Predictors of Functional Outcome after Intraoperative Cardiac Arrest

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ABSTRACT

Background: Few outcome data are available about intraoperative cardiac arrest (IOCA). The authors studied 90-day functional outcomes and their determinants in patients admitted to the intensive care unit after IOCA.

Methods: Patients admitted to 11 intensive care units in a period of 2000–2013 were studied retrospectively. The main outcome measure was a day-90 Cerebral Performance Category score of 1 or 2.

Results: Of the 140 patients (61 women and 79 men; median age, 60 yr [interquartile range, 46 to 70]), 131 patients (93.6%) had general anesthesia, 80 patients (57.1%) had emergent surgery, and 73 patients (52.1%) had IOCA during surgery. First recorded rhythms were asystole in 73 patients (52.1%), pulseless electrical activity in 44 patients (31.4%), and ventricular fibrillation/ventricular tachycardia in 23 patients (16.4%). Median times from collapse to cardiopulmonary resuscitation and return of spontaneous circulation were 0 min (0 to 0) and 10 min (5 to 20), respectively. Postcardiac arrest shock was identified in 114 patients (81.4%). Main causes of IOCA were preoperative complications (n = 46, 32.9%), complications of anesthesia (n = 39, 27.9%), and complications of surgical procedures (n = 36, 25.7%). On day 90, 63 patients (45.3%) were alive with Cerebral Performance Category score 1/2. Independent predictors of day-90 Cerebral Performance Category score 1/2 were day-1 Logistic Organ Dysfunction score (odds ratio, 0.78 per point; 95% CI, 0.71 to 0.87; *P* = 0.0001), ventricular fibrillation/tachycardia as first recorded rhythm (odds ratio, 4.78; 95% CI, 1.38 to 16.53; *P* = 0.013), and no epinephrine therapy during postcardiac arrest syndrome (odds ratio, 3.14; 95% CI, 1.29 to 7.65; *P = 0.012*).

Conclusions: By day 90, 45% of IOCA survivors had good functional outcomes. The main outcome predictors were directly related to IOCA occurrence and postcardiac arrest syndrome; they suggest that the intensive care unit management of postcardiac arrest syndrome may be amenable to improvement. (ANESTHESIOLOGY 2014; 121:482-91)

AMONG adverse events associated with anesthesia, intraoperative cardiac arrest (IOCA)[1,2] complicates up to 43 per 100,000 surgical procedures.[3] In contrast to out-of-hospital and even in-hospital cardiac arrest, IOCA occurs under conditions that allow immediate resuscitation by trained professionals who have the appropriate treatment and monitoring equipment at hand.[2,4,5] Nevertheless, IOCA is associated with high mortality rates of approximately 35% immediately[6] and 65.5% at hospital discharge.[1] The risk of death reflects the conditions associated with IOCA, most notably the main cause, which may be a feature of the health problem being treated (patient characteristics or preoperative complications) or a iatrogenic factor related to the anesthesia or surgical procedure.[7,8]

Although IOCA is an event of considerable concern for anesthesiologists, few studies have focused on the characteristics of IOCA or on the optimal intensive care unit (ICU) management of patients with successfully resuscitated IOCA.[3,7,8] More specifically, data are needed on the medium-term survival and functional outcomes of these patients.

What We Already Know about This Topic

- Little is known about functional outcomes in patients who survive intraoperative cardiac arrests

What This Article Tells Us That Is New

- In survivors, the main causes of intraoperative arrest were preoperative complications (33%), anesthetic complications (28%), and surgical complications (26%)
- The initial recorded rhythms were asystole (52%), pulseless electrical activity (31%), and ventricular fibrillation (16%)
- By day 90, 45% of the survivors had a good functional outcome

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The objective of this retrospective study was to identify factors associated with 90-day favorable functional outcomes in adults admitted to the ICU after successful resuscitation of IOCA. Knowledge of such factors might help to identify areas for improvement in the prevention and management of IOCA.

Materials and Methods

Our local ethics committee (*Comité de Protection des Personnes of Paris, Ile de France VI*) approved this study (#100713) and waived the requirement for informed consent, in compliance with French legislation on retrospective observational studies.

Patients

Adults admitted between a period of January 2000 and April 2013 to 1 of 11 participating ICUs after successful resuscitation of IOCA were included retrospectively. Case ascertainment involved a search of the hospital databases for any of the following codes in the International Statistical Classification of Diseases and Related Health Problems, 10th Revision: cardiac arrest (I46.9); intraoperative cardiac arrest (I97.71); and complications, intraoperative (H95.88). Local investigators reviewed the medical records of the patients and selected those adults admitted to the ICU after successfully resuscitated IOCA. These selected cases were then validated by consensus between two of the authors (S. Legriel and A.-L.C.).

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Definitions

Intraoperative cardiac arrest was defined as intraoperative loss of detectable pulse requiring cardiac compression and/or defibrillation. The intraoperative period was defined as the time spent in the operating room; this period did not include transport to the postanesthesia care unit, the stay in the postanesthesia care unit, or transport to the ICU.

Postcardiac arrest syndrome was defined as variably combined organ failures: postcardiac arrest shock, postanoxic encephalopathy, acute respiratory distress syndrome, bowel and/or liver ischemia, and acute renal failure.[9] Postcardiac arrest shock was defined as the need for vasoactive agents for more than 6 h despite a fluid load greater than 30 ml/kg started within 48 h after IOCA.[9] Postanoxic encephalopathy was defined as persistent coma after successful IOCA resuscitation.[10] Acute respiratory distress syndrome and acute renal failure were defined as previously described.[11,12] Bowel and/or liver failure was recorded when suspected or proven. Suspected bowel/liver failure was defined as liver cytolysis with lactic dehydrogenase greater than 10-fold the normal value and arterial serum lactate greater than 4 mmol/l and with at least one of the following: abdominal distension, vomiting, slimy or bloody diarrhea, and blood culture positive for intestinal tract bacteria. Proven bowel/liver failure was diagnosed by endoscopy, abdominal computed tomography, surgery, or autopsy.

Data Collection

Demographic data and data related to surgery and anesthesia were collected on a standardized form. Prospective collection of these data is performed routinely in accordance with a 2001 recommendation issued by the French Society of Anesthesia and Intensive Care. We recorded the following data: American Society of Anesthesiologists Physical Status classification,[13] in two groups, I to III and IV to V; whether surgery was emergent or scheduled; whether trauma was the reason for surgery; type of surgery (general, vascular, cardiac, orthopedic, urological, thoracic, gynecologic or obstetric, or neurosurgical); surgical procedures; whether anesthesia was general or regional; and the Mallampati score. We also recorded the use of rapid sequence induction, the Cormack–Lehane grade, and the drugs used during anesthesia induction and maintenance. IOCA characteristics were collected according to Utstein-style guidelines adapted to the IOCA setting: time of cardiac arrest (during patient positioning, during intubation, immediately after intubation, during anesthesia maintenance or surgery, or after extubation); IOCA occurrence outside standard working hours (6:00 PM to 7:00 AM and weekends); patient position at IOCA occurrence (supine or prone, right or left lateral decubitus, or Trendelenburg) and type of chest compression (anterior or posterior external, transdiaphragmatic, or intrathoracic); monitoring under way at IOCA occurrence (pulse oximetry, end-tidal carbon dioxide, continuous invasive or intermittent arterial blood pressure, or continuous electrocardiogram monitoring); initial IOCA rhythm; number of defibrillations; administration of epinephrine, atropine, and/

or antiarrhythmic drugs; duration of cardiopulmonary resuscitation; and time from collapse to spontaneous circulation recovery. The causes of IOCA were categorized as follows by consensus between two of the authors (S. Legriel and A.-L.C.): patient characteristics, preoperative complications, anesthesia (*e.g.*, difficult intubation, anesthesia equipment dysfunction, and adverse effect of anesthetic drugs), and surgical procedures (*e.g.*, hemorrhagic shock, cardiovascular collapse due to bone cement implantation syndrome, amniotic fluid embolism, and gas or fibrinocruoric embolism). One etiology could be classified into more than one category.

Postresuscitation data were recorded in detail including management modalities such as therapeutic hypothermia with the duration of use. Severity and organ dysfunction at ICU admission were assessed using the Simplified Acute Physiology Score II and Logistic Organ Dysfunction system score, respectively. Postcardiac arrest syndrome was assessed based on the following organ failures recorded within 7 days after IOCA: postanoxic encephalopathy, postcardiac arrest shock, acute respiratory distress syndrome, bowel/liver ischemia,[14] and acute renal failure.[9] Infectious complications in the ICU were recorded. We collected information related to treatment-limitation decisions such as persistent coma after day 3, early myoclonus before day 3, electroencephalogram evidence of postanoxic status epilepticus at any time during the ICU stay,[15,16] and somatosensory-evoked potential recording showing bilateral absence of N20 cortical responses with presence of P14 responses.[10,17]

Study Outcomes

The primary evaluation criterion was the Cerebral Performance Category (CPC) score 90 days after cardiac arrest. The CPC score reflects both mortality and morbidity.[18] CPC score values were extracted from the hospital charts or determined by interviewing the patient or the patient's next of kin, general practitioner, or neurologist. For this study, we defined a favorable outcome as a CPC score of 1 or 2,[5] that is, alive with good cerebral performance or sufficient cerebral function for independent activities of daily life, with or without mild neurological or psychological deficits; ability to work in a sheltered environment was considered to indicate a CPC score of 2. CPC scores 3 to 5 were recorded as unfavorable outcomes.

Statistical Analysis

Quantitative parameters were described as median (interquartile range [IQR]) and qualitative parameters as number (percentages). We compared categorical variables using Fisher exact tests and continuous variables using Wilcoxon rank sum tests. Survival curves were obtained using the Kaplan–Meier estimator. To identify associations between patient characteristics and day-90 CPC score 1/2, we used a logistic regression model. Factors included in the multivariate regression model were selected as clinically relevant among variables yielding *P* values less than 0.05 by univariate analysis.

The final multivariate model was built using a backward stepwise procedure. The dropping process was based on a *P* value less than 0.05. As hemorrhagic shock and IOCA during nonstandard working hours were associated with outcomes of perioperative cardiac arrest in earlier studies,[3] these two variables were forced in the final multivariate regression model. The aim of the model was to describe the sample while considering associations within this group of patients. Log-linearity was checked for continuous variables. Nonlog-linear variables were categorized. Hosmer–Lemeshow goodness-of-fit tests were computed on final models. Missing values of covariates were handled by median imputation when their numbers were low. Otherwise, missing data were first excluded from the analyses; then, sensitivity analyses were performed assuming that the missing outcome was either favorable or unfavorable, before rerunning the final models.

All tests were two sided and *P* values less than 0.05 were considered significant. Analyses were performed using R statistical software version 2.14.0 (R Foundation for Statistical Computing, Vienna, Austria).*

Results

Figure 1 is the patient flow chart. Of the 869,425 patients who received anesthesia for a surgical procedure in 11 community and university hospitals during the 13-yr study period, 140 patients with successfully resuscitated IOCA were included in the study.

Patient Characteristics and Features of Anesthesia and Surgery

Table 1 reports the main patient characteristics. There were 61 women and 79 men, with a median age of 60 yr (IQR, 46 to 70) and three (two to four) preoperative comorbidities per patient. Before hospital admission, 136 patients had good cerebral performance (n = 122, 87.1%) or moderate cerebral disability (n = 14, 10.0%). Surgery was emergent in 80 patients (57.1%). Types of surgery were as follows: abdominal in 37 patients (26.4%), thoracic in 29 (20.7%), vascular in 18 (12.9%), orthopedic in 16 (11.4%), head-and-neck in 15 (10.7%), cardiac in 8 (5.7%), gynecological in 5 (3.6%), obstetrical in 4 (2.9%), urological in 4 (2.9%), neurosurgical in 3 (2.1%), and ophthalmological in 1 (0.7%). Of the 131 patients (93.6%) who had general anesthesia, 15 also had regional/epidural/spinal anesthesia; nine patients (6.4%) had regional/epidural/spinal anesthesia only. Trauma was the reason for surgery in 13 patients (9.3%). The Glasgow Coma Scale score was 15 (13 to 15) at intubation. Rapid induction sequence was used in 43 patients (30.7%).

Characteristics and Management of Intraoperative Cardiac Arrest

Intraoperative cardiac arrest occurred before induction in 12 patients (8.6%), during induction in 18 (12.9%), just after intubation in 23 (16.4%), during anesthesia maintenance in 11 (7.9%), during surgery in 73 (52.1%), and just after extubation in 3 (2.1%). Monitoring methods

* Available at: http://www.R-project.org. Accessed January 28, 2014.

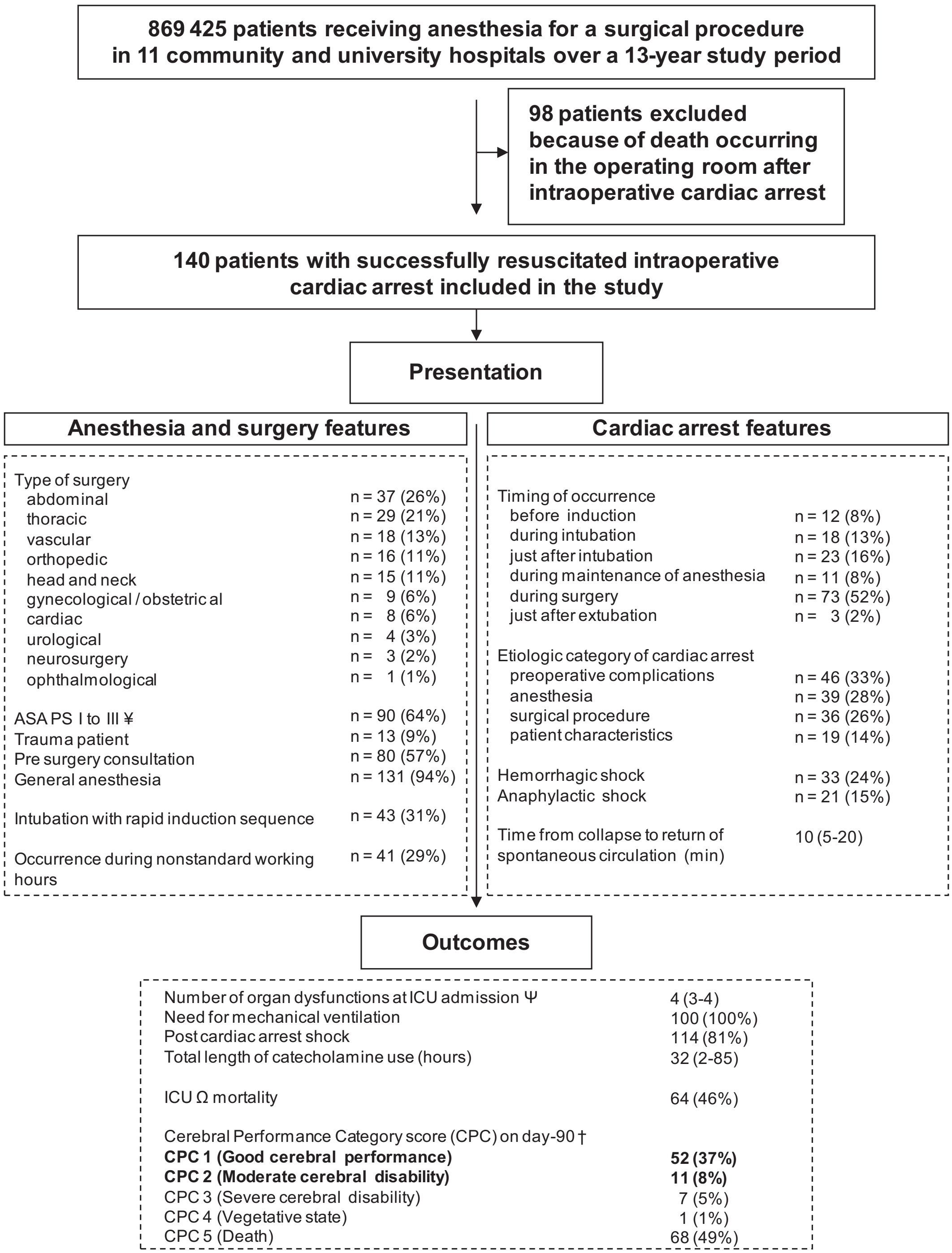

Fig. 1. Patient flow chart; characteristics of anesthesia, surgery, intraoperative cardiac arrest, and management; and 90-day outcomes in 140 patients. ¥ American Society of Anesthesiologists Physical Status (ASA PS) classification I–III. ΨAccording to the Logistic Organ Dysfunction score. ΩIntensive care unit (ICU). †The primary outcome measure was the Cerebral Performance Category (CPC) score 90 days after cardiac arrest. A score of 5 indicates death; 4, a vegetative state (patient unable to interact with the environment); 3, severe cerebral disability (patient conscious but dependent on others for daily support); 2, moderate cerebral disability (patient conscious and capable of living independently and returning to work or school in a normal or sheltered environment); and 1, good cerebral performance (patient conscious and able to work and lead a normal life). A favorable outcome was defined for this study as a score of 1 or 2 and an unfavorable outcome as a score higher than 2.

at IOCA occurrence were pulse oximetry in all patients, continuous electrocardiogram in 138 (98.6%), end-tidal carbon dioxide in 106 (76.3%), intermittent noninvasive arterial blood pressure monitoring in 76 (54.7%), and continuous invasive arterial blood pressure monitoring in 62 (44.6%). Patient position at IOCA occurrence was supine in 124 patients (88.6%), left lateral decubitus in 10 (7.1%), and right lateral decubitus in 6 (4.3%).

Table 1. ICU Management and Outcomes of Comatose Survivors after Intraoperative Cardiac Arrest According to First Recorded Rhythm (n = 140)

	N (%) or Median (Interquartile Range)				
	All Patients, n = 140	Pulseless Electrical Activity, n = 44 (31.4)	Asystole, n = 73 (52.1)	Ventricular Fibrillation/Tachycardia, n = 23 (16.4)	N Missing*
Male	79 (56.4)	22 (50.0)	41 (56.2)	16 (69.6)	
Age (yr)	60 (46–70)	61 (47–70)	61 (50–73)	59 (43–62)	
ASA PS I–III	90 (64.3)	28 (63.6)	48 (65.8)	14 (60.9)	
General anesthesia	131 (93.6)	42 (95.5)	67 (91.8)	22 (95.7)	
Occurrence during nonstandard working hours	41 (29.5)	13 (29.5)	23 (31.9)	5 (21.7)	1
Cause of cardiac arrest presumed cardiac	28 (20.0)	10 (22.7)	13 (17.8)	5 (21.7)	
Etiologic category of cardiac arrest					
Preoperative complications	46 (32.9)	13 (29.5)	27 (37.0)	6 (26.1)	
Anesthesia	39 (27.9)	16 (36.4)	15 (20.5)	8 (34.8)	
Surgical procedure	36 (25.7)	10 (22.7)	19 (26.0)	7 (30.4)	
Patient characteristics	19 (13.6)	5 (11.4)	12 (16.4)	2 (8.7)	
Time from collapse to					
Cardiopulmonary resuscitation (min) (no flow)†	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	
Return of spontaneous circulation (min) (no flow + low flow)	10 (5–20)	10 (5–18)	10 (5–22)	10 (6–20)	
Total number of defibrillations before ROSC	0 (0–1)	0 (0–0)	0 (0–0)	2 (1–4)	
Total epinephrine (mg) dose before ROSC	3 (1–8)	3 (1–7)	4 (1–8)	3 (1–7)	7
Use of atropine	21 (15.0)	7 (15.9)	13 (17.8)	1 (4.3)	
Use of bicarbonates	34 (24.3)	5 (11.4)	24 (32.9)	5 (21.7)	
Use of xylocaine	20 (14.3)	3 (6.8)	9 (12.3)	8 (34.8)	
Use of amiodarone	19 (13.6)	6 (13.6)	3 (4.11)	10 (43.5)	
Best $Etco_2$ (mmHg) value after ROSC	33 (28–39)	32 (25–38)	34 (29–38)	34 (32–40)	57
SAPS II score at ICU admission	66 (44–86)	64 (49–83)	70 (48–89)	63 (44–85)	1
LOD score at ICU admission	11 (7–15)	12 (7–15)	12 (7–14)	9 (4–13)	
Therapeutic hypothermia	28 (20.0)	11 (25.0)	8 (11.0)	9 (39.1)	
Mechanical ventilation duration (days)	4 (1–11)	5 (2–14)	3 (1–8)	3 (1–9)	1
ICU stay length (days)	5 (3–16)	9 (4–23)	4 (2–11)	6 (3–16)	
ICU discharged alive	76 (54.3)	25 (56.8)	35 (47.9)	16 (69.6)	
Neurologic outcome on day 90:					1
CPC 1 (good cerebral performance)	52 (37.4)	13 (30.2)	25 (34.2)	14 (60.9)	
CPC 2 (moderate cerebral disability)	11 (7.9)	3 (7.0)	6 (8.2)	2 (8.7)	
CPC 3 (severe cerebral disability)	7 (5.0)	4 (9.3)	3 (4.1)	0 (0.0)	
CPC 4 (vegetative state)	1 (0.7)	0 (0.0)	1 (1.4)	0 (0.0)	
CPC 5 (death)	68 (48.9)	23 (53.5)	38 (52.1)	7 (30.4)	

* Number of missing observations, unless Ø. † Fifteen patients with time from collapse to cardiopulmonary resuscitation >0 min (median time, 1 min [1–3]).
ASA PS = American Society of Anesthesiologists physical status; CPC = Cerebral Performance Category; $Etco_2$ = end-tidal carbon dioxide concentration in expired air; ICU = intensive care unit; LOD = Logistic Organ Dysfunction; ROSC = return of spontaneous circulation; SAPS II = Simplified Acute Physiology Score version II.

Cardiopulmonary resuscitation was started immediately in all cases. Cardiac massage was anterior external in 121 patients (87.0%), intrathoracic in 25 (18.0%), and internal transdiaphragmatic in 1 (0.7%); two of these techniques were used in combination in eight patients. First recorded rhythm was asystole in 73 patients (52.1%), pulseless electrical activity in 44 (31.4%), and ventricular fibrillation/tachycardia in 23 (16.4%). Median times from collapse to cardiopulmonary resuscitation (no-flow) and return of spontaneous circulation were 0 min (0 to 0) and 10 min (5 to 20), respectively. IOCAs occurred during nonstandard working hours in 41 patients (29.5%).

ICU Management of Comatose Survivors

At ICU arrival, mechanical ventilation was needed in all patients, median Logistic Organ Dysfunction score was 11 (IQR, 7 to 15) with a median of 4 (3 to 4) organ dysfunctions per patient, Glasgow Coma Scale score was 3 (3 to 6), and serum lactate was 6.8 mmol/l (3.7 to 11.8). Postcardiac arrest syndrome was diagnosed in 114 patients (81.4%) and total catecholamine therapy duration was 32 h (2 to 85). Organ failures associated with postcardiac arrest syndrome during the first ICU week were acute respiratory distress syndrome in 47 patients (34.1%), with a worst $Pa{O_2}/F{IO_2}$ ratio of 97 (66 to 123); acute renal failure requiring renal replacement therapy in 34 (24.3%); and bowel ischemia in 14 (10.0%). Therapeutic hypothermia was used in 28 patients (20.0%), with a median hypothermia duration of 18 h (10 to 24).

The cause of IOCA was identified in all patients (table 2). The most common causes were hemorrhagic shock and anaphylactic shock, with 33 (23.6%) and 21 (15.0%) cases, respectively. Categories of IOCA causes were preoperative complications in 46 patients (32.9%), complications of anesthesia in 39 (27.9%), complications of surgical procedures in 36 (25.7%), and patient characteristics in 19 (13.6%).

Short-term and Medium-term Outcomes

Median ICU and hospital stay lengths were 5 days (IQR, 3 to 16) and 10 days (IQR, 3 to 26), respectively. Crude ICU mortality rate was 45.7% (95% CI, 37.3 to 54.3%; 64 deaths). During the 90-day follow-up, one patient was lost to follow-up after hospital discharge and four other patients died, yielding an overall 90-day mortality rate of 48.6% (95% CI, 39.6 to 56.2%; fig. 2). Among the 64 ICU deaths, 41 were ascribed to multiple organ failure induced by postcardiac arrest syndrome and 22 occurred after treatment-limitation decisions, including 10 in patients with bilateral absence of pupillary or absence of motor response to nociceptive stimulation on day 3 after cardiac arrest, 2 in patients with bilateral absence of N20 cortical responses, and 5 in patients with postanoxic myoclonus and/or postanoxic status epilepticus. Some patients met more than one criterion for treatment-limitation decisions. Median time from IOCA to treatment-limitation decisions was 4 days (3 to 10). For one patient, we were unable to identify the cause of death. Of the three patients who were discharged alive from the ICU after treatment-limitation decisions, two died within 90 days and 1 was CPC 3 on day 90.

Ninety-day Functional Outcome

The 90-day CPC score was known for 139 patients, of whom 63 (45.3%) had a good outcome (alive with CPC 1/2; fig. 1). Table 3 reports the results of the univariate and multivariate analyses. By univariate analysis, nine variables were associated with the outcome at the 0.05 level. The final multivariable model selected three variables and two additional variables previously reported to affect outcomes, namely, occurrence during nonstandard working hours and hemorrhagic shock.[3] The results showed that one covariate was negatively associated with a favorable functional outcome, namely, day-1 Logistic Organ Dysfunction score (odds ratio, 0.78 per point; 95% CI, 0.71 to 0.87; P = 0.0001) and two positively associated with a favorable functional outcome, namely, ventricular fibrillation/tachycardia as first recorded rhythm (odds ratio, 4.78; 95% CI,1.38 to 16.53; P = 0.013) and no epinephrine to treat postcardiac arrest shock (odds ratio, 3.14; 95% CI,1.29 to 7.65; P = *0.012*). These findings were not modified when we classified the only patient with missing data as having either favorable or unfavorable outcome.

Table 2. Causes and Etiologic Categories of Intraoperative Cardiac Arrest (n = 140)

Causes of Cardiac Arrest*	N (%) All Patients n = 140
Related to reason for surgery	46 (32.9%)
Hemorrhagic shock	17 (12.1%)
Septic shock	11 (7.9%)
Airway obstruction	6 (4.3%)
Cardiogenic shock	4 (2.9%)
Cardiac tamponade	4 (2.9%)
Pneumothorax	3 (2.1%)
Anaphylactic shock (carcinoid syndrome)	1 (0.7%)
Related to anesthesia	39 (27.8%)
Anaphylactic shock	19 (13.6%)
Hypovolemia	10 (7.1%)
Heart rhythm disorder	3 (2.1%)
Difficult intubation	2 (1.4%)
Respiratory depression during vigil anesthesia	2 (1.4%)
Bronchospasm	1 (0.7%)
Drug interference with background regimen	1 (0.7%)
Dysfunction of anesthesia equipment	1 (0.7%)
Surgical complications	36 (25.7%)
Hemorrhagic shock	16 (11.4%)
Surgical iatrogenic etiology	7 (5.0%)
Collapse due to bone cement implantation syndrome	5 (3.6%)
Gas embolism	4 (2.9%)
Amniotic fluid embolism	2 (1.4%)
Anaphylactic shock (carcinoid syndrome)	1 (0.7%)
Fibrinocruoric embolism	1 (0.7%)
Patients characteristics related	19 (13.6%)
Heart rhythm disorder	11 (7.9%)
Coronary ischemia	6 (4.3%)
Bronchospasm	2 (1.4%)

* A single cause can belong to more than one category.

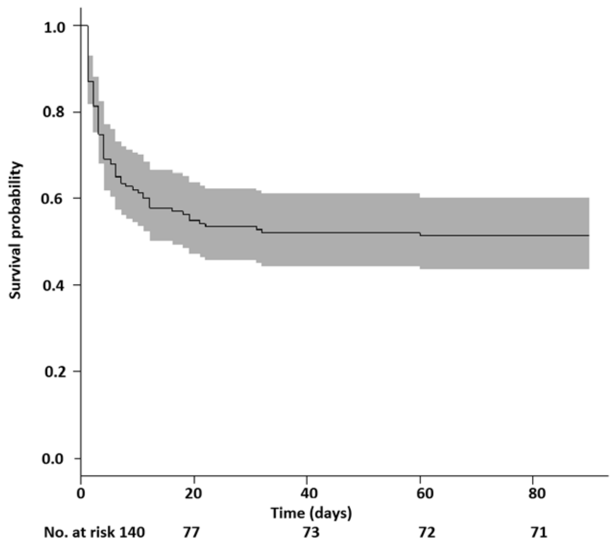

Fig. 2. Kaplan–Meir estimates of 90-day survival in 140 patients with successfully resuscitated intraoperative cardiac arrest.

Discussion

In this retrospective multicenter study of 140 patients requiring ICU management after successfully resuscitated IOCA, 68 patients (48.6%) died before day 90 and 63 (45.3%) achieved a good recovery defined as a CPC score of 1 or 2. A worse Logistic Organ Dysfunction score on day 1 was the only independent predictor of not achieving a good outcome. Independent predictors of a good outcome were ventricular fibrillation/tachycardia as the first recorded rhythm and no epinephrine to treat postcardiac arrest shock.

Most of the previous studies of IOCA were retrospective and described the management strategies and hospital outcomes.[1] They used various definitions of IOCA, with some studies including cardiac arrest occurring up to 24 h after anesthesia.[1,19] Hospital mortality rates varied across studies, and no data on medium- or long-term functional outcomes were obtained, in contradiction to current recommendations.[5] Finally, few studies identified the factors associated with outcomes.[3] Our study design provides a reliable picture of the presentation, management, and predictors of functional outcome in adults successfully resuscitated after IOCA. We reviewed each patient's medical record, using a standardized form to abstract a broad range of data about patient characteristics, history of the event requiring surgery, anesthesia, surgical procedure, resuscitation, and ICU management. As recommended, we also obtained detailed information on each IOCA using the Utstein style.[18] Our patient population reflects the everyday practice of multiple ICUs in both community and university hospitals. Finally, in addition to ICU mortality, we obtained information on day-90 functional outcomes.

Patient characteristics were consistent with previous studies showing that IOCA occurred predominantly in middle-aged men with serious comorbidities and impaired physical status scores at presentation.[3,20,21] A minority of cases occurred during nonstandard working hours and over half of them complicated emergent surgery, also in keeping with earlier data.[2,3,20,21] IOCA has been reported with all types of anesthesia[3,6,19–22] and all types of surgical procedures. Pulseless electrical activity as the initial rhythm is a unique presentation of IOCA and often complicates unrecognized bradycardia and/or hypotension.[23] Finally, IOCA can be related to the anesthesia, comorbidities, preoperative complications, and/or surgical procedures.[21] Bleeding is a common cause that has been identified as an independent predictor of hospital mortality.[3] IOCA hold a very special place among the category of intrahospital cardiac arrest. It is characterized by exceptional conditions of occurrence allowing immediate identification and management by specialized and experienced teams. Patients are already monitored and venous and/or even airway accesses are most of the time already available, facilitating resuscitation. Causes of cardiac arrest are also singular. All these parameters justify that this complication should be studied separately from other intrahospital cardiac arrest.

We identified three factors independently associated with day-90 functional outcomes. Worse Logistic Organ Dysfunction score on day 1 was independently associated with a poor outcome, reflecting the adverse effect of organ dysfunctions related to postcardiac arrest syndrome. Cardiac arrest is followed by ischemia–reperfusion syndrome involving all the major organs, as well as by nonspecific activation of the systemic inflammatory response.[9] Postcardiac arrest shock is among the most common organ failures, with an occurrence rate of approximately 50% overall after successfully resuscitated cardiac arrest and of 80% in our study. This higher rate in our population may be related to the reasons for surgery. Postcardiac arrest shock deserves special attention because of its impact on outcomes and its potential reversibility.[24] The underlying mechanisms is a combination of myocardial failure, with severe systolic dysfunction, and of vasodilation.[9] The management of postcardiac arrest syndrome requires treatment of the shock and other organ failures combined with neuroprotective strategies. Postcardiac arrest shock requires epinephrine and/or norepinephrine therapy as indicated by the hemodynamic monitoring data. Therapeutic hypothermia used for neuroprotection has become a cornerstone of the management of postcardiac arrest syndrome. Therapeutic hypothermia was rarely used in our population despite a 2002 International Liaison Committee on Resuscitation recommendation to use this treatment modality in comatose cardiac arrest survivors with ventricular fibrillation or other rhythms as the initial rhythm and in survivors of in-hospital cardiac arrest.[25] These guidelines were updated recently.[5] Several factors may explain the low rate of therapeutic hypothermia use in our patients: patient recruitment for our study started in 2000, before the recommendation was issued; and 24% of our patients had hemorrhagic shock, which contraindicates therapeutic hypothermia.[25] In addition, therapeutic hypothermia raises technical challenges in postoperative patients. However, given the proven benefits of therapeutic hypothermia, studies in patients with postanoxic coma after IOCA are warranted.

Table 3. Variables Associated with a Favorable 90-day Outcome (Cerebral Performance Category Score of 1 to 2)

	N (%) or Median (Interquartile Range)		Univariate Analysis	Multivariable Analysis*		
	CPC 3–5, n = 76	CPC 1–2, n = 63	*P* Value	OR	95% CI	*P* Value
Demographics						
Age (yr)	62 (49–71)	60 (39–69)	0.27			
Male sex	41 (53.9)	37 (58.7)	0.61			
ASA PS scores I–III	42 (55.3)	47 (74.6)	0.021			
Emergency surgery	52 (68.4)	28 (4.4)	0.006			
Rapid sequence induction	20 (26.3)	22 (34.9)	0.27			
Immediate management of IOCA						
Position at IOCA occurrence			0.43			
Supine	67 (88.2)	56 (88.9)				
Left lateral decubitus	7 (9.2)	3 (4.8)				
Right lateral decubitus	2 (2.6)	4 (6.3)				
VF/VT as first recorded rhythm	7 (9.2)	16 (25.4)	0.012	4.78	1.38–16.53	0.013
Total number of defibrillations before ROSC			0.57			
0	57 (75.0)	42 (66.7)				
1	6 (7.9)	7 (11.1)				
≥2	13 (17.1)	14 (22.2)				
Total epinephrine dose before ROSC (mg)			0.008			
0	4 (5.6)	8 (13.1)				
[0–1]	9 (12.7)	20 (32.8)				
[2–7]	32 (45.1)	20 (32.8)				
>7	26 (36.6)	13 (21.3)				
Time from collapse to ROSC (no flow + low flow) (min)	15 (8–28)	6 (2–15)	0.0004			
Occurrence during nonstandard working hours	25 (32.9)	15 (23.8)	0.26	1.62	0.62–4.24	0.32
Cause of IOCA						
Presumed cardiac disease	15 (19.7)	12 (19.0)	1.0			
Hemorrhagic shock	22 (28.9)	11 (17.5)	0.16	0.72	0.27–1.98	0.53
Etiologic category			0.10			
Preoperative complications	30 (39.5)	16 (25.4)				
Anesthesia	16 (21.0)	23 (36.5)				
Surgical procedures	18 (23.7)	18 (28.6)				
Patient characteristics	12 (15.8)	6 (9.5)				
ICU management of comatose survivors						
Glasgow score at ICU admission			<0.0001			
3–6	70 (92.1)	35 (55.6)				
7–9	2 (2.6)	16 (25.4)				
≥10	4 (5.3)	12 (19.0)				
SAPS II score at ICU admission	80 (62–92)	49 (40–68)	<0.0001			
Logistic Dysfunction Organ score at ICU admission	14 (11–18)	7 (4–10)	<0.0001	0.78	0.71–0.87	<0.0001
No norepinephrine after resuscitation	32 (42.1)	31 (49.2)	0.50			
No epinephrine after resuscitation	24 (31.6)	41 (65.1)	0.0002	3.14	1.29–7.65	0.012

Goodness-of-fit (Hosmer–Lemeshow) *P* value, 0.79.

* The following variables were entered into the model: SAPS II, time to ROSC (no-flow + low-flow), ventricular fibrillation/tachycardia, total epinephrine dose before ROSC, Logistic Dysfunction Organ score on day 1, ASA PS scores I–III, emergency *vs.* scheduled surgery, epinephrine after resuscitation, Glasgow Coma Scale score at ICU admission, hemorrhagic shock, and occurrence during nonstandard working hours.

ASA PS = American Society of Anesthesiologists physical status; CPC = Cerebral Performance Category; ICU = intensive care unit; IOCA = intraoperative cardiac arrest; OR = odds ratio; ROSC = return of spontaneous circulation; SAPS II = Simplified Acute Physiology Score version II; VF/VT = ventricular fibrillation/tachycardia.

Interestingly, in our study, not receiving epinephrine to treat postcardiac arrest shock was independently associated with a favorable outcome, whereas norepinephrine therapy was not associated with the outcome, suggesting that epinephrine use served as a marker for greater severity. Ventricular tachycardia/fibrillation, the other factor associated with a favorable outcome in our study, occurred in a similar proportion of patients to that described in earlier studies.[1] Ventricular tachycardia/fibrillation is classically associated with a good outcome after out-of-hospital cardiac arrest, but this effect seems mediated by a shorter time from collapse to cardiopulmonary resuscitation and by early defibrillation.[26,27] Therefore, the significance of ventricular fibrillation/tachycardia may be different in IOCA: 135 of 140 patients in our study received immediate resuscitation and median time to resuscitation in the 15 remaining patients was 1 min (1 to 3). As reported previously, pulseless electrical activity was more common in our population than in studies of out-of hospital cardiac arrest.[23] Ventricular tachycardia/fibrillation as the initial recorded rhythm after IOCA may be identified more rapidly than pulseless electrical activity or asystole, which may be preceded by hypotension or bradycardia. Moreover, ventricular tachycardia/fibrillation has been associated with specific cardiac comorbidities such as ischemia or structural heart disease, a situation in which early defibrillation usually ensures a good recovery.[28,29]

Interestingly, none of the variables related to anesthesia and/or surgery was associated with long-term outcomes in our patients. A previous study identified hemorrhagic shock and cardiac arrest occurrence during nonstandard working hours as independent predictors of immediate and hospital mortality after IOCA.[3] IOCA is associated with a broad range of causative factors that includes patient characteristics, preoperative complications, complications of anesthesia, and complications of surgical procedures. Emergent surgery, poor preoperative status, and organ failures increase the risk of IOCA. However, when IOCA occurs, the setting allows optimal resuscitation, as monitoring is already under way and professionals trained in resuscitation are available. Simulation-based training strategies and the use of checklists to manage anesthesia and surgical crises in the operating room might improve the outcomes of IOCA.[30–32]

Our study has several limitations. First, the extent to which our findings apply to the full spectrum of patients with IOCA is unclear. As our patients were admitted to 11 ICUs during a 13-yr period, their anesthesiological management varied widely. Moreover, we included only immediate survivors of IOCA who required ICU management. Some patients may have died in the operating room and others may have recovered fully in the postanesthesia care unit without requiring ICU admission. However, despite the retrospective study design, the participation of 11 ICUs provided a broad picture of the management and outcome of immediate survivors after IOCA. Second, although the range of surgical procedures was extensive, it may not have included all possible types of surgery. Thus, we cannot exclude that specific surgical procedures might be associated with the risk or outcome of IOCA. Third, we observed a particularly high rate of cardiac arrest related to anaphylactic shock. This could be explained by the retrospective design of the study based on patient's charts explorations that could have been influenced by medicolegal considerations. However, the rate we observed is in accordance with current literature reporting the imputability of anaphylaxis from 6 to 25% of cases of IOCA.[3,33] Fourth, the CPC is a valid, practical, and reliable tool when evaluated prospectively, but no information is available on CPC evaluation based on retrospective chart review.[18] Fifth, our definition of postcardiac arrest shock may have included other causes of heart failure such as bleeding or anaphylactic shock. Sixth, the main limitation of our study is the risk of self-fulfilling prophecy bias that is inherent in the observational design: a variable used as a criterion for treatment-limitation decisions would be spuriously found to have a strong prognostic effect. However, the rate of treatment-limitation decisions was only 14% in our study, which was low compared with other studies of cardiac arrest.[34] Last, the data-driven procedures used to identify these predictors are known to produce overly optimistic models, and thus other internal validation methods were conducted to strengthen the results of the multivariate model. See Supplemental Digital Content 1, http://links.lww.com/ALN/B53, which describes the methods in detail. However, it would be interesting to validate our findings in future studies.

In conclusion, our study delineates the ICU management and outcome of patients having survived IOCA. After 90 days, 45% of patients had achieved a good recovery. The main outcome predictors were directly related to IOCA occurrence and to postcardiac arrest syndrome. Among these factors, ICU management of postcardiac arrest syndrome may be amenable to improvement. These results warrant further investigation in a large multicenter prospective study.

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Competing Interests

The authors declare no competing interests.

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