Clinical Neurology and Neurosurgery 161 (2017) 6–13

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Factors associated with an increased risk of perioperative cardiac arrest in emergent and elective craniotomy and spine surgery

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A R T I C L E I N F O

Keywords:
Neurosurgery
Neuroanesthesia
Cardiac arrest
Perioperative medicine
Quality improvement
Risk management
Outcomes research

A B S T R A C T

Objective: Cardiac arrest following neurosurgery is a devastating complication associated with significant postoperative morbidity and mortality. There are no published studies that have used a large and robust multicenter database to specifically examine demographic and surgical risk factors associated with cardiac arrests following craniotomy and spine surgeries, respectively.

Patients and methods: We retrospectively analyzed data from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database for the period between January 1, 2007 and December 31, 2013, focusing on cardiac arrest associated with craniotomy and spine surgery from the intraoperative period to 30 days after surgery. A total of 73,584 neurosurgical patients were analyzed (59,609 spine surgeries and 13,975 craniotomies).

Results: There was an increased risk of cardiac arrest for both craniotomy and spine surgeries in patients with American Society of Anesthesiologists (ASA) Physical Status class 4 or 5, Black and Asian patients compared to White patients and patients totally dependent versus independent based on the ACS-NSQIP risk calculator. The risk of cardiac arrest for craniotomy was 66.5 per 10,000 anesthetics and for spine surgery was 21.3 per 10,000 anesthetics. Cardiac arrest associated with emergent non-traumatic craniotomy was 36.5% and with emergent non-traumatic spine surgery was only 17.3%. We found that 18% of cardiac arrests for craniotomy and 25% of cardiac arrests for spine surgery occurred from the intraoperative period through postoperative day (POD) 0. Both craniotomy and spine surgery patients who had a cardiac arrest were more likely to have acute kidney injury (AKI), failure to wean from the ventilator, postoperative dialysis, myocardial infarction (MI), venous thromboembolism (VTE) and sepsis in the postoperative period. The overall mortality rate for both craniotomy and spine surgeries who had a cardiac arrest from the intraoperative period to 30 days postoperative was 61.8% versus 1.2% in the no cardiac arrest control group.

Conclusions: Identification of patient and surgery specific characteristics from ACS-NSQIP data associated with cardiac arrest following craniotomy and spine surgery may lead to initiatives to reduce morbidity and mortality in the neurosurgical patient population.

1. Introduction

In-hospital cardiac arrest is a significant patient event with survival rates typically less than 25% [1]. One study found only 44% of patients who experienced cardiac arrest had a return of spontaneous circulation (ROSC) and only had a 17% survival rate to hospital discharge [2]. The chances of survival are likely improved if the arrest occurs at hospitals with well-trained staff initiating appropriate cardiopulmonary resuscitation (CPR) in a timely manner [3,4]. Strategies for improved survival after in-hospital cardiac arrest include competency training for hospital staff on effective CPR technique, initiating evidence-based practices for post arrest care such as glucose control and accurate assignment of 'do not resuscitate' (DNR) orders for inpatients [5]. Another potential way to improve outcomes is to identify patient characteristics and clinical situations with a high incidence of cardiac arrest and develop interventions to predict or better manage cardiac arrests. Our

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http://dx.doi.org/10.1016/j.clineuro.2017.07.014
Received 28 February 2017; Received in revised form 28 June 2017; Accepted 23 July 2017
Available online 25 July 2017
0303-8467/

hypothesis is that certain subsets of patients are more likely to suffer cardiac arrest and these patients could be identified by analysis of large heterogeneous data registries.

Several studies have attempted to qualify and quantify patient characteristics most at risk for cardiac arrest for various types of surgical specialties. However, the data are frequently limited due to narrow definitions of the perioperative period, varied patient populations, and limited follow up. The 'perioperative' time frame is ambiguous and can differ from study to study from only the post anesthesia care unit period [6] to 24-h after surgery [7] to just the time spent in the operating room or post anesthesia care unit (PACU) [8]. Additionally, the data are often limited in their generalizability, often representing just a single institution's experience [9].

To date, no published study using a large and robust multicenter database has specifically examined demographic and surgical risk factors associated with cardiac arrests following common emergent and elective neurosurgical procedures. One study analyzed the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) data on many surgical specialties, of which neurosurgery cases represented only a small subset of the sample [10]. ACS-NSQIP is a national, risk-adjusted, outcomes-based program aimed at improving surgical care and outcomes. In-depth analysis of the patient characteristics and surgery specific details for the neurosurgery cohort was lacking in the previous study. In addition, it only contained patient data from 2005 to 2010. Another study in the literature includes a review of cardiac emergencies for elective neurosurgical procedures, but the study was limited to only intraoperative cardiac arrests [11].

The goal of our study was to analyze the demographic and surgical factors associated with cardiac arrest in the neurosurgical patient population, as well as examine complications associated with post-operative cardiac arrest for these patients. We analyzed non-traumatic craniotomy and spine surgeries separately.

We hypothesized that there are specific patient characteristics and comorbidities most associated with cardiac arrest in the perioperative timeframe from the intraoperative period to 30 days after surgery. We also hypothesized that cardiac arrest would be most prevalent closest to the physiologic insults of surgery and anesthesia. The information gained from our analysis could be used to better understand and care for neurosurgical patients most at-risk for perioperative cardiac arrest.

2. Materials and methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) is a well-validated data registry consisting of de-identified cases reported from approximately 400 different participating sites. Institutional Review Board approval was obtained for analysis of the data and was exempted from the consent requirement due to the de-identified nature of the data. We retrospectively examined abstracted information for patients undergoing neurosurgical procedures between January 1, 2007 and December 31, 2013. ACS-NSQIP defines cardiac arrest as either an intra-operative or post-operative occurrence. For postoperative cardiac arrest, there is an 'absence of cardiac rhythm or presence of chaotic cardiac rhythm, intraoperatively or within 30 days following surgery, which results in a cardiac arrest requiring the initiation of cardiopulmonary resuscitation (CPR), which includes chest compressions. Patients are included who are in a pulseless ventricular tachycardia (VT) or ventricular fibrillation (VF) in which defibrillation is performed and pulseless electrical activity (PEA) arrests requiring chest compressions. Patient who receives open cardiac massage are included. Patients with automatic implantable cardioverter defibrillator (AICD) that fire but the patient has no loss of consciousness should be excluded'. For intraoperative cardiac arrests, the definition is 'absence of cardiac rhythm or 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. Patients with automatic implantable cardioverter defibrillator that fire but the patient has no loss of consciousness should be excluded'.

The primary event in this study was cardiac arrest in the intra- or post-operative period (postoperative days 0–30), and the primary aim was to identify factors associated with this adverse event. The secondary aim of the study was to assess the effects of cardiac arrest on complications, mortality and discharge in the first 30 postoperative days. We also looked at several other outcomes for cardiac arrest and non-cardiac arrest group including return to the operating room, unplanned intubation, failure to wean from the ventilator, acute kidney injury, postoperative dialysis, cerebral vascular accident (CVA), myocardial infarction (MI), transfusion, venous thromboembolism (VTE) and sepsis.

For this study, the 2007–2013 ACS-NSQIP data was compiled into a single data file containing 306 variables across 2.8 million surgical cases [12]. A complete definition of all the variables recorded can be found by following the link for the ACS-NSQIP participant user file. All cases performed by neurosurgery, as defined as 'the surgical specialty area that best characterizes the principal operative procedure or the surgeon's self-declared specialty' were included. Excluded from analysis due to exclusion from participation in ACS-NSQIP were all cases of patients under age 18 at the time of operation, trauma cases, transplant surgeries, and all cases where the patient is listed as an American Society of Anesthesiologists Physical Status (ASA PS) class 6, representing a brain dead organ donor. Additionally, concurrent cases, defined as cases performed by a different surgical team under the same anesthetic were only reported as a single operation. Lastly, all cases failing to report the cardiac arrest variables were excluded from the analysis. Given these criteria, a total of 73,854 cases were included in our analysis. Baseline preoperative demographics and clinical characteristics, index procedure characteristics and postoperative course were analyzed for craniotomy and spine surgeries, respectively. Comparison of the cohort experiencing a cardiac arrest with the cohort that did not was performed utilizing Student's *t*-test for continuous variables and Pearson's Chi-Squared test for categorical variables. After continuous covariates had been converted to functional categories, univariate and multivariate analysis between patient demographic and clinical characteristics, index procedure characteristics, and cardiac arrest were determined utilizing logistic regression. First univariate regression was utilized to identify associations with cardiac arrest. Clinically significant variables, defined as a p-value on univariate regression of < 0.2, were subsequently included in a generalized linear model. Stepwise selection of variables using a bi-directional approach was performed on this model in order to identify the best fit model. These covariates comprising the best fit model were subsequently incorporated into the multivariate model for analysis. All analyses were conducted using R Project for Statistical Computing, v3.2.3 [13]. Two-tailed p value of less than 0.05 was considered statistically significant in final analyses, while for the logistic regression, odds ratios (OR) were reported with their associated 95% confidence intervals (CI). OR not including 1.00 in their 95% CI were considered statistically significant.

3. Results

Fig. 1 shows the flowchart for craniotomy and spine surgery populations analyzed in the study.

Fig. 2 gives a visual presentation of the frequency of cardiac arrest for craniotomy (blue) and spine surgeries (orange) for from the intraoperative period through 30 days postoperative. We found that 18% of cardiac arrests for craniotomy and 25% of cardiac arrests for spine surgery occurred from the intraoperative period through postoperative day (POD) 0. Based on the limitations of the dataset, it is not possible to determine if the cardiac arrest occurred in the postoperative anesthesia unit (PACU), intensive care unit (ICU) or another part of the hospital. Of note, all cardiac arrest associated with craniotomy occurred after surgery.