

Analysis of the American College of Surgeons National Surgical Quality Improvement Program⁰ (ACS NSQIP⁰) database to identify factors associated with postoperative mortality after elective non-cardiac surgery

Amit K. Malviya

All India Institute of Medical Sciences

Melanio Bruceta

Penn State Health Milton S Hershey Medical Center

Preet M. Singh

Washington University in Saint Louis

Anthony Bonavia

Penn State Health Milton S Hershey Medical Center

Kunal Karamchandani

UT Southwestern Medical Center <https://orcid.org/0000-0003-3089-8088>

Anju Gupta (✉ dranjugupta09@gmail.com)

All India Institute of Medical Sciences

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Abstract

Background: Various surgical risk assessment tools, including the American College of Surgeons National Surgical Quality Improvement Program[®] (ACS NSQIP[®]) risk calculator have been devised to predict post-operative mortality. However, the role of individual factors on mortality is unclear. We sought to identify patient characteristics from the database that were associated with postoperative mortality in patients undergoing elective, non-cardiac surgery.

Methods: Data from the ACS NSQIP[®] database at a tertiary care academic medical center was analyzed from January 2011 to September 2016. Relevant patient related variables were extracted from the database and univariable logistic regression was used to assess the association of each potential risk factor with 30-day mortality. A multivariable logistic regression model was then used to assess the adjusted effect of each potential risk factor on the outcome.

Results: 5,254 database patient records were identified and among the analyzed variables, American Society of Anesthesiologists (ASA) physical status III and IV (odds ratio and 95%CI : 16.75 [2.29, 122.69]), poor preoperative functional health status (Odds ratio and 95%CI : 38.52 [2.46, 604.12]), and low serum albumin (Odds ratio and 95%CI : 3.76 [1.35, 10.44]) were significant predictors of 30-day postoperative mortality.

Conclusions: In a comprehensive analysis of the ACS NSQIP[®] database, spreading across multiple surgical specialties, we found an association between ASA physical status, preoperative albumin levels, and functional health status with 30-day mortality after elective non-cardiac surgery.

Background

Despite significant advances in surgical and anesthesia care, postoperative morbidity and mortality following elective, non-cardiac surgery ranges from 0.4-12%(1). Early detection of at-risk patients can help devise intervention strategies to optimize modifiable risk factors prior to surgery. Further, an estimation of the risk of postoperative complications and mortality can help guide risk-benefit discussions between patients and surgeons prior to elective surgery. As a consequence, many risk assessment tools have been developed with the goal of identifying those patients at high risk of perioperative complications (2).

The American College of Surgeons National Surgical Quality Improvement Program[®] (ACS NSQIP[®]) is a nationally validated, risk-adjusted, and outcomes-based risk assessment tool (3). The database is comprised of de-identified patient information and tracks surgical outcomes with the goal of providing

feedback to participating institutions.(4) The database contains preoperative and intraoperative variables which have been used to devise a surgical risk calculator (SRC).(5) The SRC has shown mixed results in predicting postoperative complications in different surgical populations(6, 7) and this discordance could, in part, be due to varying effect of the included predictors. The aim of this retrospective cohort study is to identify the role of individual contributors of the ACS NSQIP⁰ SRC in impacting postoperative mortality in patients undergoing a wide array of non-cardiac surgical procedures.

Methods

Data Source

After approval by the Penn State College of Medicine Institutional Review Board (Study no: 7024, approval date: 03/28/2017), information on all elective non-cardiac surgical cases was obtained from the ACS NSQIP⁰ database for the Penn State Milton S. Hershey Medical Center, from January 2011 through September 2016. We used the methodology previously described by Bruceta et al. (8) The ACS NSQIP⁰ obtains its data from randomly assigned patients by rigorously trained and audited data abstractors. The database records hospital-reported preoperative and post-surgical outcomes for 30 days (4). Demographic details, preoperative comorbidities, preoperative laboratory results and postoperative complications were extracted from the database and are detailed in supplementary table 1.

Study Sample

Patients who were older than 18 years, underwent elective inpatient non-cardiac surgery at Penn State Health Milton S. Hershey Medical Center and whose records were part of the hospital ACS NSQIP⁰ database were included in the study.

Statistical Analysis

We applied the statistical approach previously described by Bruceta et al.(8) Specifically, the descriptive data are reported as frequencies and percentages for categorical variables and as means and standard deviations (SD) for continuous variables. Furthermore, continuous variables were assessed for normality by examining normal probability plots. Univariable logistic regression was used to assess the association of each potential risk factor with 30-day mortality after surgery. The effect size from each logistic regression model was quantified using the odds ratio (OR) and 95% confidence interval (CI). A multivariable logistic regression model was then used to assess the adjusted effects (i.e., the adjusted odds ratio) of each potential risk factor on the outcome. All hypothesis tests were two-sided and all statistical analyses were performed using R, a software for statistical computing (R version 3.5.3).

Results

A total of 5254 patients were included in the analysis. A significant proportion of patients were young (65.3%), however the majority of patients had an ASA status III or IV (65.8%) and almost half of the

patients were obese. The mean procedure duration was about 4 hours and 83% of patients had surgical duration less than 6 hours. The most common comorbidity in the study population was hypertension (51.3%) and about 20% of the patients were active smokers. The mean hospital length of stay was 4.7 days, and 20% of the patients stayed in the hospital for a week or more. The overall 30-day mortality in the study cohort was 0.6% (33 patients). Table 1 depicts the univariable and multivariable analysis for 30-day mortality. Cases with missing predefined covariates and variables without significant odds ratio were excluded from the multivariable logistic regression analyses. ASA physical status III and IV (OR and 95%CI : 16.75 [2.29, 122.69]), poor preoperative functional health status (OR and 95%CI : 38.52 [2.46, 604.12]), and low serum albumin (OR and 95%CI : 3.76 [1.35, 10.44]) were identified as significant predictors of 30-day postoperative mortality in the multivariable model. Table 2 shows the percentage of cases with postoperative mortality specified by each surgical specialty.

Discussion

In a comprehensive analysis of the ACS NSQIP[®] database, spreading across multiple surgical specialties, we found that a higher ASA PS, less than normal preoperative albumin levels and impaired preoperative functional capacity were associated with 30-day mortality in patients undergoing elective non-cardiac surgery. Despite significant advances in perioperative care, postoperative mortality remains high and although the ACS NSQIP[®] SRC provides an estimate of this risk, identification of specific risk factors is essential to implement targeted interventions and our analysis is such an attempt.

We identified less than normal preoperative serum albumin levels to be a significant predictor of postoperative mortality. Although serum albumin levels can be impacted by a multitude of conditions, in patients undergoing elective surgery, these could be considered surrogate markers of preoperative nutritional status. Low preoperative serum albumin levels have been found to be associated with significant risk of postoperative complications including poor wound healing, surgical site infections and mortality in various surgical populations.(9-11) However, most of these studies included both elective and emergency surgeries, or were confined to a sample involving specific pathologies and surgical procedures. In a large prospective observational study spread across forty-four tertiary care veterans affairs (VA) medical centers more than a decade ago, the authors concluded that serum albumin concentration is a better predictor of surgical outcomes than many other preoperative patient characteristics.(12) Despite awareness of the association of a low preoperative albumin with worse outcomes, over 10% of the patients in our cohort had less than normal albumin values prior to surgery.

Although the relationship of hypoalbuminemia and poor surgical outcome has been known for many years, the pathophysiology behind the relationship is unclear. Hypoalbuminemia may be an indicator of poor nutritional status, and hence contribute towards poor postoperative outcomes. Secondly, since

albumin has antioxidant and carrier properties, a lack or deficiency thereof, might result in inadequate performance of these tasks, thus further pre-disposing to postoperative complications. Thirdly, since albumin is a known negative acute phase protein, hypoalbuminemia might represent a pre-existing amplified inflammatory status of the patient. Kim et al(13) reviewed this relationship in detail, explored the fallacies with these hypothesis and concluded that Interventions designed solely to correct preoperative hypoalbuminemia, in particular intravenous albumin infusion, do little to change the patient's course of hospitalization. In essence, it is the optimization of preoperative nutritional status that is important and whether elective surgery should be delayed until nutritional status has been optimized and preoperative serum albumin levels are normalized needs to be explored in future studies. A direct relationship between improvement in nutritional status and correction of serum albumin values has yet to be established.

Impaired preoperative FHS was another factor that was associated with a higher likelihood of postoperative mortality in our cohort. Functional health status is often defined as one's ability to perform daily activities required to meet basic needs, fulfill usual roles, and maintain their health and well-being. (14) For documentation into the NSQIP database, patient charts are manually reviewed to determine the level of patient's functional health status. Patients are placed into one of three categories: independent, partially dependent, and totally dependent. An independent patient is defined as one who does not require assistance from another person for any activities of daily living. A partially dependent patient requires some assistance from another person for activities of daily living regardless of use of prosthetics, equipment, and/or devices. Finally, a totally dependent patient requires total assistance for all activities of daily living. The best functional status demonstrated by the patient, within the 30 days prior to the principal operative procedure or at the time the patient is being considered a candidate for surgery is recorded.

Functional health status has been identified as a major risk factor for postoperative complications in isolated surgical cohorts(15, 16) and as part of the preoperative mortality predictor (PMP) in patients undergoing major abdominal surgery.(17) However, its association with mortality across all surgical procedures has not been explored before. Patients with poor functional capacity are generally sicker, tend to have more comorbidities, and may present later in their disease process, which may result in higher mortality. The decision to operate on patients with poor FHS should be thoroughly reviewed with a detailed preoperative workup and in patients in whom surgery is indicated, optimization pathways should be implemented. Functional health status is also an important determinant of preoperative cardiovascular non-invasive testing and forms an integral part of the American College of Cardiology (ACC)/American Heart Association (AHA) guidelines on perioperative cardiovascular evaluation and management of patients undergoing elective non-cardiac surgery.(18)

Improvement of FHS prior to elective surgery can be beneficial and pre-habilitation prior to major abdominal surgery was recently found to reduce overall and pulmonary morbidity.(19) However, in a systematic review of the impact of pre-habilitation programs in abdominal cancer surgery, no significant difference between patients undergoing pre-habilitation and standard care groups were observed. (20) There seems to be heterogeneity in the composition, mode of administration and the outcome measures of functional capacity that are used to evaluate the impact of pre-habilitation programs that may account for these incongruent findings.

The ASA Classification System, introduced in 1941, is routinely assigned to patients prior to procedures where an anesthesia professional is present, and application of this system has become a standard component of anesthetic practice worldwide. We found that a higher ASA physical status was associated with postoperative mortality and prior studies have also reported similar association.(21) Although, the ASA classification system is associated with inter-observer variability and can be inconsistent, it does demonstrate validity as a marker of patients' preoperative health status.(22, 23)

We believe that the strength of this study is the inclusion of a diverse population of patients who underwent varied surgical procedures. However, there are a few limitations. Our analysis is limited by our observed low mortality rate of 0.6%, likely due to the heterogeneity of surgical cases reported in the NSQIP database. Further, NSQIP audited cases are chosen randomly, and thus may not be reflective of the overall surgical case mix. In addition, the lack of reporting of intraoperative complications in the NSQIP database makes the evaluation of valuable data such as blood loss, transfusions, and anesthesia type, unfeasible. Also, the NSQIP database fails to report important clinical risk factors, such as frailty. The retrospective nature and analysis of surgical cases from a single center also limit the generalizability of our findings.

Conclusion

In conclusion, our comprehensive analysis of the ACS NSQIP[®] database identified preoperative functional health status, low serum albumin, and a high ASA physical status as significant predictors of 30-day mortality in patients undergoing elective non-cardiac surgeries. Optimization of nutritional and functional status prior to surgery and including preoperative nutrition counselling and pre-habilitation programs to early recovery after surgery (ERAS) pathways may help decrease the impact of these modifiable variables on postoperative outcomes. Further studies are required to assess that impact.

Declarations

Ethics approval and consent to participate: The study was approved by the Penn State College of Medicine Institutional Review Board (Study no: 7024, approval date: 03/28/2017 and a waiver for patient consent was granted.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

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Authors' contributions:

All authors have read and approved the manuscript.

AKM Analyzed the data and wrote the initial draft as well as edited the manuscript.

MB Collected and analyzed the data and edited the manuscript.

PMS Analyzed the data and edited the manuscript

AB Analyzed the data and edited the manuscript

KK Conceptualized the study, collected and analyzed the data and edited the manuscript.

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Abbreviations

ACS NSQIP⁰ American College of Surgeons National Surgical Quality Improvement Program

SRC surgical risk calculator

ASA American Society of Anesthesiologists

BMI body mass index

SD standard deviations

OR odds ratio

CI confidence interval

VA veterans affairs

PMP preoperative mortality predictor

ACC American College of Cardiology

AHA American Heart Association

ERAS early recovery after surgery

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Tables

Table 1. Univariable and Multivariable Logistic Regression Analysis of NSQIP variables and association with postoperative mortality.

Variable	n	Postop death within 30 days (# of cases)	Univariable OR (95% CI)	Multivariable OR (95% CI)
Total	5254	33		
Age (%)				
Mean Age (SD)	57.7 ± 15.1			
≤ 65	3432 (65.3)	12	1	1
> 65	1822 (34.7)	21	1.06 (1.03, 1.09)	1.01 (0.98, 1.06)
Gender (%)				
Female	2524 (48.0)	11	1	
Male	2730 (52.0)	22	1.86 (0.90, 3.84)	1.68 (0.65, 4.31)
Procedure Duration (%)				
Mean Duration (SD)	232.6 ± 151.4			
< 6 hours	4372 (83.2)	17	1	1
≥ 6 hours	882 (16.8)	16	1	1
ASA Classification (%)				
ASA I + II	1795 (34.2)	1	1	1
ASA III + IV	3459 (65.8)	32	4.07 (2.12, 7.83)	16.75 (2.29, 122.69)
Total	5245			
BMI (%)			1.03 (0.96, 1.09)	
Mean BMI (SD)**	31.7 ± 9.0			
< 30	2651 (50.5)	10	1	1

≥ 30	2594 (49.5)	13	0.96 (0.91, 1.00)	1.03 (0.96, 1.10)
Total	5254			
IDDM	353 (6.7)	1	0.51 (0.07, 3.75)	0.31 (0.04, 2.60)
NIDDM	599 (11.4)	8	2.41 (1.08, 5.40)	2.00 (0.71, 5.65)
Smoker	1021 (19.4)	12	2.39 (1.17, 4.86)	2.27 (0.82, 6.32)
Presence of Dyspnea	713 (13.6)	8	2.29 (1.09, 4.83)	1.74 (0.69, 4.40)
FHS-Partial Dependent	69 (1.3)	2	5.13 (1.20, 21.88)	1.47(0.18,12.29)
FHS-Total Dependent	4 (0.1)	1	57.23 (5.79, 566)	38.52 (2.46, 604.12)
COPD	314 (6.0)	6	3.54 (1.45, 8.65)	1.21 (0.34, 4.27)
HTN Requiring Med	2693 (51.3)	24	2.55 (1.18, 5.50)	1.70 (0.58, 4.94)
Dialysis	31 (0.6)	1	5.41 (0.72, 40.86)	5.97 (0.54, 66.38)
Disseminated Cancer	319 (6.1)	4	2.15 (0.75, 6.15)	1.34 (0.42, 4.24)
Weight Loss	309 (5.9)	6	3.61 (1.48, 8.80)	1.59 (0.50, 5.10)
Sodium abnormality	223 (4.2)	1	0.48 (0.06, 3.46)	–
Creatinine > 1.2	575 (13.0)	7	1.87 (0.71, 4.90)	–
Albumin < 3.5	253 (10.0)	8	4.93 (2.07, 11.75)	3.76 (1.35, 10.44)
Total Bilirubin > 1.2	119 (5.2)	1	1.00 (0.57, 1.73)	–
Hematocrit < 30	131 (2.7)	2	0.92 (0.86, 0.98)	0.99 (0.91, 1.08)
INR > 1.2	191 (7.7)	2	1.16 (0.15, 8.65)	–
Hospital length of stay				

Mean length (SD)	4.7 ± 4.6			
Length of stay <6 days	4199 (79.9)	15	1	1
Length of stay ≥7 days	1055 (20.1)	18	1.06 (1.03, 1.09)	1.01 (0.96, 1.05)

Number in parenthesis is the percentage of total cases pertaining to that group and variable.

Chosen references are indicated by number 1. For preoperative diagnoses, a chosen reference is not having the diagnosis ex. no diabetes, non-smoker, no dyspnea, etc. This is not reported on the table. For preoperative laboratory results, a chosen reference is the normal value of the laboratory test (serum sodium 135-145 mEq/L, creatinine <1.2 mg/dl, albumin >3.5 g/dl, Total bilirubin <1.2 mg/dl, hematocrit >30, and INR <1.2). Normal values are not reported in the table.

Covariates for the multivariable logistic regression analysis include all of those with a statistically significant OR.

Abbreviations: ASA, American Society of Anesthesiology; ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program; OR, Odds Ratio; CI, Confidence Interval; SD, Standard Deviation; BMI, Body Mass Index; IDDM, Insulin Dependent Diabetes Mellitus; NIDDM, Non-Insulin Dependent Diabetes Mellitus; FHS, Functional Health Status; COPD, Chronic Obstructive Pulmonary Disease; Med, Medication; HTN, Hypertension; INR, International Normalized Ratio

** BMI was not recorded for 9 patients

Table 2. Percentage of Cases for each Surgical Specialty Reported to have postoperative mortality.

Surgical Specialty	Number of patients	Postoperative death within 30 days n(%)
General	3270	23 (0.7)
Urology	1185	2 (0.2)
Vascular	306	4 (1.3)
Thoracic	247	3 (1.2)
Plastic	212	0
Otolaryngology	34	1 (2.9)

Percentages were calculated from the total cases from each individual specialty.

Supplementary Files

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