HHS Public Access

Author manuscript

J Surg Res. Author manuscript; available in PMC 2017 November 01.

Published in final edited form as:

J Surg Res. 2016 November ; 206(1): 106–112. doi:10.1016/j.jss.2016.07.013.

Blood Transfusion is an Independent Predictor of Morbidity and Mortality after Hepatectomy

Allison N. Martin, MD, MPH[a], **Matthew J. Kerwin, BS**[a], **Florence E. Turrentine, PhD, RN**[a,c], **Todd W. Bauer, MD**[a], **Reid B. Adams, MD**[a], **George J. Stukenborg, PhD**[b,c], and **Victor M. Zaydfudim, MD, MPH**[a,c]

[a]Department of Surgery, University of Virginia, Charlottesville, VA, USA

[b]Division of Patient Outcomes, Policy & Population Research, University of Virginia, Charlottesville, Virginia

[c]Surgical Outcomes Research Center, University of Virginia, Charlottesville, VA

Abstract

Background—Previous studies have indicated that blood transfusion is associated with increased risk of worse outcomes among patients selected for hepatectomy. However, the independent effect of transfusion has not been confirmed. We hypothesize that blood transfusion is an independent factor that affects outcomes in patients undergoing hepatectomy.

Materials and Methods—Patients at tertiary care center who underwent hepatectomy between 2006 and 2013 were identified and linked with the ACS-NSQIP PUF dataset. Multivariable logistic regression analysis was used to estimate the effect of blood transfusion on 30-day mortality and morbidity, adjusted for differences in extent of resection and estimated probabilities of morbidity and mortality.

Results—Among 522 patients in the study, 48 (9.2%) patients required perioperative blood transfusion within 72 hours of resection, and 172 (33%) underwent major hepatectomy. Indications for hepatectomy included metastatic neoplasm (n=229, 44%), primary hepatic neoplasm (n=108, 21%), primary extra-hepatic biliary neoplasm (n=23, 4%), and non-malignant indications (n=162, 31%). Eighty-eight (17%) patients had a postoperative morbidity. Blood transfusion was significantly associated with postoperative morbidity (OR 4.18, 95% CI 2.18–

Corresponding Author: Victor M. Zaydfudim, MD, MPH, Assistant Professor of Surgery, Section of Hepatobiliary and Pancreatic Surgery, Box 800709, University of Virginia, Charlottesville, VA 22908-0709, Phone: (434) 924-2839, Fax: (434) 982-4778, vz8h@virginia.edu.

Presented in part at the 11th Annual Academic Surgical Congress, February 2–4, 2016, Jacksonville, FL.

Authors' contributions:
Study concept and design: Martin, Turrentine, Stukenborg, Zaydfudim
Acquisition of data: Martin, Kerwin, Turrentine
Analysis and interpretation of data: Martin, Turrentine, Bauer, Adams, Stukenborg, Zaydfudim
Drafting of manuscript: Martin, Kerwin, Zaydfudim
Critical revisions: Turrentine, Bauer, Adams, Stukenborg

8.02, p=0.0001) and mortality (OR 14.5, 95% CI 3.08–67.8, p=001), after adjustment for the concurrent effect of NSQIP estimated probability of morbidity (OR 1.15, 95% CI 0.11–12.2, p=0.042). The extent of resection was not significantly associated with morbidity (OR 1.30, 95% CI 0.74–2.28, p=0.366) or mortality (OR 1.14, 95% CI 0.24–5.50, p=0.870).

Conclusions—Blood transfusion is a highly statistically significant independent predictor of morbidity and mortality after hepatectomy. Judicious use of perioperative transfusion is indicated in patients with benign and malignant indications for liver resection.

Keywords

hepatectomy; liver resection; blood transfusion; perioperative mortality; perioperative morbidity

1. Introduction

Prior to the 1980s, the perioperative mortality rate for hepatectomy was greater than 10%. Improvements in operative technique, perioperative and anesthetic care, and patient selection, has resulted in present-day mortality rates of less than 2–4% at experienced centers [1–4]. Improvement in technique and reduction in mortality has been demonstrated to be correlated with decrease in perioperative blood transfusion [5].

Hepatectomy remains a high-risk operation with estimated transfusion rates between 20 and 30% [6, 7]. Blood transfusion is associated with higher costs and increased risk of associated morbidity. Multiple recent studies have suggested worse oncologic outcomes most notably in patients with primary or metastatic malignancies leading to proposals for transfusion restrictions in patients undergoing hepatectomy [8, 9].

Despite the advancements in surgical technique, more extensive liver resections may be associated with greater transfusion requirements [10]. Whether blood transfusion represents an independent variable or a surrogate for more complex or extensive liver resection has not been well defined. We hypothesized an independent association between blood transfusion and postoperative morbidity and mortality in patients undergoing hepatectomy, regardless of extent of resection.

2. Materials and Methods

2.1 Patient selection criteria and outcome definitions

The present study utilized patient records obtained from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) public use file (PUF) linked with additional clinical information available from an institutional liver resection database. The NSQIP dataset is a comprehensive, national database that collects patient-level, Health Insurance Portability and Accountability Act (HIPAA) compliant data provided by participating hospitals. The University of Virginia Institutional Review Board for Health Sciences Research has approved this study (IRB-HSR #17477).

All adult patients ≥ age 18 who had hepatectomy between 2006 and 2013 were linked with the ACS NSQIP PUF dataset and included in this retrospective cohort study. Information

regarding the extent of liver resection was abstracted from patient records and categorized as subsegmentectomy, segmentectomy, bisegmentectomy, 2–3 segments resected, right hepatectomy, left hepatectomy and trisectionectomy. Major hepatectomy was categorized as resection of > 3 segments. Diagnoses were categorized as primary hepatic neoplasm, metastatic neoplasm to the liver, primary extra-hepatic biliary neoplasm, and non-malignant indication for resection. Perioperative transfusion was defined as administration of greater than or equal to 1 unit of packed red blood cells (PRBC) given from operative start up until 72 hours postoperatively. The definition for blood transfusion changed in 2010 and all patients between 2006 and 2009 (inclusive) were reviewed to capture complete 72 hour transfusion data. All operations were performed by hepatobiliary and/or liver transplant surgeons using low central venous pressure (CVP) anesthetic maneuvers. Inflow occlusion and method of parenchymal transection varied at the discretion of operating surgeon and extent/anatomic configuration of planned resection.

The NSQIP estimated probabilities of morbidity and mortality were obtained for each case. NSQIP calculates these estimated probabilities utilizing a hierarchical regression model that takes into account twenty-one patient-level factors and represents the probability that an individual will experience a mortal or morbid event based on these factors [11]. Patient specific probabilities of mortality and morbidity can also be estimated directly for clinical use with the ACS NSQIP Surgical Risk Calculator (http://riskcalculator.facs.org/). Mortality was defined as any death occurring within 30 days following the date of surgery or in-hospital mortality. Composite overall morbidity was defined as the occurrence of any of the following events: surgical site infection, wound disruption, pneumonia, unplanned intubation, pulmonary embolism, > 48 hour ventilator requirement, renal failure, urinary tract infection, stroke or cerebral vascular accident, cardiac arrest, myocardial infarction, deep venous thrombosis, or systematic sepsis.

2.2 Data analysis

Demographic and clinical factors for the patient cohort were summarized, including age, body mass index (BMI), race/ethnicity, sex, diabetes, smoking status, extent of hepatectomy, and diagnosis. Bivariable analysis was used to compare the distributions of selected patient characteristics between patient subgroups. The statistical significance of differences in the proportional distribution of categorical variables was assessed using both the Fisher's exact test and Chi-squared test, as appropriate. Distributional characteristics of categorical variables are expressed as frequencies and percentages for category values. The distributional characteristics of continuous variables are expressed using the median and interquartile range (IQR), and the statistical significance of differences in medians was assessed using the Mann-Whitney test. The threshold for statistical significance for each comparison was set at an alpha level of 0.05.

Multivariable logistic regression analysis was used to estimate the effect of blood transfusion on 30-day morbidity and mortality, adjusted for concurrent differences in the extent of resection, and for differences in the NSQIP estimated probabilities of morbidity and mortality, respectively. The NSQIP estimated probabilities of morbidity and mortality were used to include an overall adjustment for differences in morbidity and mortality risk. The

capacity of the multivariable logistic regression models to discriminate between patients with and without the predicted events was assessed using the C statistic. STATA version 14.1 (StataCorp LP, College Station, TX) software was used for data management and statistical analysis.

3. Results

3.1 Patient demographics and individual risk factors

Five hundred and twenty-two adult patients ≥18 years of age undergoing hepatectomy between 2006 and 2013 were included in this study. Forty-eight (9.2%) patients required a perioperative blood transfusion. The median age of patients who received blood transfusion was 61.4 years (IQR 52.9–70.0) and was not significantly different from the median age of non-transfused patients (58.1 years [IQR 49.9–67.8], p-value=0.184). There were no significant differences in the distributions of sex, BMI, or race between transfused and non-transfused patient groups (Table 1). The majority of patients underwent minor hepatectomy (N=350, 67%). Patients who had major hepatectomy were more likely to receive perioperative blood transfusion (13.4% versus 7.1%, p=0.021). Indications for resection did not differ between the two patient groups (p=0.176) and included primary hepatic neoplasm (N=108, 21%), metastatic neoplasm (N=229, 44%), primary extra-hepatic biliary neoplasm (N=23, 4%), and non-malignant diagnoses (N=162, 31%).

3.2 Post-hepatectomy morbidity and mortality

Eighty-eight patients (17%) had one or more postoperative morbidities. The most common postoperative morbidity was a surgical site infection (42 patients, 8.1%), followed by prolonged mechanical ventilation (20 patients, 3.8%). Table 2 summarizes individual causes of morbidity. After adjusting for the effects of NSQIP estimated probability of morbidity (OR = 1.15, 95% CI 0.11–12.2, p=0.042) and for the extent of resection (OR = 1.30, 95% CI 0.74–2.28, p=0.366), perioperative blood transfusion was independently associated with a statistically significant increase in postoperative morbidity (OR = 4.18, 95% CI 2.18–8.02, p=0.0001, see Table 3).

Eight (2%) patients died within 30 days of operation or during initial inpatient hospitalization (if exceeding 30 days). After adjusting for the effects of NSQIP estimated probability of mortality (OR = 2.16, 95% CI $2.2e^{6}$–$2.2e^{12}$, p=0.276) and extent of resection (OR = 1.14, 95% CI 0.24–5.50, p=0.870), perioperative blood transfusion was independently associated with significant increase in postoperative mortality (OR = 14.5, 95% CI 3.08–67.8, p=0.001, see Table 4). The morbidity model had a C-statistic of 0.68 indicating moderate capacity to discriminate between patients with any 30-day morbidity event. Mortality model had a C-statistic of 0.88 indicating good discrimination between patients with and without 30-day mortality.

4. Discussion

Blood transfusion is associated with increased risk of morbidity and mortality after hepatectomy, independent of differences in patient comorbidities and extent of resection. The negative effects of blood transfusion in morbidity and mortality models have large effect

sizes and strongly significant independent results. In addition to the well-described transfusion-associated risks of lung injury and hemolytic transfusion reaction, transfusion has been associated with poor immune-modulated perioperative outcomes. The relationship between blood transfusion and higher risk for cancer recurrence and cancer-related death has been demonstrated in a recent described in a population of patients undergoing hepatobiliary resection for malignancy [12]. While the precise impact of individual variables is difficult to quantify, it is likely that negative effects of blood transfusion and postoperative morbidity are additive [13].

Not surprisingly, a higher proportion of patients who had major liver resection required blood transfusion than patients who had a minor hepatectomy. In addition, the revised 72-hour NSQIP-reported blood transfusion variable allows for improved data recording and outcome estimates compared to the pre-2010 variable, which only captured blood transfusions greater than 4 units. The interaction between extent of resection and blood transfusion has been proposed previously [8]. In addition, other surrogates of more extensive operation including intraoperative management, tumor size, and associated resections have been described [14, 15]. Postoperative complications including bile leakage have also been associated with blood transfusion [16]. We recoded extent of liver resections using individual patient operative reports, rather than CPT codes, to discriminate between major and minor hepatectomy. The data in this study support an independent negative effect of blood transfusion on postoperative outcomes.

NSQIP-estimated probabilities of morbidity and mortality are important covariates in both morbidity and mortality models. Infectious and pulmonary complications were most common in our patient population. The NSQIP-estimated probability of morbidity has a statistically significant effect independent of other covariates. The 30-day outcome probabilities are calculated using parameters estimated with random intercept, fixed slope hierarchical models including a series of 21 perioperative risk factors [11]. Use of these summary probability estimates is useful in developing multivariable models and adjustment for patient specific risk, particularly among limited datasets, such as our 522 patient cohort.

Previous studies support reducing blood transfusion in liver resection patients [9]. The current study was conducted on a population of patients with both malignant and non-malignant diagnoses. Almost a third of the patients in the study did not have a malignancy. Although multiple studies examining associations between liver resection for malignancy and blood transfusions have demonstrated the adverse impact on oncologic outcomes when blood products are used [17–21], few studies have established whether or not blood transfusion poses an additional risk for hepatectomy patients undergoing resection for a non-oncologic indication [1, 22]. In our study, transfusion use did not differ between patients undergoing resection for malignancy and non-malignant diagnoses. We did not include diagnosis variable in the multivariable models. Inclusion of diagnoses variable did not improve performance of morbidity model (C-statistic 0.67 with and without inclusion of diagnosis), did not alter the results of the morbidity model, and resulted in poor performance of mortality model since there were no deaths in patients with non-malignant diagnosis.

While both models demonstrate highly significant negative effects of perioperative blood transfusion on morbidity and mortality after liver resection, the effects of minimally invasive operative techniques were not included. Laparoscopic, and more recently robotic, hepatectomy has increased in the last decade and has been reported to be safe and acceptable when used at experienced centers [23, 24]. A minority of patients at our center had minimally invasive hepatectomy. With implementation of the targeted hepatobiliary modules including targeted hepatectomy data collection, the population-level associations between minimally invasive hepatectomy, transfusions, and outcomes can be assessed in future investigations [25–27]. The 30-day NSQIP-defined follow-up period is another potential limitation. While a majority of postoperative complications likely occur within the included follow-up time frame, recent studies urge for extension of postoperative outcome reporting to a 90-day period [28, 29]. In addition, given retrospective institutional data abstraction and limitation of NSQIP data collection accurate and precise International Study Group of Liver Surgery definition of posthepatectomy liver failure and number of units of blood transfused cannot be included in this study.

Not surprisingly, patients undergoing major hepatectomy are more likely to receive a perioperative blood transfusion. Similarly preoperative anemia and intraoperative blood loss are associated with blood transfusion. A number of strategies have been described and implemented to decrease blood product use is liver surgery. Coordination of hepatic parenchymal transection with low central venous pressure anesthesia is critical for limiting blood loss during liver resection [30]. Multiple studies have confirmed importance of low CVP in decreasing intraoperative blood loss [14, 31]. Methods and utility of vascular inflow occlusion are more variable. Intermittent inflow occlusion as well as ischemic preconditioning followed by continuous occlusion during parenchymal transection have both been used with safety and success to minimize blood loss during resection [32]. Studies evaluating selective versus total vascular exclusion in addition to inflow occlusion focused on rare and complex resections requiring vascular control of the outflow [33, 34].

Growing evidence supports limiting blood transfusions in all patients including patients who need liver resections. Preoperative anemia has been associated with worse postoperative outcomes [35, 36] and multidisciplinary perioperative patient blood management strategies including preoperative hemoglobin optimization have been proposed [37]. Although other groups have developed simplified scoring models for predicting postoperative morbidity in hepatectomy [38], utilizing the online NSQIP calculator to carefully consider preoperative risk in conjunction with minimizing perioperative transfusion may result in decreased morbidity and mortality.

5. Conclusions

Blood transfusion is a highly statistically significant independent predictor of morbidity and mortality after hepatectomy. Judicious use of perioperative transfusion is indicated in patients with both benign and malignant indications for liver resection.

Acknowledgments

This study was supported in part by funding provided by the Institutional National Research Service Award T32 CA 163177 from the National Cancer Institute to A.N.M.

American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of a portion of data used herein; they have not verified and are not responsible for the statistical validity of the data analyses or the conclusions derived by the authors.

References

1. Poon RT, Fan ST, Lo CM, Liu CL, Lam CM, Yuen WK, et al. Improving perioperative outcome expands the role of hepatectomy in management of benign and malignant hepatobiliary diseases: analysis of 1222 consecutive patients from a prospective database. Ann Surg. 2004; 240(4):698–708. discussion -10. [PubMed: 15383797]
2. Wang CC, Iyer SG, Low JK, Lin CY, Wang SH, Lu SN, et al. Perioperative factors affecting long-term outcomes of 473 consecutive patients undergoing hepatectomy for hepatocellular carcinoma. Ann Surg Oncol. 2009; 16(7):1832–42. DOI: 10.1245/s10434-009-0448-y [PubMed: 19365625]
3. Newhook TE, LaPar DJ, Lindberg JM, Bauer TW, Adams RB, Zaydfudim VM. Morbidity and mortality of hepatectomy for benign liver tumors. Am J Surg. 2016; 211(1):102–8. DOI: 10.1016/j.amjsurg.2015.06.010 [PubMed: 26307421]
4. Wrighton LJ, O'Bosky KR, Namm JP, Senthil M. Postoperative management after hepatic resection. J Gastrointest Oncol. 2012; 3(1):41–7. DOI: 10.3978/j.issn.2078-6891.2012.003 [PubMed: 22811868]
5. Day RW, Brudvik KW, Vauthey JN, Conrad C, Gottumukkala V, Chun YS, et al. Advances in hepatectomy technique: Toward zero transfusions in the modern era of liver surgery. Surgery. 2015; doi: 10.1016/j.surg.2015.10.006
6. Ejaz A, Spolverato G, Kim Y, Frank SM, Pawlik TM. Identifying variations in blood use based on hemoglobin transfusion trigger and target among hepatopancreaticobiliary surgeons. J Am Coll Surg. 2014; 219(2):217–28. DOI: 10.1016/j.jamcollsurg.2014.02.033 [PubMed: 25038960]
7. Palavecino M, Kishi Y, Chun YS, Brown DL, Gottumukkala VN, Lichtiger B, et al. Two-surgeon technique of parenchymal transection contributes to reduced transfusion rate in patients undergoing major hepatectomy: analysis of 1,557 consecutive liver resections. Surgery. 2010; 147(1):40–8. DOI: 10.1016/j.surg.2009.06.027 [PubMed: 19733879]
8. Wehry J, Cannon R, Scoggins CR, Puffer L, McMasters KM, Martin RC. Restrictive blood transfusion protocol in liver resection patients reduces blood transfusions with no increase in patient morbidity. Am J Surg. 2015; 209(2):280–8. DOI: 10.1016/j.amjsurg.2014.06.016 [PubMed: 25305797]
9. Shiba H, Ishida Y, Fujiwara Y, Wakiyama S, Gocho T, Ito R, et al. Practice to minimize the use of blood products improve outcome after hepatic resection for hepatocellular carcinoma. Hepatogastroenterology. 2013; 60(127):1681–3. [PubMed: 24634937]
10. Simillis C, Li T, Vaughan J, Becker LA, Davidson BR, Gurusamy KS. A Cochrane systematic review and network meta-analysis comparing treatment strategies aiming to decrease blood loss during liver resection. Int J Surg. 2015; 23(Pt A):128–36. DOI: 10.1016/j.ijsu.2015.09.064 [PubMed: 26432546]
11. Bilimoria KY, Liu Y, Paruch JL, Zhou L, Kmiecik TE, Ko CY, 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(5):833–42. e1–3. DOI: 10.1016/j.jamcollsurg.2013.07.385 [PubMed: 24055383]
12. Ejaz A, Spolverato G, Kim Y, Margonis GA, Gupta R, Amini N, et al. Impact of blood transfusions and transfusion practices on long-term outcome following hepatopancreaticobiliary surgery. J Gastrointest Surg. 2015; 19(5):887–96. DOI: 10.1007/s11605-015-2776-5 [PubMed: 25707813]
13. Huang J, Tang W, Hernandez-Alejandro R, Bertens KA, Wu H, Liao M, et al. Intermittent hepatic inflow occlusion during partial hepatectomy for hepatocellular carcinoma does not shorten overall

survival or increase the likelihood of tumor recurrence. Medicine (Baltimore). 2014; 93(28):e288.doi: 10.1097/MD.0000000000000288 [PubMed: 25526466]

14. McNally SJ, Revie EJ, Massie LJ, McKeown DW, Parks RW, Garden OJ, et al. Factors in perioperative care that determine blood loss in liver surgery. HPB (Oxford). 2012; 14(4):236–41. DOI: 10.1111/j.1477-2574.2011.00433.x [PubMed: 22404261]
15. Pulitano C, Arru M, Bellio L, Rossini S, Ferla G, Aldrighetti L. A risk score for predicting perioperative blood transfusion in liver surgery. Br J Surg. 2007; 94(7):860–5. DOI: 10.1002/bjs.5731 [PubMed: 17380562]
16. Hong J, Zhang X, Luo R, Cai X. The clinical risk factors associated with postoperative bile leakage after hepatectomy: a meta-analysis. Minerva Med. 2016
17. Kimura N, Toyoki Y, Ishido K, Kudo D, Yakoshi Y, Tsutsumi S, et al. Perioperative blood transfusion as a poor prognostic factor after aggressive surgical resection for hilar cholangiocarcinoma. J Gastrointest Surg. 2015; 19(6):1194–5. DOI: 10.1007/s11605-015-2823-2 [PubMed: 25895979]
18. Stephenson KR, Steinberg SM, Hughes KS, Vetto JT, Sugarbaker PH, Chang AE. Perioperative blood transfusions are associated with decreased time to recurrence and decreased survival after resection of colorectal liver metastases. Ann Surg. 1988; 208(6):679–87. [PubMed: 3196088]
19. Yamamoto J, Kosuge T, Takayama T, Shimada K, Yamasaki S, Ozaki H, et al. Perioperative blood transfusion promotes recurrence of hepatocellular carcinoma after hepatectomy. Surgery. 1994; 115(3):303–9. [PubMed: 8128355]
20. Kooby DA, Stockman J, Ben-Porat L, Gonen M, Jarnagin WR, Dematteo RP, et al. Influence of transfusions on perioperative and long-term outcome in patients following hepatic resection for colorectal metastases. Ann Surg. 2003; 237(6):860–9. discussion 9–70. DOI: 10.1097/01.SLA.0000072371.95588.DA [PubMed: 12796583]
21. Hallet J, Tsang M, Cheng ES, Habashi R, Kulyk I, Hanna SS, et al. The Impact of Perioperative Red Blood Cell Transfusions on Long-Term Outcomes after Hepatectomy for Colorectal Liver Metastases. Ann Surg Oncol. 2015; 22(12):4038–45. DOI: 10.1245/s10434-015-4477-4 [PubMed: 25752895]
22. Coelho JC, Claus CM, Machuca TN, Sobottka WH, Goncalves CG. Liver resection: 10-year experience from a single institution. Arq Gastroenterol. 2004; 41(4):229–33. doi:/S0004-28032004000400006. [PubMed: 15806266]
23. Buell JF, Cherqui D, Geller DA, O'Rourke N, Iannitti D, Dagher I, et al. The international position on laparoscopic liver surgery: The Louisville Statement, 2008. Ann Surg. 2009; 250(5):825–30. [PubMed: 19916210]
24. Nomi T, Fuks D, Govindasamy M, Mal F, Nakajima Y, Gayet B. Risk factors for complications after laparoscopic major hepatectomy. Br J Surg. 2015; 102(3):254–60. DOI: 10.1002/bjs.9726 [PubMed: 25522176]
25. Cohen ME, Ko CY, Bilimoria KY, Zhou L, Huffman K, Wang X, 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(2):336–46. e1. DOI: 10.1016/j.jamcollsurg.2013.02.027 [PubMed: 23628227]
26. Pitt HA, Kilbane M, Strasberg SM, Pawlik TM, Dixon E, Zyromski NJ, et al. ACS-NSQIP has the potential to create an HPB-NSQIP option. HPB (Oxford). 2009; 11(5):405–13. DOI: 10.1111/j.1477-2574.2009.00074.x [PubMed: 19768145]
27. Spolverato G, Ejaz A, Kim Y, Hall BL, Bilimoria K, Cohen M, et al. Patterns of care among patients undergoing hepatic resection: a query of the National Surgical Quality Improvement Program-targeted hepatectomy database. J Surg Res. 2015; 196(2):221–8. DOI: 10.1016/j.jss.2015.02.016 [PubMed: 25881789]
28. Egger ME, Ohlendorf JM, Scoggins CR, McMasters KM, Martin RC 2nd. Assessment of the reporting of quality and outcome measures in hepatic resections: a call for 90-day reporting in all hepatectomy series. HPB (Oxford). 2015; 17(9):839–45. DOI: 10.1111/hpb.12470 [PubMed: 26228262]

29. Mise Y, Vauthey JN, Zimmitti G, Parker NH, Conrad C, Aloia TA, et al. Ninety-day Postoperative Mortality Is a Legitimate Measure of Hepatopancreatobiliary Surgical Quality. Ann Surg. 2015; 262(6):1071–8. DOI: 10.1097/SLA.0000000000001048 [PubMed: 25590497]

30. Huntington JT, Royall NA, Schmidt CR. Minimizing blood loss during hepatectomy: a literature review. J Surg Oncol. 2014; 109(2):81–8. DOI: 10.1002/jso.23455 [PubMed: 24449171]

31. Smyrniotis V, Kostopanagiotou G, Theodoraki K, Tsantoulas D, Contis JC. The role of central venous pressure and type of vascular control in blood loss during major liver resections. Am J Surg. 2004; 187(3):398–402. DOI: 10.1016/j.amjsurg.2003.12.001 [PubMed: 15006570]

32. Petrowsky H, McCormack L, Trujillo M, Selzner M, Jochum W, Clavien PA. A prospective, randomized, controlled trial comparing intermittent portal triad clamping versus ischemic preconditioning with continuous clamping for major liver resection. Ann Surg. 2006; 244(6):921–8. discussion 8–30. DOI: 10.1097/01.sla.0000246834.07130.5d [PubMed: 17122617]

33. Zhang J, Lai EC, Zhou WP, Fu S, Pan Z, Yang Y, et al. Selective hepatic vascular exclusion versus Pringle manoeuvre in liver resection for tumours encroaching on major hepatic veins. Br J Surg. 2012; 99(7):973–7. DOI: 10.1002/bjs.8764 [PubMed: 22539200]

34. Zhou W, Li A, Pan Z, Fu S, Yang Y, Tang L, et al. Selective hepatic vascular exclusion and Pringle maneuver: a comparative study in liver resection. Eur J Surg Oncol. 2008; 34(1):49–54. DOI: 10.1016/j.ejso.2007.07.001 [PubMed: 17709229]

35. Tee MC, Shubert CR, Ubl DS, Habermann EB, Nagorney DM, Que FG. Preoperative anemia is associated with increased use of hospital resources in patients undergoing elective hepatectomy. Surgery. 2015; 158(4):1027–36. discussion 36–8. DOI: 10.1016/j.surg.2015.06.004 [PubMed: 26162941]

36. Tohme, SV.; Patrick, R.; Landsittel, Douglas P.; Chidi, Alexis P.; Tsung, Allan. Preoperative anemia and postoperative outcomes after hepatectomy. HPB (Oxford). 2015. Epub November 13, 2015 http://dx.doi.org/10.1016/j.hpb.2015.09.002

37. Shander A, Van Aken H, Colomina MJ, Gombotz H, Hofmann A, Krauspe R, et al. Patient blood management in Europe. Br J Anaesth. 2012; 109(1):55–68. DOI: 10.1093/bja/aes139 [PubMed: 22628393]

38. Andres A, Toso C, Moldovan B, Schiffer E, Rubbia-Brandt L, Terraz S, et al. Complications of elective liver resections in a center with low mortality: a simple score to predict morbidity. Arch Surg. 2011; 146(11):1246–52. DOI: 10.1001/archsurg.2011.175 [PubMed: 21768406]

Table 1

Patient Demographic and Clinical Factors

	Transfused (N = 48)	Not transfused (N = 474)	p-value
Age, Median (IQR)	61.4 (52.9–70.0)	58.1 (49.9–67.8)	0.184
Sex, N (%)			
Male	25 (52.1)	230 (48.5)	0.638
Female	23 (47.9)	244 (51.5)	
BMI, Median (IQR)	28.5 (25.1–31.8)	27.2 (23.9–31.4)	0.246
Preoperative HCT, Median (IQR)			
Male	38.9 (33.9–42.0)	41.2 (38.9–44.1)	0.0021
Female	36.1 (35.0–40.5)	39 (36.8–41.2)	
Estimated Blood Loss, Median (IQR)	1400 (750–2150)	300 (150–500)	<0.0001
Race/Ethnicity, N (%)			
White	40 (83.3)	401 (84.6)	0.767
Black	6 (12.5)	55 (11.6)	
Asian	1 (2.08)	8 (1.69)	
Hispanic	0	4 (0.84))	
Unknown	1 (2.08)	6 (1.27)	
Surgery Type, N (%)			
Major hepatectomy	23 (47.9)	149 (31.4)	0.021
Minor hepatectomy	25 (52.1)	325 (68.6)	
Diagnosis, N (%)			
Primary hepatic neoplasm	11 (22.9)	97 (20.5)	0.176
Metastatic neoplasm	19 (39.5)	210 (44.3)	
Primary extra-hepatic biliary neoplasm	5 (10.4)	18 (3.80)	
Non-malignant indications	13 (27.1)	149 (31.4)	
Diabetes, N (%)			
Yes	12 (25.0)	81 (17.1)	0.172
No	36 (75.0)	393 (82.9)	
Smoking, N (%)			
Yes	9 (18.8)	79 (16.7)	0.713
No	39 (81.3)	395 (83.3)	

IQR: interquartile range; HCT: hematocrit

Table 2

Causes of 30 day morbidity stratified by transfusion status

	Transfused (N = 48)	Not transfused (N = 474)	p-value*	All patients N = 522
Surgical Site Infection	7 (14.6)	35 (7.4)	0.389	42 (8.1)
Ventilator >48 hours	12 (25.0)	8 (1.7)	<0.001	20 (3.8)
Unplanned Intubation	8 (16.7)	8 (1.7)	<0.001	16 (3.1)
Sepsis or Septic Shock	3 (6.3)	12 (2.5)	0.151	15 (2.9)
Renal Failure	5 (10.4)	9 (1.9)	0.006	14 (2.7)
Urinary Tract Infection	1 (2.1)	12 (2.5)	1.000	13 (2.5)
Pneumonia	2 (4.2)	6 (1.3)	0.162	8 (1.5)
Pulmonary Embolism	1 (2.1)	5 (1.1)	0.441	6 (1.2)
Wound Disruption	0 (0.0)	6 (1.3)	1.000	6 (1.2)
DVT Requiring Therapy	2 (4.2)	2 (0.4)	0.044	4 (0.8)
Myocardial infarction	1 (2.1)	0 (0.0)	0.092	1 (0.2)

Data reported as n (%)

*p-value comparisons between transfused and not transfused patients

Table 3

Multivariable morbidity risk model

	Odds Ratio	95% CI min	95% CI max	Wald Chi-Square	P-value
Perioperative transfusion	4.18	2.18	8.02	4.29	0.0001
Major hepatectomy vs. minor hepatectomy	1.30	0.74	2.28	0.90	0.366
NSQIP morbidity probability (unit change = 0.10)	1.15	0.11	12.2	2.03	0.042

Model C-statistic: 0.68

Table 4

Multivariable mortality risk model

	Odds Ratio	95% CI min	95% CI max	Wald Chi-Square	P-value
Perioperative transfusion	14.5	3.08	67.8	3.39	0.001
Major hepatectomy vs. minor hepatectomy	1.14	0.24	5.50	0.16	0.870
NSQIP mortality probability (unit change = 0.10)	2.16	$2.2e^{6}$	$2.2e^{12}$	1.09	0.276

Model C-statistic: 0.88