.4		13.7	
Preoperative blood transfusion					
No	5991 (93.9)	71.1	.001	19.7	<.001
Yes	390 (6.1)	78.7		11.7	

Abbreviations: ACS-NSQIP, American College of Surgeons–National Surgical Quality Improvement Program; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CPR, cardiopulmonary resuscitation.

[a] Percentages were rounded and may not total 100.

rest and intraoperative arrest were 0.42% and 0.07%, respectively. A total of 240 patients (3.8%) sustained more than 1 arrest. Nearly 9.0% of patients who experienced an intraoperative arrest had a postoperative arrest. Approximately half of postoperative arrests occurred within 5 days after surgery. The mortality for intraoperative arrest was 61.1%, and for postoperative arrest, 73.1% ($P < .001$). Compared with patients who experienced postoperative arrest, those who experienced an intraoperative event had a higher rate of survival to hospital discharge (17.0% vs 33.7%; $P < .001$).

A total of 77.6% of CPR patients sustained a complication. A total of 13 467 postoperative complications other than cardiac arrest occurred among these patients; 75.2% of complications occurred before or on the day of arrest. As indicated in **Table 3**, the most common postoperative complications among CPR patients included respiratory distress, septicemia, renal dysfunction, and bleeding that required 5 U or more of blood. When categorized by timing of complications, mortality rates were worse when complications occurred before, rather than after, CPR (**Figure 1**).

INCIDENCE AND OUTCOMES OF CPR BY SURGICAL SPECIALTY

The incidence of CPR in the ACS-NSQIP database varied by surgical specialty (**Table 4**). The rates of preexisting DNR orders in the database varied also, ranging

Table 3. Rate and Timing of Complications Experienced by CPR Patients, ACS-NSQIP (2005-2010)

Complication[a]	No. (%) of Patients[a,b]	Timing of Complication, %[c]			
		>1 Day Before Arrest	1 Day Before Arrest	Day of Arrest	≥1 Day After Arrest
Wound	721 (11.3)	47.6	7.2	12.6	32.6
Pneumonia	1106 (17.3)	39.3	7.4	16.4	36.9
DVT or PE	446 (7.0)	36.1	5.8	26.2	31.8
Intubation	2965 (46.5)	15.3	5.8	74.0	4.9
Prolonged ventilator use	2360 (37.0)	44.6	4.8	10.5	40.1
ARI or ARF	1132 (17.7)	36.1	11.7	19.1	33.1
UTI	340 (5.3)	40.9	7.9	10.0	41.2
Stroke	150 (2.4)	30.0	7.3	20.0	42.7
Coma >24 h	298 (4.7)	15.4	4.0	15.1	65.4
MI	475 (7.4)	28.0	9.5	52.6	9.9
Bleeding	1018 (16.0)	40.2	10.3	36.8	12.7
Sepsis or shock	2139 (33.5)	35.2	11.3	33.1	20.4

Abbreviations: ACS-NSQIP, American College of Surgeons–National Surgical Quality Improvement Program; ARF, acute renal failure; ARI, acute renal insufficiency; CPR, cardiopulmonary resuscitation; DVT, deep venous thrombosis; MI, myocardial infarction; PE, pulmonary embolism; UTI, urinary tract infection.

[a] All percentages were rounded and may not total 100. Definitions of complications are provided in the "Methods" section of the text. A total of 224 patients had (1) missing values for timing of complications, (2) multiple occurrences of the same complication for which only data for the timing of the initial complication are provided, or (3) graft failure (n = 84) or peripheral nerve injury (n = 9), which are not listed in this table because of a paucity of outcome.

[b] Percentage of all CPR patients (N = 6382) in the study.

[c] Percentage of CPR patients who experienced the specified complication.

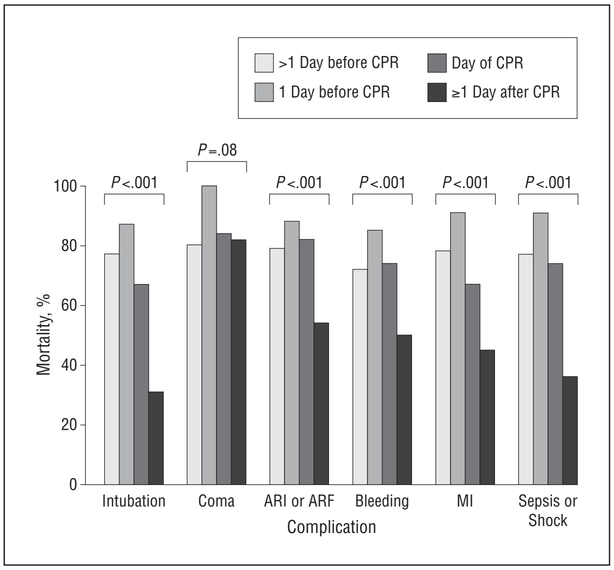

Figure 1. Mortality rates of select complications stratified by timing with respect to the day of cardiopulmonary resuscitation (CPR). ARF indicates acute renal failure; ARI, acute renal insufficiency; and MI, myocardial infarction.

Table 4. Incidence of CPR by Surgical Specialty, ACS-NSQIP (2005-2010)

Specialty	No. of CPR Cases	Incidence of CPR in ACS-NSQIP	
		Incidence, %	Ratio
Cardiac	240	3.0	1:33
General	3713	0.387	1:258
Gynecology	25	0.06	1:1666
Neurosurgery	55	0.268	1:373
Orthopedic	141	0.169	1:592
Otolaryngology	31	0.169	1:592
Plastic surgery	15	0.098	1:1020
Thoracic	91	1.14	1:88
Urology	49	0.172	1:581
Vascular	2022	1.31	1:76
Overall	6382	0.492	1:203

Abbreviations: ACS-NSQIP, American College of Surgeons–National Surgical Quality Improvement Program; CPR, cardiopulmonary resuscitation.

from 0.1% among gynecologic surgery patients to 1.3% among vascular surgery patients.

Patients who experienced CPR underwent a variety of procedures. Common procedures among cardiac surgery patients included coronary artery bypass grafts (43.8%) and valve replacement or repair (37.5%); 56.0% of gynecology patients underwent hysterectomy; 42.0% of neurosurgery patients had laminectomy; 52.5% of orthopedic patients underwent femur or hip fracture repairs; 19.0% of otolaryngology patients underwent neck dissection; 33.3% of plastic surgery patients underwent abscess drainage or wound debridement; 22.9% and 20.9% of thoracic surgery patients underwent cardiac-related procedures and pneumonectomy, respectively; and 57.1% of urology patients underwent nephrectomy or prostatectomy. Aortic repairs (31.6%), bypass procedures (18.3%), and amputations (15.4%) were common among vascular surgery patients who underwent CPR. Colectomy (25.3%), small-bowel procedures (12.3%), and exploratory laparotomy (9.7%) were the most common procedures performed on general surgery patients who underwent CPR.

All outcomes of interest varied by surgical specialty (**Figure 2**). Given the considerable disparity in outcomes of cardiac surgery patients who received CPR vs those in other surgical specialties, a subanalysis of baseline characteristics of cardiac vs general surgery patients was performed. In terms of their noncardiac comorbidity profile, cardiac surgery patients who received CPR appeared to be healthier than general surgery pa-

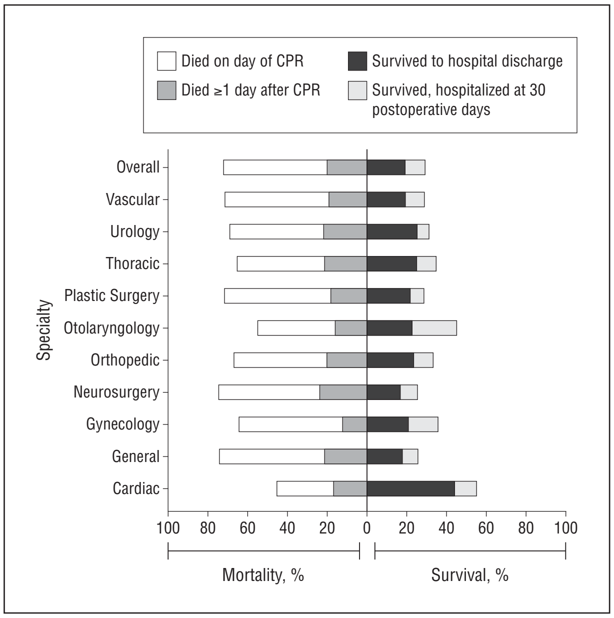

Figure 2. Outcomes (≤30 postoperative days) of patients who experienced cardiopulmonary resuscitation (CPR) by surgical specialty, American College of Surgeons–National Surgical Quality Improvement Program (2005-2010).

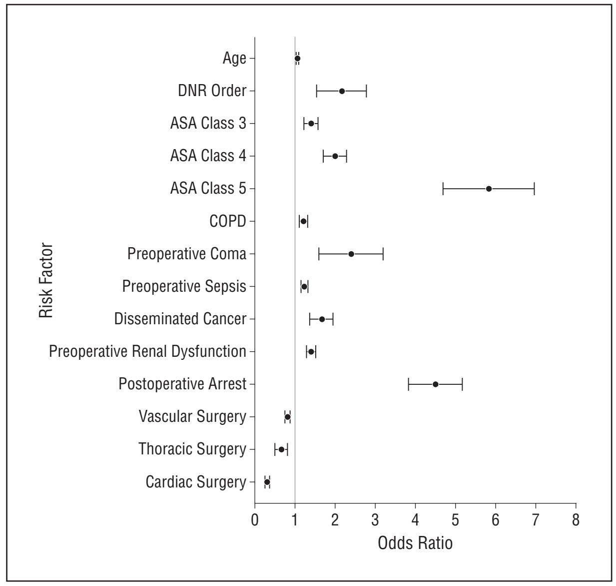

Figure 3. Multivariate analysis of factors associated with 30-day mortality among patients who experienced cardiopulmonary resuscitation, American College of Surgeons–National Surgical Quality Improvement Program (2005-2010). Multivariate regression model adjusted for more than 30 risk factors. Referents are as follows: age was analyzed as a continuous variable; do-not-resuscitate (DNR) status, no preexisting DNR order; American Society of Anesthesiologists (ASA) class, 2 or less; surgical specialty, general surgery; arrest type, intraoperative arrest; all other referents, not present. COPD indicates chronic obstructive pulmonary disease. Error bars indicate 95% CIs.

tients. They had lower rates of disseminated cancer, preoperative ventilator dependence, ascites, dialysis, and preoperative sepsis (all $P < .001$). However, cardiac surgery patients were more likely to have cardiac comorbidities, such as a recent history of myocardial infarction, congestive heart failure, and cardiac catheterization (all $P < .001$). Overall, cardiac surgery patients were less likely to be assigned an ASA class of 5 ($P < .001$).

MULTIVARIATE ANALYSIS

After adjusting for more than 30 risk factors in multivariate analysis, several baseline factors remained independently associated with mortality (**Figure 3**). Older age (odds ratio, 1.018; 95% CI, 1.01-1.02; $P < .001$) was associated with worse survival. An ASA class of 5 was most strongly associated with compromised survival.

COMMENT

Surgical patients who receive CPR are generally older and have more comorbidities than the average surgical patient. The overall incidence of CPR (4.9 arrests per 1000 surgical cases) found in this study is within the range of 1 to 5 arrests per 1000 admissions reported in the medical literature.[5,14] The incidence of intraoperative arrest in this study (6.7 per 10 000 cases) is also within a reported range of 4.6 to 19.7 per 10 000 cases.[17] Our results are consistent with published data indicating that prearrest factors, such as metastatic cancer, impaired renal function, and sepsis, have prognostic value in the evaluation of CPR outcomes.[5,11,21,22] The ultimate goal of resuscitation is to improve survival with good neurologic outcomes.[23] The rate of postarrest coma (3.1%) in our study is similar to the 3.6% rate found in a predominantly nonsurgical database of cardiac arrests.[1]

Our results suggest that cardiac arrest is a more survivable event among surgical patients than medical patients. In this study, mortality on the day of CPR was 51.5%. An analysis of more than 14 000 CPR events, of which more than 80% occurred among medical patients, revealed a 56% mortality on the day of CPR.[1] Compared with the 40.6% 1-day postarrest survival in this study, Nadkarni et al[23] reported a 24-hour survival of 30% for predominantly nonsurgical adult CPR patients included in a multicenter registry of cardiac arrests. The 19.2% rate of survival to hospital discharge found in this study compares favorably to the 17.5% rate found in a meta-analysis of CPR outcomes in the medical literature.[11] Considering that nearly 60% of patients in this study underwent nonemergency surgery, surgical patients who receive CPR may be healthier patients at baseline than patients described in the CPR medical literature. The improved CPR outcomes of surgical patients relative to patients in the CPR medical literature could also be a reflection of the superior outcomes of intraoperative arrests than arrests outside the operating room.[17]

Perioperative cardiac arrest is often fatal. Because only a few patients survive, prevention is crucial. An expert panel that reviewed 118 cases of in-hospital cardiac arrest concluded that more than 60% were potentially avoidable.[24] Evidence of clinical deterioration during the 8 hours before in-hospital CPR has been reported in up to 84% of cases.[25] It is a significant finding that more than 1100 patients in this study who were operated on without evidence of preoperative sepsis experienced postoperative sepsis or shock, and of these, 790 died. Sepsis among surgical patients is associated with an estimated 30% to 39%

mortality[26]; we found that the mortality rate more than doubled if sepsis occurred before arrest compared with after arrest. Overall, three-quarters of complications, including sepsis, hypotension, and acute impairment of renal function, occurred before or on the day of cardiac arrest. The timing of complications affected patient mortality; patients were more likely to die of an arrest if they had a prearrest complication. These findings indicate that a large proportion of cardiac arrests and periarrest deaths among surgical patients might be preventable if prearrest complications would be avoided or expediently treated.

As highlighted in our subanalysis of cardiac vs general surgery patients, variations in the incidence and outcomes of CPR by surgical specialty likely reflect differences in baseline characteristics of the patient cohorts by specialty. Differences in postoperative care also may play a role. Cardiac surgery patients often receive postoperative care in an intensive care unit (ICU); vascular and thoracic patients also are more likely to receive care in the ICU. Most studies[2,5,22,27] have reported better outcomes of CPR events in the ICU compared with the general hospital. This finding might be explained by the availability of better monitoring and specialty skilled care in the ICU.[27-30] Intensive monitoring, immediate availability of medical intervention, and potentially reversible causes of arrest also could explain improved survival from intraoperative arrest.

Limitations of our study largely stem from the fact that the Participant Use Data File is an administrative database; although there may be coding errors, it has been validated.[31] A cause-effect relationship between prearrest complications and mortality cannot be inferred because in-depth analysis of periarrest events was not possible; intra-arrest factors known to influence resuscitation outcomes, such as promptness, duration, and quality of CPR; type of arrest rhythm; and location of the patient and monitoring status (ICU vs general hospital), are not captured in the database. Measures of severity of surgical illness and complexity of comorbidity also are not provided. Complication rates may have been underestimated because resuscitation-related injuries, such as rib and sternal fractures, pneumothorax, cervical hematoma, and perforation of abdominal organs, including liver, stomach, and spleen,[32] are not captured in the ACS-NSQIP database; occurrence of such complications could affect postarrest complications or mortality risk. One study[1] found that 63% of patients who survived arrest but eventually died were assigned a DNR order, and 43% had life support withdrawn in the interval between survival and death; such decisions could influence postarrest mortality rates. The ACS-NSQIP database does not capture changes in DNR status instituted during the admission under study. There is no information about hospital-level factors and outcomes beyond 30 postoperative days, so readmissions and long-term outcomes could not be analyzed. The strengths of our study include its multi-institutional nature and large sample size, both of which attenuate bias related to patient and physician characteristics.

In summary, surgical patients who experience CPR have a high mortality rate. More than three-quarters of arrest patients experienced a complication often in the prearrest period; this finding suggests that some CPR events may be preventable with timely interventions. Fastidious care is especially important for vulnerable patients who are elderly, functionally impaired, or admitted from other care facilities and who in this study had higher rates of CPR occurrence and compromised outcomes after CPR. Cardiopulmonary resuscitation has economic implications given that a third of CPR survivors continue to use in-hospital resources more than a month after surgery. Prevention, early detection of complications, and aggressive interventions may improve outcomes of CPR surgical patients. These data have implications on patient-physician discussions regarding DNR orders and the assessment of prognosis should cardiac arrest occur. Modifiable risk factors that predispose surgical patients to cardiac arrest need to be studied further because they may be specialty specific.

Accepted for Publication: March 20, 2012.
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Author Contributions: *Study concept and design:* Kazaure, Roman, and Sosa. *Acquisition of data:* Kazaure. *Analysis and interpretation of data:* Kazaure, Roman, Rosenthal, and Sosa. *Drafting of the manuscript:* Kazaure, Roman, and Sosa. *Critical revision of the manuscript for important intellectual content:* Roman, Rosenthal, and Sosa. *Statistical analysis:* Kazaure and Sosa. *Administrative, technical, and material support:* Roman, Rosenthal, and Sosa. *Study supervision:* Roman and Sosa.
Conflict of Interest Disclosures: None reported.

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SURGICAL CARE OF THE AGING POPULATION

Cardiopulmonary Resuscitation in Surgical Patients

It Is All in the Timing

During the past 20 years, much has been written about do not resuscitate (DNR) orders and cardiopulmonary resuscitation (CPR) in surgical patients, but because no prospective data are available, most of these articles are opinion pieces. Kazaure et al[1] are one of the first to address this matter using information from the National Surgical Quality Improvement Project. Their article gives us a glimpse into the incidence, risk factors, outcomes, and ability to improve our care based on accurate data. The authors do not address the functional status of the patients who survive—their neurologic status, ability to care for themselves, or to where they are ultimately discharged. These are the next questions that need to be asked.

I would stress the following observations from this study (none of which are surprising). The need for CPR in surgical patients is fortunately rare but devastating. Older age, American Society of Anesthesiologists score, and the presence of comorbidities are significant risk factors. Survival is better in a cardiothoracic or vascular surgical patient compared with a general surgical patient and if the event occurs while the patient is in the operating room. Finally, CPR mortality is greatly affected by the development of postoperative complications.

The most important finding in the study by Kazaure et al[1] is that early postoperative complications (postoperative day 1 or 2) occurred in 75.2% of patients before arrest. These complications, including sepsis, respiratory failure, renal failure, and bleeding, were typical for those who need aggressive treatment in the intensive care unit. This finding suggests that aggressive prevention, recognition, and treatment of postoperative complications can reduce the incidence of CPR.

This concept is not new. Failure to rescue is a known determinant of outcome after complicated surgery.[2,3] The determinants for success are hospital demographic characteristics, such as size, occupancy, and presence of teaching and technology. The National Surgical Quality Improvement Project has the ability to stratify such hospitals, so the authors can now address these variables.

Rescue of patients who are identified to be at risk for adverse events should be our next goal. Identification of which patients are at risk and early aggressive