Published in final edited form as:

Am J Surg. 2018 September ; 216(3): 487–491. doi:10.1016/j.amjsurg.2018.02.015.

The Negative Effect of Perioperative Red Blood Cell Transfusion on Morbidity and Mortality After Major Abdominal Operations

Nathan R. Elwood, MD^{1,4}, Allison N. Martin, MD MPH^{1,4}, Florence E. Turrentine, PhD RN^{1,2}, R. Scott Jones, MD MS^{1,2}, and Victor M. Zaydfudim, MD MPH^{1,2,3}

¹Department of Surgery, University of Virginia, Charlottesville, VA

²Surgery Outcomes Research Center, University of Virginia, Charlottesville, VA

³Division of Surgical Oncology, University of Virginia, Charlottesville, VA

⁴The first two authors contributed equally to the manuscript

Abstract

Background—This study aims to test associations between perioperative blood transfusion and postoperative morbidity and mortality after major abdominal operations.

Methods—The 2014 ACS NSQIP dataset was queried for all patients who underwent one of the ten major abdominal operations. Separate multivariable regression models, were developed to evaluate the independent effects of perioperative blood transfusion on morbidity and mortality.

Results—Of 48,854 patients in the study cohort, 4,887 (10%) received a blood transfusion. Rates of transfusion ranged from 4% for laparoscopic gastrointestinal resection to 58% for open AAA. After adjusting for significant effects of NSQIP-estimated probabilities, transfusion was independently associated with morbidity and mortality after open AAA repair (OR=1.99/14.4 respectively, $p = 0.010$), esophagectomy (OR=2.80/3.0, $p < 0.001$), pancreatectomy (OR=1.88/3.01, $p < 0.001$), hepatectomy (OR=2.82/5.78, $p < 0.001$), colectomy (OR=2.15/3.17, $p < 0.001$), small bowel resection (OR=2.81/3.83, $p = 0.004$), and laparoscopic gastrointestinal operations (OR=2.73/4.05, $p < 0.001$).

Conclusions—Perioperative blood transfusion is independently associated with an increased risk of morbidity and mortality after most major abdominal operations.

Keywords

Blood transfusion; abdominal surgery; surgical outcomes; morbidity; mortality

Corresponding Author: Victor M. Zaydfudim, MD, MPH, Assistant Professor of Surgery, Division of Surgical Oncology, PO Box 800709, University of Virginia, Charlottesville, VA 22908-0709, Phone: (434) 924-0391, Fax: (434) 982-6552, vz8h@virginia.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Disclosures: The authors have no conflicts of interest to disclose.

Introduction

Blood transfusion is a common clinical intervention, with more than 11 million units of packed red blood cells administered annually, and has been identified by the Joint Commission as among the most overused inpatient procedures^{1,2}. A number of clinical studies have demonstrated detrimental effects of intraoperative and postoperative blood transfusions on patient outcomes after cardiac surgery and cancer resections. Immunomodulatory effects of blood products^{3,4} may increase rates of infectious complications as well as worse long-term oncologic outcomes in transfused patients⁵⁻⁸.

The association of blood transfusion with worse outcomes in patients undergoing cardiac surgery prompted the development of guidelines to minimize the prevalence of transfusion during the perioperative period for patients requiring cardiac operations⁹⁻¹³. Recent studies have also suggested increased morbidity in patients receiving blood transfusions across surgical specialties^{14,15}. Even among trauma patients, a group in whom transfusions are often life-saving, overuse of blood transfusions has been associated with an increase the risk of infection and mortality, after controlling for multiple markers of injury severity and degree of shock¹⁶⁻¹⁸. More restrictive transfusion practices have been advocated in non-surgical patients, as well¹⁹⁻²³.

Two studies predominate investigation of perioperative blood transfusion in general surgery. Both used the data from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database to evaluate the associations between intraoperative red blood cell transfusion and outcomes^{14,15}. Changes in ACS NSQIP data definitions and collection related to red blood cell transfusions and patient selection criteria in these studies limit applicability of these data to patients selected for major abdominal operations. We aimed to evaluate the effect of perioperative blood transfusion on postoperative morbidity and mortality after major abdominal operations.

Materials and Methods

Patient characteristics and data definitions

The ACS NSQIP is a risk-adjusted, independently collected surgical database supported by American College of Surgeons. Independent Surgical Clinical Reviewers at each participating institution abstract standardized, predetermined, and pertinent perioperative risk factors, laboratory values, and 30-day postoperative outcomes using standardized definitions for selected general surgery, vascular surgery and surgical sub-specialty operations²⁴. The 2014 ACS NSQIP Participant Use File (PUF), a de-identified aggregate dataset of 750,397 cases submitted from 517 hospitals, was queried for all patients undergoing any of the following ten categories of major, elective abdominal operations: open abdominal aortic aneurysm repair, esophagectomy, gastrectomy, pancreatectomy, hepatectomy, colectomy, proctectomy, small bowel resection, abdominal tumor resection, and laparoscopic gastrointestinal operation. Abdominal tumor resection encompassed a variety of operations for intra-abdominal tumors including benign and malignant diagnoses such as cystic neoplasms and sarcomas. Laparoscopic gastrointestinal resection included laparoscopic bowel operations including small bowel and colon resections. These procedures

were selected a priori as intra-abdominal major operations associated with a high rate of blood transfusion. Laparoscopic and open bariatric operations and hernia repairs were not included given procedure heterogeneity and significant procedure-specific risk profile of individual operation. Emergent operations and patients with severe pre-operative illness defined as American Society of Anesthesiologists (ASA) 4 or 5 classification were specifically excluded to avoid confounding. Trauma and pediatric patients are not included in the ACS NSQIP PUF. Patient level demographic and clinical characteristics, including age, race, sex, body-mass index (BMI in kg/m²), co-morbid conditions (including smoking and diabetes), preoperative serum albumin (g/dL), ASA classification, operative time, vital status, and ACS NSQIP-calculated predicted risk of morbidity and mortality were summarized and included in the dataset.

ACS NSQIP data summarizes the number of red blood cell transfusions up to 72 hours following start time of the operation. Thus, this study evaluates the effects associated with any red blood cell transfusion from the beginning of the operation through the 72-hour immediate postoperative period. The primary outcome tested the effect of perioperative transfusion on 30-day mortality, defined as any death during the inpatient admission or within 30 days of operation. The secondary outcome tested the effect of perioperative transfusion on 30-day morbidity. 30-day morbidity was defined as the occurrence of any of the following ACS NSQIP defined postoperative complications within 30 days of the index procedure: wound-related (e.g.: wound dehiscence, organ space infection, deep incisional surgical site infection, superficial incisional surgical site infection), pulmonary (e.g.: pneumonia, unplanned intubation, mechanical ventilation >48 hours, pulmonary embolism), renal (e.g.: acute kidney injury requiring dialysis or progressive renal insufficiency), neurologic (e.g.: cerebrovascular accident), cardiac (e.g.: myocardial infarction, cardiac arrest, symptomatic arrhythmia), sepsis or septic shock, and unplanned re-operation.

Data analyses

Categorical variables were expressed as frequencies with associated percentages. Differences in the distribution of categorical clinical and demographic variables between transfused and non-transfused patients were assessed using Chi-squared. Continuous variables were expressed as median with interquartile range (IQR) and compared using Wilcoxon rank-sum test. Univariate logistic regression was used to evaluate the association between perioperative blood transfusion and occurrence of 30-day morbidity or mortality for each of the ten major abdominal operations. Operations with significant univariate associations between transfusion and perioperative morbidity or mortality, were included in sequential multivariable logistic regression models to test the independent effect of blood transfusion on morbidity or mortality. Multivariable model for each operation included adjustment for differences in NSQIP estimated probabilities of morbidity and mortality, respectively. The NSQIP estimated probabilities of morbidity and mortality were used as an overall risk adjustment for all clinically relevant patient-specific variables included in ACS NSQIP risk adjustment prediction models²⁵⁻²⁷. These estimated probabilities adjust for pertinent demographic and clinical covariates and are used in calculating ACS NSQIP adjusted risk. Inclusion of estimated probabilities in multivariable modeling allows for statistical adjustment for clinically meaningful confounders without necessity to use

multiple individual variable components and risking model overfit or multiple comparisons. The discriminatory capacity of the multivariable logistic regression models was assessed using the C statistic. The threshold for statistical significance was set at an alpha level of 0.05 for all comparisons. STATA version 14.4 (StataCorp LP, College Station, TX) software was used for all data management and statistical analysis.

Results

Patient demographics and proportions of transfusion

A total of 48,854 patients were included in the study. Frequencies of individual operations are summarized in Figure 1. The overall proportion of patients who had perioperative transfusion was 10.0% (4,887 patients). Demographic and clinical differences between patients who did and did not have a perioperative blood transfusion are summarized in Table 1. Overall, patients who received a blood transfusion were older, had higher preoperative ASA class, and required longer median operative time compared to non-transfused patients (all $p < 0.001$).

Administration of red blood cell transfusion varied by operation ($p < 0.001$, Table 1). Data summarizing blood transfusion by operation are summarized in Figure 2. Laparoscopic gastrointestinal resection was the only operation with a transfusion rate of less than 10%; proportion of transfusions for most operations varied between 10 and 20%.

Estimates of the impact of perioperative transfusion on morbidity

A total of 6,458 (13.2%) of patients had at least one postoperative morbidity within 30 days after the index operation. Univariate comparisons demonstrated significant associations between blood transfusion and morbidity for all operations (OR [95% CI] range 1.86 [1.18-2.90] for gastrectomy to 4.72 [2.78-7.99] for abdominal tumor resection, all $p < 0.007$), Table 2. Multivariable models were created for each operation to adjust for ACS NSQIP estimates of morbidity. Blood transfusion was associated with increased risk of morbidity after all operations with exception of gastrectomy (Table 2).

Estimates of the impact of perioperative transfusion on operative mortality

Five hundred and forty (1.1%) patients died within 30 days after index operation or during initial post-operative hospitalization. Univariate comparisons demonstrated a statistically significant association between blood transfusion and mortality for all operations except proctectomy and abdominal tumor resection (Table 3). For the remaining eight operations, OR [95% CI] ranged from 3.43 [1.29-9.11] for gastrectomy to 15.9 [2.13-119.5] for open AAA repair, (all $p < 0.013$). Mortality was significantly associated with blood transfusion after multivariable adjustment for all 8 of these operations (all $p < 0.027$; Table 3).

Discussion

This study uses retrospective ACS NSQIP data to evaluate population level effects of perioperative red blood cell transfusion administered within 72-hours after start of the operation on 30-day and/or in-hospital morbidity and mortality in patients who had major

abdominal operations. These data demonstrate that after multivariable adjustment for clinically meaningful ACS NSQIP probabilities of morbidity and mortality, blood transfusion remains an important independent factor associated with risk of morbidity and mortality for most major abdominal operations. Both morbidity and mortality were independently associated with perioperative blood transfusion after open AAA repair, esophagectomy, pancreatectomy, hepatectomy, colectomy, small bowel resection, and laparoscopic gastrointestinal resection. Blood transfusion was independently associated with mortality, but not morbidity, after gastrectomy. Morbidity, but not mortality, was associated with blood transfusions after proctectomy and abdominal tumor resection.

Previous studies described associations between blood transfusion and post-operative outcomes particularly after hepatobiliary surgery including pancreatectomy^{28,29}, and hepatectomy^{30,31,34}, as well as after gastric and colorectal cancer resections^{32,33}. Data in this study corroborate these published findings and also highlight independent risk of morbidity and mortality associated with perioperative blood transfusions, in a broader population of major abdominal surgery patients. Importantly, independent risk associated with blood transfusion is present not only in the major vascular, hepatobiliary, and open gastrointestinal surgery, but also in patients who have minimally invasive, laparoscopic, intestinal resections.

Two previous studies examined population-level associations between blood transfusion and morbidity and mortality in non-cardiac surgery patients^{14,15}. This study has a number of important differences which improve applicability of these data to patients scheduled for major abdominal surgery. First, nine of ten selected operations included patients who had major intra-abdominal operations; the tenth group included patients who had well-established minimally invasive operations and were used to compare risk between laparoscopic and open gastrointestinal surgery. Notably, while there were fewer blood transfusions after minimally invasive operations, independent risk associated with blood transfusion was similar. Second, a more precise definition of perioperative blood transfusion is used in this study. While previous studies used a blood transfusion definition which was limited to intra-operative use of blood or if >4 units of packed red blood cells were administered within 72 hours after operation, ACS NSQIP patient cohort described in our data has an improved definition of red blood cell transfusion which summarizes any blood administration in any patient during any time between start of the operation and 72 hours after surgery. This modified definition improves data capture of patients who had a blood transfusion in the perioperative period. Third, we excluded all patients who had emergency operations and patients with ASA 4 to specifically exclude confounding associated with relatively rare and high-risk patients. While trauma patient population is not included in this database, select group of patients who are at the extremes of risk are better evaluated with more granular data than population based approach.

Limitations of this study are those inherent to the retrospective population-based analysis. Neither the indication nor the necessity of administration of blood transfusion can be ascertained for each individual patient. The number of units transfused for individual patient is not available in the ACS NSQIP PUF used in this study. Additionally, the ACS NSQIP program only collects data on 30-day outcomes or patient specific outcomes related to initial hospitalization if it exceeds 30 day. As such, possible effect of blood transfusion on

oncologic outcomes cannot be studied with this data set. Finally, no retrospective observational study can determine the causal relationship between transfusion and outcome.

Conclusions

Blood transfusion during the perioperative period is independently associated with morbidity and mortality for most major abdominal operations. Limiting the use of blood products in the perioperative period should improve surgical outcomes in this patient population. Further studies can determine appropriate transfusion parameters, allow better informed clinical decision-making, and minimize the harmful effects of blood transfusion.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. This study was supported in part by funding support provided by the Institutional National Research Service Award T32 CA 163177 from the National Cancer Institute to ANM and Loan Repayment Program Award 1 L30 CA220861-01 from the National Cancer Institute to VMZ.

References

1. Ellingson KD, Sapiano MRP, Haass KA, et al. Continued decline in blood collection and transfusion in the United States-2015. *Transfusion*. 2017; 57(Suppl 2):1588–98. [PubMed: 28591469]
2. The Joint Commission. Proceedings from the National Summit on Overuse. Sep 24.2012
3. Blajchman MA. Immunomodulation and blood transfusion. *Am J Ther*. 2002; 9:389–95. [PubMed: 12237730]
4. Raghavan M, Marik PE. Anemia, allogenic blood transfusion, and immunomodulation in the critically ill. *Chest*. 2005; 127:295–307. [PubMed: 15653997]
5. Amato A, Pescatori M. Perioperative blood transfusions for the recurrence of colorectal cancer. *Cochrane Database Syst Rev*. 2006:CD005033. [PubMed: 16437512]
6. Braga M, Vignali A, Radaelli G, Gianotti L, Di Carlo V. Association between perioperative blood transfusion and postoperative infection in patients having elective operations for gastrointestinal cancer. *Eur J Surg*. 1992; 158:531–6. [PubMed: 1360824]
7. Kneuert PJ, Patel SH, Chu CK, et al. Effects of perioperative red blood cell transfusion on disease recurrence and survival after pancreaticoduodenectomy for ductal adenocarcinoma. *Ann Surg Oncol*. 2011; 18:1327–34. [PubMed: 21369744]
8. Ojima T, Iwahashi M, Nakamori M, et al. Association of allogeneic blood transfusions and long-term survival of patients with gastric cancer after curative gastrectomy. *J Gastrointest Surg*. 2009; 13:1821–30. [PubMed: 19655208]
9. Engoren MC, Habib RH, Zacharias A, Schwann TA, Riordan CJ, Durham SJ. Effect of blood transfusion on long-term survival after cardiac operation. *Ann Thorac Surg*. 2002; 74:1180–6. [PubMed: 12400765]
10. Murphy GJ, Reeves BC, Rogers CA, Rizvi SI, Culliford L, Angelini GD. Increased mortality, postoperative morbidity, and cost after red blood cell transfusion in patients having cardiac surgery. *Circulation*. 2007; 116:2544–52. [PubMed: 17998460]
11. Scott BH, Seifert FC, Grimson R. Blood transfusion is associated with increased resource utilisation, morbidity and mortality in cardiac surgery. *Ann Card Anaesth*. 2008; 11:15–9. [PubMed: 18182754]

12. Society of Thoracic Surgeons Blood Conservation Guideline Task F. Ferraris VA, Ferraris SP, et al. Perioperative blood transfusion and blood conservation in cardiac surgery: the Society of Thoracic Surgeons and The Society of Cardiovascular Anesthesiologists clinical practice guideline. *Ann Thorac Surg.* 2007; 83:S27–86. [PubMed: 17462454]
13. Hajjar LA, Vincent JL, Galas FR, et al. Transfusion requirements after cardiac surgery: the TRACS randomized controlled trial. *JAMA.* 2010; 304:1559–67. [PubMed: 20940381]
14. Bernard AC, Davenport DL, Chang PK, Vaughan TB, Zwischenberger JB. Intraoperative transfusion of 1 U to 2 U packed red blood cells is associated with increased 30-day mortality, surgical-site infection, pneumonia, and sepsis in general surgery patients. *J Am Coll Surg.* 2009; 208:931–7. 7 e1–2. discussion 8–9. [PubMed: 19476865]
15. Ferraris VA, Davenport DL, Saha SP, Austin PC, Zwischenberger JB. Surgical outcomes and transfusion of minimal amounts of blood in the operating room. *Arch Surg.* 2012; 147:49–55. [PubMed: 22250113]
16. Claridge JA, Sawyer RG, Schulman AM, McLemore EC, Young JS. Blood transfusions correlate with infections in trauma patients in a dose-dependent manner. *Am Surg.* 2002; 68:566–72. [PubMed: 12132734]
17. Dunne JR, Malone DL, Tracy JK, Napolitano LM. Allogenic blood transfusion in the first 24 hours after trauma is associated with increased systemic inflammatory response syndrome (SIRS) and death. *Surg Infect (Larchmt).* 2004; 5:395–404. [PubMed: 15744131]
18. Malone DL, Dunne J, Tracy JK, Putnam AT, Scalea TM, Napolitano LM. Blood transfusion, independent of shock severity, is associated with worse outcome in trauma. *J Trauma.* 2003; 54:898–905. discussion-7. [PubMed: 12777902]
19. Callum JL, Waters JH, Shaz BH, Sloan SR, Murphy MF. The AABB recommendations for the Choosing Wisely campaign of the American Board of Internal Medicine. *Transfusion.* 2014; 54:2344–52. [PubMed: 25100209]
20. Goodnough LT, Maggio P, Hadhazy E, et al. Restrictive blood transfusion practices are associated with improved patient outcomes. *Transfusion.* 2014; 54:2753–9. [PubMed: 24995770]
21. Holst LB, Haase N, Wetterslev J, et al. Lower versus higher hemoglobin threshold for transfusion in septic shock. *N Engl J Med.* 2014; 371:1381–91. [PubMed: 25270275]
22. Salpeter SR, Buckley JS, Chatterjee S. Impact of more restrictive blood transfusion strategies on clinical outcomes: a meta-analysis and systematic review. *Am J Med.* 2014; 127:124–31 e3. [PubMed: 24331453]
23. Villanueva C, Colomo A, Bosch A, et al. Transfusion strategies for acute upper gastrointestinal bleeding. *N Engl J Med.* 2013; 368:11–21. [PubMed: 23281973]
24. Khuri SF, Henderson WG, Daley J, et al. Successful implementation of the Department of Veterans Affairs' National Surgical Quality Improvement Program in the private sector: the Patient Safety in Surgery study. *Ann Surg.* 2008; 248:329–36. [PubMed: 18650645]
25. Bilimoria KY, Liu Y, Paruch JL, et al. Development and evaluation of the universal ACS NSQIP surgical risk calculator: a decision aid and informed consent tool for patients and surgeons. *J Am Coll Surg.* 2013; 217:833–42. e1–3. [PubMed: 24055383]
26. Cohen ME, Ko CY, Bilimoria KY, et al. Optimizing ACS NSQIP modeling for evaluation of surgical quality and risk: patient risk adjustment, procedure mix adjustment, shrinkage adjustment, and surgical focus. *J Am Coll Surg.* 2013; 217:336–46 e1. [PubMed: 23628227]
27. Liu Y, Cohen ME, Hall BL, Ko CY, Bilimoria KY. Evaluation and Enhancement of Calibration in the American College of Surgeons NSQIP Surgical Risk Calculator. *J Am Coll Surg.* 2016; 223:231–9. [PubMed: 27212006]
28. Hallet J, Mahar AL, Tsang ME, et al. The impact of peri-operative blood transfusions on post-pancreatectomy short-term outcomes: an analysis from the American College of Surgeons National Surgical Quality Improvement Program. *HPB (Oxford).* 2015; 17:975–82. [PubMed: 26301741]
29. Sun RC, Button AM, Smith BJ, Leblond RF, Howe JR, Mezhir JJ. A comprehensive assessment of transfusion in elective pancreatectomy: risk factors and complications. *J Gastrointest Surg.* 2013; 17:627–35. [PubMed: 23423430]

30. Kim S, Maynard EC, Shah MB, et al. Risk factors for 30-day readmissions after hepatectomy: analysis of 2444 patients from the ACS-NSQIP database. *J Gastrointest Surg.* 2015; 19:266–71. [PubMed: 25451735]
31. Pessaux P, van den Broek MA, Wu T, et al. Identification and validation of risk factors for postoperative infectious complications following hepatectomy. *J Gastrointest Surg.* 2013; 17:1907–16. [PubMed: 23661000]
32. Halabi WJ, Jafari MD, Nguyen VQ, et al. Blood transfusions in colorectal cancer surgery: incidence, outcomes, and predictive factors: an American College of Surgeons National Surgical Quality Improvement Program analysis. *Am J Surg.* 2013; 206:1024–32. discussion 32-3. [PubMed: 24296103]
33. Elmi M, Mahar A, Kagedan D, et al. The impact of blood transfusion on perioperative outcomes following gastric cancer resection: an analysis of the American College of Surgeons National Surgical Quality Improvement Program database. *Can J Surg.* 2016; 59:322–9. [PubMed: 27668330]
34. Martin AN, Kerwin MJ, Turrentine FE, et al. Blood transfusion is an independent predictor of morbidity and mortality after hepatectomy. *J Surg Res.* 2016; 206:106–12. [PubMed: 27916348]

Brief Summary

In this study, the independent effects of perioperative blood transfusion on postoperative morbidity and mortality were estimated for ten different major abdominal operations. Perioperative blood transfusion was independently associated with an increased risk of morbidity and mortality after most major abdominal operations.

Research Highlights

- Ten percent of patients who have major abdominal operations receive perioperative blood transfusions.
- Independent effects of perioperative blood transfusion within 72 hours of index operation were evaluated.
- Blood transfusion is associated with morbidity after 9 of 10 major abdominal operations studied.
- Blood transfusion is associated with mortality after 8 of 10 major abdominal operations studied.

Elective Major Abdominal Operations (N = 48,854)

Figure 1.
Distribution of patient specific intra-abdominal operations included in the study (n=48,854)

Proportion of Patients Receiving Perioperative Transfusion (N = 48,854)

Figure 2.
Proportion of patients who had red blood cell transfusion for each operation

Table 1

Patient demographics stratified by transfusion status

Variable	Transfused (N = 4,887)	Not transfused (N = 43,967)	p-value
Age, Median (IQR)	65 (55–73)	61 (51–70)	<0.001
Female Sex, N (%)	2565 (52.5)	22380 (50.9)	0.036
BMI, Median (IQR)	26.7 (23.0–31.2)	27.6 (24.0–31.9)	<0.001
Race/Ethnicity, N (%)			<0.001
White	3460 (81.7)	32442 (84.2)	
Black	487 (11.5)	3544 (9.20)	
Asian	263 (6.21)	2231 (5.79)	
Hispanic	25 (0.59)	308 (0.80)	
Operation type, N (%)			<0.001
Abdominal Aortic Aneurysm	308 (6.30)	219 (0.50)	
Esophagectomy	143 (2.93)	930 (2.12)	
Gastrectomy	115 (2.35)	886 (2.02)	
Pancreatectomy	1006 (20.6)	4691 (10.7)	
Hepatectomy	651 (13.3)	3101 (7.05)	
Colectomy	1134 (23.2)	8822 (20.1)	
Proctectomy	428 (8.76)	2203 (5.01)	
Small bowel resection	113 (2.31)	1062 (2.42)	
Tumor resection	132 (2.70)	722 (1.64)	
Laparoscopic GI resection	857 (17.5)	21331 (48.5)	
Diabetes, N (%)	1023 (20.9)	6508 (14.8)	<0.001
Smoking, N (%)	822 (16.8)	7501 (17.1)	0.672
Preoperative albumin, Median (IQR)	3.8 (3.3–4.1)	4.0 (3.7–4.3)	<0.001
ASA Class, N (%)			<0.001
ASA Class 1	41 (0.84)	1092 (2.49)	
ASA Class 2	1178 (24.2)	19880 (45.3)	
ASA Class 3	3656 (75.0)	22959 (52.3)	
Operative time, Median (IQR)	274 (178–390)	180 (125–262)	<0.001
30-Day mortality, N (%)	203 (4.15)	337 (0.77)	<0.001
NSQIP-estimated probability morbidity	0.21 (0.15–0.28)	0.13 (0.089–0.19)	<0.001
NSQIP-estimated probability mortality	0.011 (0.0047–0.024)	0.0035 (0.0014–0.0088)	<0.001

IQR: interquartile range; BMI: body mass index; ASA: American Society of Anesthesiologists

Table 2
Univariable and multivariable analyses of associations between blood transfusion and morbidity

Procedure	Univariate OR	95% CI	p-value	Multivariable OR	95% CI	p-value
Open AAA Repair	2.16	1.34–3.47	0.002	1.99	1.23–3.22	0.005
Hepatectomy	3.63	2.98–4.41	<0.001	2.82	2.29–3.46	<0.001
Laparoscopic GI Resection	3.56	2.99–4.23	<0.001	2.73	2.28–3.27	<0.001
Small Bowel Resection	3.31	2.18–5.02	<0.001	2.81	1.82–4.34	<0.001
Colectomy	2.70	2.35–3.11	<0.001	2.15	1.86–2.48	<0.001
Esophagectomy	3.16	2.20–4.53	<0.001	2.80	1.93–4.05	<0.001
Pancreatectomy	2.16	1.87–2.50	<0.001	1.88	1.62–2.19	<0.001
Gastrectomy	1.86	1.18–2.90	0.007	1.49	0.93–2.36	0.094
Abdominal Tumor Resection	4.72	2.78–7.99	<0.001	3.48	1.98–6.13	<0.001
Proctectomy	3.07	2.44–3.87	<0.001	2.66	2.09–3.38	<0.001

AAA: abdominal aortic aneurysm; GI: gastrointestinal; OR: odds ratio; CI: confidence interval

Table 3

Univariable and multivariable analyses of associations between blood transfusion and mortality

Procedure	Univariate OR	95% CI	p-value	Multivariable OR	95% CI	p-value
Open AAA Repair	15.9	2.13–119.5	0.007	14.4	1.90–109.5	0.010
Hepatectomy	7.20	4.29–12.1	<0.001	5.78	3.41–9.81	<0.001
Small Bowel Resection	4.68	1.97–11.1	<0.001	3.83	1.54–9.57	0.004
Colectomy	4.53	3.11–6.58	<0.001	3.17	2.12–4.72	<0.001
Gastrectomy	3.43	1.29–9.11	0.013	3.06	1.14–8.23	0.027
Esophagectomy	3.97	1.91–8.25	<0.001	3.00	1.39–6.45	0.005
Laparoscopic GI Resection	5.50	3.41–8.86	<0.001	4.05	2.47–6.64	<0.001
Pancreatectomy	3.61	2.49–5.24	<0.001	3.01	2.05–4.42	<0.001
Proctectomy	1.48	0.48–4.50	0.50			
Abdominal Tumor Resection	1.83	0.19–17.7	0.60			

AAA: abdominal aortic aneurysm; GI: gastrointestinal; OR: odds ratio; CI: confidence interval