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Drivers of hospital length of stay in 56,000 orthopaedic trauma patients: The impact of postoperative cardiac events

Diana G. Douleh, Mahesh Yarlagadda, Michelle S. Shen, Gerard Williams, Idine Mousavi, Manish K. Sethi*

The Vanderbilt Orthopaedic Institute Center for Health Policy, 1215 21st Avenue South, Suite 4200 Medical Center East, South Tower, Nashville, TN 37232 (615), United States

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ABSTRACT

Purpose: To determine whether postoperative cardiac complications following orthopaedic trauma treatment are associated with longer lengths of stay.

Methods: This was a retrospective cohort study. We analyzed orthopaedic trauma patients in the United States for whom data was collected in the ACS-NSQIP database between the years of 2006 and 2013. The patient population included 56,217 orthopaedic trauma patients meeting any 1 of the 89 CPT codes selected in the ACS-NSQIP database. The main outcome measure was hospital length of stay following orthopaedic trauma treatment.

Result: Of the 56,217 orthopaedic trauma patients, 749 (1.3%) developed postoperative adverse cardiac events. There was a significant difference in total length of stay ($p < 0.001$): patients with cardiac complications on average stayed 10.6 days compared to 5.2 days for patients who did not experience such cardiac complications. This amounted to a difference of \$24,316 in total hospital costs. Through multiple linear regression modeling controlling for multiple patient and surgical factors, the presence of cardiac complications significantly added 1.5 days in total hospital stay ($p < 0.05$).

Conclusion: Orthopaedic trauma patients sustaining postoperative cardiac events have significantly longer hospital lengths of stay when compared to those who do not develop cardiac complications. This difference amounts to significantly higher health care costs.

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1. Introduction

As health care costs in the United States continue to rise there has been increased emphasis on cost containment. With health care spending totaling close to 20% of the United States' Gross Domestic Product (GDP) it becomes increasingly important to determine those factors driving increased spending. In the surgical patient, a major determinant of hospital costs and measure of the quality of care is length of hospital stay. Currently, little data exists on whether postoperative cardiac events prolong the length of stay for orthopaedic trauma patients. Previous literature has documented a correlation between post-operative cardiac events and increased length of stay in specific cohorts, but there has yet to be a study that examines this relationship within the orthopaedic trauma population.^{1–3} This study utilized the American College of Surgeons – National Surgical Quality Improvement Program (ACS-

NSQIP) database to determine whether postoperative cardiac complications were associated with longer lengths of stay in a large, multicenter, prospective cohort of orthopaedic trauma patients.

Following noncardiac surgery, adverse cardiovascular events are the largest contributor to morbidity and mortality, driving increased length of hospital stay and hospitalization costs.⁴ Postoperative myocardial injury was found to increase hospital length of stay by five to eleven days.^{4,5} Increased length of stay is a function of the need for increased hemodynamic monitoring following cardiac events and monitoring of concomitant chronic disease in these patients. There have been a number of studies that examine the factors affecting the length of stay among orthopaedic patients. Pugely et al. showed that medical comorbidities in patients undergoing total knee arthroplasty, including obesity, diabetes, and hypertension, increases hospital length of stay, resource utilization, and hospital costs.⁶ Medical comorbidities showed an incremental effect on hospital costs and length of stay; each additional comorbidity was found to add to costs and length of stay. Belmont et al. showed age greater than 80, hypertension,

* Corresponding author.

E-mail address: manish.sethi@vanderbilt.edu (M.K. Sethi).

and history of cardiac disease to be significant independent predictors for the development of post-operative cardiac complications in patients undergoing primary unilateral total knee arthroplasty and total hip arthroplasty.⁷ However, despite these data, the effect of post-operative cardiac events on length of stay for orthopaedic trauma patients has not been evaluated.

The American College of Cardiology (ACC) and the American Heart Association (AHA) reported orthopaedic surgery is associated with significant perioperative cardiovascular morbidity and mortality with up to 5% of patients experiencing postoperative cardiac complications.⁸ However, limited data exists that investigates which types of orthopaedic patients are at greatest risk for developing postoperative cardiac complications. Even fewer data exist to determine the financial impact of sustained postoperative cardiac events in orthopaedic trauma patients due to increased length of hospital stay. With a healthcare system in which postoperative complications are continually assessed and examined as indicators of

quality of care and possess potential consequence on reimbursement models, understanding the financial impact of these complications and working to reduce them will be of great significance for practicing orthopaedists.⁹

The purpose of this study was to determine the incidence of postoperative cardiac complications in the orthopaedic trauma patient and the relationship of such events with hospital length of stay and total hospital costs in a large, diverse, multicenter patient cohort. The ACS-NSQIP database was used in conjunction with Current Procedural Terminology codes (CPT) to identify over 56,000 orthopaedic trauma patients and assess the impact of postoperative cardiac complications on length of hospital stay.

2. Materials and methods

2.1. Data

Retrospective identification of 361,402 patients from 2006 to 2013 in the ACS-NSQIP database was conducted through a Current Procedural Terminology (CPT) code search. Of these patients 56,217 orthopaedic trauma cases were identified through a search of 89 CPT codes (Appendix A).

Cases were deemed to have developed a postoperative cardiac event, the main associated factor of interest, if either (1) a

myocardial infarction or (2) cardiac arrest occurred within 30 days following treatment of an orthopaedic trauma event. These two variables were represented in the NSQIP data as their respective frequencies within the 30-day postoperative period. Therefore, both myocardial infarction and cardiac arrest were recoded into a single binary variable represented by adverse cardiac event.

A total of thirty-one independent variables, including adverse cardiac events, were chosen based on their suspected relationship with hospital length of stay to be used in a linear regression model further characterizing those factors influencing hospital length of stay in orthopaedic trauma patients. These associated factors included the following: gender, type of anesthesia, diabetes status, smoking status, body mass index, chronic obstructive pulmonary disease, hypertension, preoperative renal failure, preoperative dialysis, American Society of Anesthesiologists (ASA) Grade 2, preoperative pneumonia, postoperative pneumonia, urinary tract infection, prior operation within 30 days, failure to wean off of ventilation, cancer, previous myocardial infarction, postoperative acute renal failure, congestive heart failure, superficial surgical site infection, deep surgical site infection, emboli, organ space infection, postoperative chronic renal insufficiency, radiation therapy, wound disruption, need to reintubate, stroke, peripheral nerve damage, and ventilator use prior to operation.

2.2. Analysis

Statistical analyses were conducted utilizing IBM SPSS Statistics™ Software Version 22. A *t*-test was performed to determine the difference in mean hospital length of stay for those individuals experiencing a postoperative adverse cardiac event versus those who did not experience such an event. Following, a multiple linear regression model was fit to hospital length of stay data to determine the impact of all independent variables on length of stay following orthopaedic trauma treatment. This regression model controlled for multiple patient and surgical factors including type of anesthesia used, diabetes status, smoking status, body mass index, chronic obstructive pulmonary disease, hypertension, preoperative renal failure, and preoperative dialysis. The difference in hospital costs between patients who sustained cardiac complications and those who did not was determined

Table 1
Baseline characteristics of entire orthopaedic trauma cohort and subset of those experiencing adverse cardiac events postoperatively.

Patient and Surgical Factor	Orthopaedic Trauma Cohort		Adverse Cardiac Event Cohort	
	n (Total)	100%	749	100%
Male	19,900	35.4	289	38.6
Female	36,316	64.6	460	61.4
Smokers	9782	17.4	98	13.1
History of COPD	4497	8.0	157	21
ASA 1	5453	9.7	2	0.3
ASA 2	17,708	31.5	63	8.4
ASA 3	26,253	46.7	443	59.1
ASA 4	6690	11.9	238	31.8
ASA 5	56	0.1	3	0.4
General Anesthesia	44,692	79.5	542	72.4
Diabetes	8995	16	214	28.6
Hypertension	29,964	53.3	601	80.2
Body Mass Index Heavy	12,861	22.9	124	17.9
	(56,160)		(692)	
Congestive Heart Failure	1237	2.2	67	8.9
Myocardial Infarction	211	1.0	11	4.1
	(21,533)		(267)	
Cancer	1278	2.3	14	1.9
Prior Operation	553	2.6	2	0.7
	(21,625)		(270)	

using the author's associated institutional cost of \$4503 per hospital night.

3. Results

A total of 361,402 orthopaedic patients were identified from 2005 to 2013 in the ACS- NSQIP database. Of these, 56,217 (15.6%) were identified as orthopaedic trauma patients. During the study period, 749 (1.3%) of the 56,217 orthopaedic trauma patients experienced adverse cardiac events, with an average age of 66 years old. Approximately 61% ($n=460$) of the cardiac event cohort was female, 13% ($n=98$) were classified as smokers, and 21% ($n=157$) had a history of chronic obstructive pulmonary disease (Table 1).

There was a statistically significant difference in total length of stay ($p < 0.001$) among patients who experienced adverse cardiac events versus those who did not. Patients with cardiac complications on average stayed 10.6 days (± 10.5) compared to 5.2 days (± 8.1) for patients who did not sustain cardiac complications. A histogram of length of hospital stay was positively skewed, as expected, in Fig. 1. Using the author's institutional cost of \$4503 per hospital night, this amounted to a difference of \$24,316 in total hospital costs for those orthopaedic trauma patients experiencing postoperative adverse cardiac events versus those who did not.

A multiple linear regression model, controlling for multiple patient and surgical factors, indicated that the presence of cardiac complications significantly added 1.5 days in total hospital stay ($p < 0.05$) (Table 2; Fig. 2). Additionally, the regression model indicated individuals with no surgical or baseline characteristics of interest experienced a total of 3.2 days in the hospital following orthopaedic trauma treatment. The most significant patient factors found to increase hospital length of stay were preoperative

pneumonia (8.1 days), failure to wean off of ventilation postoperatively (7.6 days), postoperative acute renal failure (7.0 days), postoperative pneumonia (6.4 days), and history of myocardial infarction preoperatively (4.6 days) (Table 2; Fig. 2). Tolerance and variance inflation factor measure for those variables presented in Table 2 were within the acceptable range.

4. Discussion

This study adds to the limited data further characterizing the relationship between postoperative cardiac events and length of stay for orthopaedic trauma patients. For example, in 2012, Huddleston et al. found that 10.4% of patients undergoing hip fracture surgery had clinically verifiable myocardial infarction.¹⁰ Furthermore, in 2014, Belmont's group found in the NSQIP dataset that the cardiac complication rate was 0.33% for patients undergoing total knee arthroplasty or total hip arthroplasty.⁷ These studies highlighted the increased risk of adverse cardiac events in trauma patients. Utilizing these data, this study investigated the impact of this relationship in order to understand whether postoperative cardiac complications are associated with longer lengths of stay in a large, multicenter, prospective cohort of orthopaedic trauma patients. In conjunction with the financial impact, by linear regression analysis involving over thirty patient variables including age, gender, ASA grade, and presence of cardiac complications, significant drivers of hospital length of stay were calculated as illustrated by Fig. 2. These risk factors present opportunities for physician intervention in pre-operative planning and may present opportunities to reduce cardiac events.

The importance of understanding and exploring these associations is further highlighted by the American College of Cardiology (ACC) and the American Heart Association (AHA) report that

Fig. 1. Histogram of hospital length of stay for entire orthopaedic trauma cohort ($n=56,217$).

Table 2

Most significant patient and surgical factors impacting hospital length of stay.

Patient/Surgical Factor	Hospital Length of Stay (Days)	95% Confidence Interval (days)
None [*]	3.2	(2.993, 3.654)
Organ/Deep Space Infection ^{**}	3.6	(1.283, 5.842)
Adverse Cardiac Event ^{**}	1.5	(0.578, 2.520)
Emboli [*]	2.0	(1.013, 2.910)
Superficial Surgical Site Infection [*]	2.7	(1.629, 3.797)
History of Congestive Heart Failure [*]	2.5	(1.651, 3.264)
Acute Renal Failure Postoperative [*]	7.0	(5.034, 8.910)
History of Myocardial Infarction [*]	4.6	(3.533, 5.653)
Cancer [*]	3.5	(2.769, 4.179)
Failure to Wean Off Ventilation [*]	7.6	(6.126, 9.056)
Prior Operation within 30 days [*]	4.0	(3.347, 4.658)
Urinary Tract Infection [*]	3.7	(3.085, 4.291)
Pneumonia Preoperative [*]	8.1	(6.772, 9.429)
Pneumonia Postoperative [*]	6.4	(5.545, 7.236)
ASA Grade 2 [*]	2.8	(2.591, 3.090)
Dialysis Preoperative [*]	3.6	(2.771, 4.405)

^{*} p < 0.001.^{**} p < 0.05. **Fig. 2.** Most significant patient and surgical factors increasing hospital length of stay in multivariate model.

orthopaedic surgery is associated with significant perioperative cardiovascular morbidity and mortality with up to 5% of patients experiencing postoperative cardiac complications.⁸ However, it is important to note that all orthopaedic patients are not equal as this 5% is significantly more concentrated within trauma patients. Furthermore, within the trauma group, cardiac complications are more prevalent within certain subsets of trauma patients, such as hip and pelvic surgical patients.^{11,12} Further studies should be

conducted to explore the factors influencing post-operative adverse cardiac events and varying types of trauma patients, including length of stay.

Our study contained limitations. We were restricted to patient factors available in the NSQIP dataset. Many other factors, such as high cholesterol and family history of cardiac disease are known to precipitate cardiac disease; however, we were unable to assess the impact of these preexisting conditions. Furthermore, myocardial

infarctions and cardiac arrests as defined in this dataset occurred within 30 days after surgery. We were therefore unable to evaluate patients who sustained these complications past the 30-day time point. Another limitation of the NSQIP database is that it currently does not record the incidence of polytraumas, which characteristically have more associated complications. We also acknowledge that, intuitively, it is clear that post-operative cardiac events would increase hospital length of stay. However, this association has not previously been studied within the orthopaedic trauma population.

Despite these limitations, the study presented determined the financial impact and significant drivers of increased length of stay for orthopaedic trauma patients sustaining a postoperative adverse cardiac event. To reduce mortality and prevent extraneous hospital costs, attention must focus on optimizing health status preoperatively, preventing postoperative complications, and when these complications develop, providing optimal specialist medical care. Particularly in a healthcare system in which postoperative complications are continually assessed and examined as indicators of quality of care and possess potential consequence on reimbursement models, understanding the financial impact of these complications and working to reduce them will be of great significance for practicing orthopaedists.⁹

Orthopaedic trauma patients who sustained postoperative cardiac events stay significantly longer than those not experiencing such an event. This difference accounts for a substantially increased hospital costs possibly contributing to the high cost of insurance and overall health services. However, a multiple linear regression model revealed a different relationship highlighting the importance primary care management of comorbidities and lifestyle conditions is in the prognosis of surgical recovery.

Conflict of interests

The authors have none to declare.

Table A1

Current Procedural Technology (CPT) codes selected for orthopaedic trauma cohort.

23515	25515	27244	27759
23585	25525	27245	27766
23615	25526	27248	27769
23616	25545	27253	27784
23630	25574	27254	27792
24515	25575	27256	27814
24516	25607	27258	27822
24538	25608	27259	27823
24545	25609	27269	27826
24546	25611	27506	27827
24566	25620	27507	27828
24575	25628	27509	27880
24579	25920	27511	27881
24586	27125	27513	27882
24587	27187	27514	27888
24615	27215	27519	27889
24635	27217	27535	28420
24665	27218	27536	28445
24666	27226	27590	28800
24685	27227	27591	28805
24800	27228	27592	
24900	27235	27756	
24930	27236	27758	

Appendix A

See Table A1.

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