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Effect of critical care complications on perioperative mortality and hospital length of stay after hepatectomy: A multicenter analysis of 21,443 patients

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ABSTRACT

Objective: To determine predictors of critical care complications (CCC) in patients undergoing hepatectomy.
Methods: All hepatectomy patients in NSQIP from 2012 to 2016 were analyzed. CCC included prolonged ventilation (>48 h), sepsis/septic shock, renal failure/insufficiency, cardiac arrest/AMI and pulmonary embolism.
Results: A total of 21,443 patients underwent hepatectomy during the study period. Overall rate of CCC was 11%, with the most common being sepsis/septic shock (6.1%) and respiratory failure (4.9%). On multivariate analysis the preoperative risk factors associated with CCC included ASA Class IV-V (OR:2.04, $p < 0.0001$), diabetes (OR = 1.28, $p = 0.0001$), pre-operative ventilator use (OR: 17.75, $p = 0.0003$); COPD (OR: 1.65, $p < 0.0001$); pre-operative weight loss >10% (OR: 1.35, $p = 0.0026$); pre-operative sepsis (OR: 2.14, $p < 0.0001$). Propensity score matched analysis demonstrated a significant increased risk of mortality in patients with CCC (OR: 26.75, $p < 0.0001$) and a prolonged LOS of 10.5 days above the mean (β Estimate: 10.51, $p < 0.0001$).
Conclusions: ASA class, diabetes, COPD, pre-operative weight loss >10% and pre-operative sepsis are the strongest predictors of CCC after hepatectomy. The presence of CCC significantly increased the risk of peri-operative mortality 26-fold.

Introduction

From 2000 to 2010, the hepatectomy rate in the US increased from 2.4 to 3.3 per 100,000 adults.[1] As the surgical procedure has become more common in the treatment of benign, primary, and metastatic liver and biliary malignancies,[2] the perioperative mortality has decreased significantly, from 17% to less than 5%, in the past four decades.[3–5] Single institution and multicenter studies have demonstrated that refinements in surgical techniques, a deeper understanding of segmental liver anatomy, as well as improved patient selection and perioperative care have all helped reduce morbidity and mortality (M&M).[1,6–9] Several recent studies report 30-day major morbidity rates at around 20% and describe a linear correlation between the extent of the liver resection and perioperative M&M rates.[10,11]

It is anticipated that severe postoperative complications especially those requiring admission to the critical care unit would be associated with worse outcomes. However, the impact of such major morbidities, defined herein as critical care complications (CCC) after liver resection has not been investigated.

The aim of our study is to determine perioperative risk factors involved in the development of CCC and assess their effect on length of hospital stay and perioperative mortality after liver resection.

Methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) is a nationally validated, risk

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adjusted, outcomes-based database intended to measure and improve the quality of surgical care using clinical data from public and private hospitals. Data maintained by ACS NSQIP includes pre-, intra-, and postoperative variables. The ACS NSQIP Participant Use Files (PUF) for the years 2012–2016 were queried to identify all cases with a hepatectomy as the primary Current Procedural Terminology (CPT) code. For the purposes of this study the hepatectomy type by CPT codes included were: Partial Resection (47120), Trisectionectomy (47122), Left Hepatectomy (47125) and Right Hepatectomy (47130). Cases with secondary procedures were excluded. Since patient aged 90 or greater are identified as "90+" in the NSQIP PUF, an arbitrary age of 90 was imputed for these cases. A secondary analysis was performed to assess predictors of CCC on elective cases with satisfactory functional status. For this analysis of elective cases we excluded patients with ASA class of IV or V, totally dependent functional status, ventilator dependent at the time of surgery, and emergent cases to better reflect the majority of cases undergoing elective hepatectomy. Patients with missing data for ASA class, functional status, transfer status, elective status, height or weight were excluded from this analysis.

The primary endpoint of the study was the development of a CCC defined as the presence of at least one of the following: respiratory failure (prolonged ventilation >48 h or unplanned intubation), sepsis/septic shock, renal failure/insufficiency, cardiac arrest/AMI, and pulmonary embolism as a surrogate of major morbidity.[12–15] The intraoperative and perioperative characteristics of the CCC group were compared to a control group, defined as patients who did not experience a CCC.

Secondary outcome measures included perioperative mortality (defined as death within 30 days of the procedure) and length of hospital stay (LOS) calculated from the day of admission to day of discharge. In addition, we investigated the rates of CCC in patients with COPD and diabetes who underwent major LR (right hepatecomy and trisectionectomy).

Univariate analyses were performed using chi-squared or Fisher's Exact test as appropriate for categorical variables. Continuous variables were tested for normality using the Shapiro-Wilk normality test. Normally distributed variables were reported using means and standard deviations (SD) and compared using Welch two sample t-tests. Non-parametric data was reported as medians and interquartile ranges (Q1 − Q3), and comparisons were made using the Mann-Whitney *U* test.

Multivariate logistic regression was performed to determine independent demographic, preoperative clinical findings, and intraoperative risk factors for the presence of CCCs in post-hepatectomy.

A multivariate analysis was performed to assess the impact of CCCs on mortality and LOS. Predictors of CCCs were determined using a stepwise procedure that identifies the most predictive logistic regression model by minimizing Akaike's information criterion (AIC).

Propensity score matching was used to create a subsample that was balanced with regard to observed confounders. Propensity scores were estimated using a logistic regression model with CCCs prior to discharge as the outcome variable and all pre- and perioperative variables (all of those from Tables 1 and 2) as predictors. A 5:1 non-CCC to CCC match was made using a nearest-neighbor matching algorithm with a caliper of size 0.20. Post-match balance was assessed using standardized mean differences (SMD) where variables with SMD values < 0.10 were considered to be balanced. The same analysis was perform for elective cases.

Outcomes were analyzed in the propensity score-matched subsample using generalized estimating equations (GEE) that account for the matched groups. Clusters were taken to be the propensity score matched groups and the correlation structure was assumed to be exchangeable. For binary outcomes, the error distribution was assumed to be binomial with a logit link function. For continuous outcomes, the error distribution was assumed to be normal with an identity link function.

All analyses were done in R programming language, version 3.5.0 (R Core Team; Vienna, Austria). Propensity score matching was done in the MatchIt R package (version 3.0.2) and GEEs were fit using the geepack R package (version 1.2-1). Statistical significance was defined to be $p < 0.05$.

Results

A total of 21,443 patients underwent hepatectomy from 2012 to 2016 (13,914 partial resections, 3785 right hepatectomies, 2026 left hepatectomies, and 1718 trisectionectomies). Among all included patients, 2355 (11%) developed at least one CCCs. The most common indications for LR in the CCC group were: metastatic liver disease 738 (31.3%), primary liver cancer 728 (30.9%), gallbladder cholangiocarcinoma 67 (2.8%), benign liver and biliary neoplasm 53 (2.2%), extrahepatic bile ducts malignancies 52 (2.2%) and liver abscesses 29 (1.2%).

The most common CCC was sepsis/septic shock (6.1%) followed by respiratory failure (4.9%). Complications associated with the highest incidence of mortality were cardiac arrest (68%), acute renal failure/insufficiency (37%) and respiratory failure (28.4%).

Patient characteristics according to their complication status is summarized in Table 1. CCCs were more commonly seen in males ($p < 0.001$) and the CCC patient cohort was older than the non-CCC group (61.7 vs 58.3 years; $p < 0.001$). The incidence of ASA class 4 or greater in the CCC group was 13.7% compared to the non-CCC group 5.7% ($p < 0.0001$). Eighteen percent of patients who developed CCC were smokers vs 15.1% in the control group ($p < 0.01$). The CCC group exhibited higher rates of severe COPD, 6.1% vs 3.0% ($p < 0.0001$), and a greater incidence of congestive heart failure, 0.9% vs 0.3%, than the non-CCC group ($p < 0.001$). Patients who developed CCC had significantly higher rates of medically-treated diabetes, hypertension, and preoperative diagnoses of SIRS/Sepsis ($p < 0.001$). The requirement for a pre-operative transfusion also increased rates of CCC ($p < 0.0001$).

Perioperative factors related to the development of a CCC are summarized in Table 2. Patients undergoing trisectionectomy were found to have the highest rates of CCC at 21.7% followed by right hepatectomy (16.7%), left hepatectomy (11.3%), and partial resection (8.0%). The mean operative duration for those developing a CCC was longer at (321.6 vs. 233.8 min; $p < 0.0001$). Although emergent procedures were uncommon, rates of CCCs were higher at 29.4% compared to elective procedures (10.3%). Patients with a wound class defined as dirty/infected wounds had higher rates of CCC ($p < 0.0001$).

Assessment of 30-day outcomes in relation to the presence of CCCs (Table 3) revealed that the median hospital stay, reoperation, and mortality rates were greater in patients experiencing a CCC ($p < 0.0001$). Patients with CCC accounted for a 31.5% of un-planned re-admissions. Pre-operative comorbidities such as diabetes and COPD significantly increased the occurrence of CCC in patients undergoing major LR (right hepatectomy and trisectionectomy). Diabetes increased the incidence of CCC in right hepatectomies from 14.8% to 27% and 20%–31.8% in patients with trisectionectomy. COPD increased the rates of CCC from 16.2% to 34.3% and 21.3%–34.8%% following right hepatectomy and trisectionectomy, respectively.

Predictors of critical care related complications after hepatectomy

Regression analysis (Table 4) revealed that patients with ASA

Table 1
Patient characteristics stratified by critical care complication status (N = 21,443).

	Overall	Critical Care Complication		
		None	1 or More	
Total number of patients (%)	21,443 (100.0)	19,088 (89.0)	2355 (11.0)	
Mean age (SD), years	58.6 (13.7)	58.3 (13.7)	61.7 (13.0)	<0.0001
Male, N (%)	10,476 (48.9)	9080 (47.6)	1396 (59.3)	<0.0001
Race, N (%)				<0.001
White	14757 (68.8)	13194 (69.1)	1563 (66.4)	
African American	1854 (8.6)	1647 (8.6)	207 (8.8)	
Asian	1299 (6.1)	1180 (6.2)	119 (5.1)	
Other	128 (0.6)	119 (0.6)	9 (0.4)	
Unknown	3405 (15.9)	2948 (15.4)	457 (19.4)	
Hispanic, N (%)				<0.001
No	17302 (80.7)	15474 (81.1)	1828 (77.6)	
Yes	1203 (5.6)	1066 (5.6)	137 (5.8)	
Unknown	2938 (13.7)	2548 (13.3)	390 (16.6)	
Mean BMI (SD), kg/m^2	28.4 (6.3)	28.4 (6.3)	28.6 (6.4)	0.1438
Missing data	N = 161	N = 137	N = 24	
BMI > 30, N (%)	7157 (33.6)	6329 (33.4)	828 (35.5)	0.0428
Missing data	N = 161	N = 137	N = 24	
ASA class, N (%)				<0.0001
I – II	5826 (27.2)	5404 (28.4)	422 (18.0)	
III	14,151 (66.1)	12,546 (65.9)	1605 (68.3)	
IV – V	1418 (6.6)	1095 (5.7)	323 (13.7)	
Missing data	N = 48	N = 43	N = 5	
Treatment for diabetes, N (%)	3528 (16.5)	2993 (15.7)	535 (22.7)	<0.0001
Smoking, N (%)	3309 (15.4)	2884 (15.1)	425 (18.0)	0.0002
Dyspnea, N (%)	1148 (5.4)	953 (5.0)	195 (8.3)	<0.0001
Partially/totally dependent functional status, N (%)	154 (0.7)	121 (0.6)	33 (1.4)	<0.0001
Missing data	N = 67	N = 59	N = 8	
Ventilator use preop. N (%)	19 (0.1)	3 (0.0)	16 (0.7)	<0.0001
History of COPD, N (%)	720 (3.4)	576 (3.0)	144 (6.1)	<0.0001
Ascites, N (%)	160 (0.7)	123 (0.6)	37 (1.6)	<0.0001
History of CHF, N (%)	69 (0.3)	48 (0.3)	21 (0.9)	<0.0001
Med. for hypertension, N (%)	9752 (45.5)	8474 (44.4)	1278 (54.3)	<0.0001
Renal failure preop. N (%)	16 (0.1)	10 (0.1)	6 (0.3)	0.0053
Currently on dialysis, N (%)	67 (0.3)	48 (0.3)	19 (0.8)	<0.0001
Disseminated cancer, N (%)	9065 (42.3)	8122 (42.6)	943 (40.0)	0.0213
Wound infection preop. N (%)	167 (0.8)	123 (0.6)	44 (1.9)	<0.0001
Steroid use, N (%)	743 (3.5)	641 (3.4)	102 (4.3)	0.0175
Preop. weight loss > 10% within 6 months of procedure, N (%)	834 (3.9)	666 (3.5)	168 (7.1)	<0.0001
Bleeding disorder, N (%)	710 (3.3)	599 (3.1)	111 (4.7)	<0.0001
Transfusion preop. N (%)	166 (0.8)	117 (0.6)	49 (2.1)	<0.0001
Sepsis preop. N (%)	353 (1.6)	238 (1.2)	115 (4.9)	<0.0001

SD = standard deviation.

class IV-V had a 2-fold increased risk of CCC compared to the control group (OR: 2.04, CI: 1.71–2.44, p < 0.0001). Other relevant factors associated with increased risk of CCC are the following: Preoperative ventilator use (OR: 17.75, CI: 4.50–118.84, p = 0.0003); Diabetes (OR: 1.28, CI: 1.14–1.44, p = 0.0001); COPD (OR: 1.65, CI: 1.33–2.04, p < 0.0001); steroid use (OR: 1.33, CI: 1.05–1.66,

Table 2
Operative characteristics stratified by critical care complication status (N = 21,443).

	Overall	Critical Care Complication		
		None	1 or More	
Total number of patients (%)	21,443 (100.0)	19,088 (89.0)	2355 (11.0)	
Mean operative duration (SD), minutes	243.5 (125.7)	233.8 (116.8)	321.6 (162.6)	<0.0001
Primary CPT, N (%)				<0.0001
Partial Resection (47120)	13,914 (64.9)	12,794 (67.0)	1120 (47.6)	
Trisectionectomy (47122)	1718 (8.0)	1345 (7.0)	373 (15.8)	
Left hepatectomy (47125)	2026 (9.4)	1797 (9.4)	229 (9.7)	
Right hepatectomy (47130)	3785 (17.7)	3152 (16.5)	633 (26.9)	
Elective, N (%)	20,010 (93.4)	17,952 (94.1)	2058 (87.4)	<0.0001
Missing data	N = 8	N = 8	N = 0	
Emergent, N (%)	156 (0.7%)	110 (0.6)	46 (2.0)	<0.0001
Outpatient, N (%)	272 (1.3)	260 (1.4)	12 (0.5)	0.0007
Wound class, N (%)				<0.0001
Clean	3155 (14.7)	2923 (15.3)	232 (9.9)	
Clean/contaminated	16,767 (78.2)	14,975 (78.5)	1792 (76.1)	
Contaminated	1078 (5.0)	898 (4.7)	180 (7.6)	
Dirty/infected	443 (2.1)	292 (1.5)	151 (6.4)	

SD = standard deviation.

Table 3
Thirty-day outcomes stratified by critical care complication status (N = 21,443).

	Overall	Critical Care Complication		*P*-value
		None	1 or More	
Total number of patients (%)	21,443 (100.0)	19,088 (89.0)	2355 (11.0)	
Median hospital LOS (Q1 - Q3), days	6.0 (4.0–8.0)	5.0 (4.0–7.0)	11.0 (7.0–20.0)	<0.0001
Missing data	N = 23	N = 12	N = 11	
Median Postop LOS (Q1 - Q3), days	5.0 [4.0, 7.0]	5.0 [4.0, 7.0]	10.0 [7.0, 19.0]	<0.001
Missing data	N = 23	N = 12	N = 11	
Mortality, N (%)	342 (1.6)	43 (0.2)	299 (12.7)	<0.0001
Readmissions, N (%)				
For any reason	2228 (10.4)	1478 (7.7)	750 (31.8)	<0.0001
Unplanned	2179 (10.2)	1436 (7.5)	743 (31.5)	<0.0001
Unplanned and likely related to the principal procedure	1971 (9.2)	1266 (6.6)	705 (29.9)	<0.0001
Reoperations, N (%)				
Unplanned	714 (3.3%)	292 (1.5)	422 (17.9)	<0.0001
Unplanned and likely related to principal procedure	641 (3.0)	249 (1.3)	392 (16.6)	<0.0001

LOS = length of stay; (Q1 − Q3) = 1st and 3rd quartiles.

p = 0.0146); pre-operative weight loss >10% (OR: 1.35, CI: 1.11–1.63, p = 0.0026); pre-operative sepsis (OR: 2.14, CI: 1.6–2.83, p < 0.0001); and pre-operative dirty/infected wounds (OR: 3,5, CI: 2.67–4.58, p < 0.0001).

Patients undergoing trisectionectomy (OR: 2.06, CI: 1.78–2.38, p < 0.0001) and right hepatectomy (OR: 1.77, CI: 1.58–1.99, p < 0.0001) were found to have increased rates of CCC of 2-fold and 77%, respectively.

Impact of CCC on perioperative mortality and LOS

Patients who presented at least one CCC had an increased 30-day mortality of 12.7% and a median LOS of 11 days compared to the non-CCC group, whose 30-day mortality was 0.2% and average LOS of 5 days (p < 0.001).

After performing a 5:1 propensity score matched analysis, we found a 26-fold increased risk of mortality (30-day) in patients with at least one CCC (OR: 26.75, CI: 17.83–40.13, p < 0.0001). After PS

Table 4
Predictors of critical care complications. All cases with missing data were removed (N = 21,163).

Parameter	Odds Ratio	95% Confidence Limits	*P*-value
Age (5-year increase)	1.09	1.07–1.11	<0.0001
Male	1.26	1.15–1.39	<0.0001
Race			
White	1.00	ref.	ref.
African American	1.06	(0.9, 1.25)	0.503
Asian	0.85	(0.69, 1.05)	0.144
Other	0.63	(0.29, 1.21)	0.200
Unknown	1.28	(1.14, 1.45)	<0.001
ASA class			
I – II	*ref.*	*ref.*	*ref.*
III	1.19	1.06–1.35	0.0043
IV – V	2.04	1.71–2.44	<0.0001
Treatment for diabetes	1.28	1.14–1.44	0.0001
Smoking	1.18	1.04–1.33	0.0112
Dyspnea	1.26	1.05–1.51	0.0136
Partially or totally dependent	1.43	0.91–2.17	0.1059
Ventilator use	17.75	4.50–118.84	0.0003
History of COPD	1.65	1.33–2.04	<0.0001
History of CHF	1.77	0.96–3.14	0.0592
Meds. for hypertension	1.20	1.08–1.33	0.0005
Wound infection	1.46	0.97–2.15	0.0649
Steroid use	1.33	1.05–1.66	0.0146
Preop. weight loss > 10%	1.35	1.11–1.63	0.0026
Preop. transfusion	1.52	0.99–2.27	0.0485
Preop. sepsis	2.14	1.60–2.83	<0.0001
Operative duration (30-min. increase)	1.13	1.12–1.14	<0.0001
Primary CPT code			
Partial Resection (47120)	*ref.*	*ref.*	*ref.*
Trisectionectomy (47122)	2.06	1.78–2.38	<0.0001
Left hepatectomy (47125)	1.11	0.95–1.30	0.1892
Right hepatectomy (47130)	1.77	1.58–1.99	<0.0001
Elective surgery	0.66	0.56–0.78	<0.0001
Wound class			
Clean	*ref.*	*ref.*	*ref.*
Clean/contaminated	1.22	1.06–1.43	0.0082
Contaminated	1.61	1.28–2.01	<0.0001
Dirty/infected	3.50	2.67–4.58	<0.0001

matching patients with CCC had a prolonged LOS of 10.5 days above the mean (β Estimate: 10.51, CI: 9.60–11.43, $p < 0.0001$).

Critical care complications following elective hepatectomies

During the study period 19,648 elective hepatectomies were identified,1,981 (10.08%) of which developed at least one CCC. The overall elective perioperative mortality was 1.3% (260) vs. 11.4% (226) in those with CCC. Patients in the CCC cohort had 10.0 days of total hospital LOS, doubling the overall LOS (5.0 days) of the non-complicated cases. The most prevalent CCC in elective LR was respiratory failure (4.3%) followed by sepsis (4.1%). The highest mortality was found on individuals who developed cardiac arrest (68.5%), acute renal failure (48.55%) and respiratory failure (26.91%).Factors strongly associated with CCC were dirty/infected wounds (OR: 3.71, CI: 2.77–4.95, $p < 0.001$), trisectionectomy (OR: 2.1, CI: 1.79–2.44, $p < 0.001$) and history of COPD (OR: 1.77, CI: 1.39–2.25, $p < 0.001$).

Following a 5:1 propensity score matched on elective cases alone, patients with at least one CCC had 31-fold increased risk of 30-day mortality (OR: 31.86, CI: 19.70–51.54, $p < 0.001$). LOS was prolonged in the CCC elective cohort by 10.68 days above the mean (β Estimate: 10.68, CI: 9.7–11.67, $p < 0.001$).

Discussion

Despite significant advances in surgical and perioperative care, hepatic resections are still considered high morbidity and resource intensive procedures.[16] Postoperative complications substantially impact the risk of mortality and demands on resources after major abdominal surgeries, including hepatectomy.[2,17–20] This study is the first to analyze predictors for major critical complications and its impact on perioperative mortality and LOS for patients undergoing hepatectomy using the ACS NSQIP database.

Of the 21,443 patients undergoing liver resection during the study period, 11% developed at least 1 complication. The overall mortality of this study group was 1.6% (342 patients), which is an improvement over rates reported in earlier studies. Evaluating 587 hepatic resections, Schroeder et al. reported in 2006 an overall morbidity of over 30% and a mortality rate of 8.5%.[21] Another study using NSQIP in hepatectomy patients from years 2005–2007 reported a 19.6% morbidity and 2.5% mortality rates.[10]

These findings confirm that perioperative outcomes after liver resection have improved. There is no doubt that the decline in morbidity and mortality is related to the development of new and refined surgical techniques, quality perioperative patient care, and a better understanding of hepatic anatomy. Importantly, we demonstrated that more complex hepatectomies, such as trisectionectomy and right hepatectomy, carried higher CCC rates and mortality consistent with previously published research.[22]

A multivariable regression analysis demonstrated that ASA class IV-V had significantly higher rates of CCC. Patients on steroid therapy or with chronic conditions such as diabetes, hypertension, and COPD were found to have increased CCC rates following hepatectomy. As other studies have suggested, preoperative optimization of patients with these conditions should be considered prior to elective hepatectomies to improve perioperative outcomes.[22,23] Our data indicates a better than 17-fold increase in risk of critical complications with preoperative ventilator use. Likewise, the presence of preoperative sepsis resulted in a 2-fold increased risk of CCC.

Our findings also showed that preoperative weight loss >10% resulted in a major increase in the risk of CCC. Moghadamyeghaneh Z et al. reported similar findings in patients undergoing colorectal surgery. Unintentional preoperative weight loss of more than 10% was strongly associated with worse overall outcomes.[24] We speculate that the increase in CCC rates for this group is linked to the underlying condition. The additional risk may be associated with the presence of sarcopenia and malnutrition, which has been reported in other major surgical procedures.[25–27] Pre-operative management with specific dietary interventions (immune-nutrition) has shown to reduce overall morbidity after abdominal surgery.[28]

The actual effect of CCC on perioperative outcomes and LOS/resource utilization after hepatic resection has not been objectively measured. While most efforts have been made to demonstrate the association of complications on perioperative mortality, our analysis focused on the direct effect that severe complications have on 30-day mortality and LOS. We found that the presence of at least one CCC in this cohort resulted in an alarming 26-fold increase in mortality after matched analysis. With these complications, we observed a significant increase in hospital LOS that is commonly associated with a concomitant postsurgical strain on resources. Severe complications often translated into a prolonged hospital stay of more than 15 days compared to just five days for those patients without a single CCC. Due to the striking impact of CCC on overall perioperative mortality and LOS, a secondary analysis of elective hepatectomies was performed. We found that patients undergoing elective LR with CCC have an increased risk of mortality of 31.86 fold and a prolonged LOS of over 10 days above the mean.

There are limitations to our study that should be acknowledged. Even though NSQIP is a robust database for evaluating patient complications and tracking mortality after surgery, post procedure data beyond 30 days is not available. Data on preoperative therapies and/or preoperative and postoperative decision-making is also lacking. Furthermore, the dataset does not capture more direct measures of malnutrition and/or sarcopenia, which could be the subject of further analysis for their effect on CCC and peri-operative outcomes.

In conclusion, the strongest factors associated with CCC after hepatectomy are ASA class IV-V, preoperative comorbid conditions such as diabetes, hypertension, and COPD, and pre-operative sepsis. Preoperative weight loss of more than 10%, a likely surrogate of malnutrition/sarcopenia, was also associated with increased rates of CCC.

The presence of at least one the following complication (CCC) - Respiratory failure (ventilation >48 h or unplanned intubation); sepsis/septic shock; renal failure/progressive renal insufficiency; cardiac arrest/AMI; or pulmonary embolism - significantly increased the risk of peri-operative mortality up to 26-fold after propensity score matched analysis. Length of hospital stay was impacted in those with CCC to almost triple compared to those patients who avoided complications.

A prospective study should be performed to assess how nutrition and exercise may influence patient's pre-operative performance and physiologic status to impact post hepatectomy outcomes. Our results suggest that diabetes, blood pressure control and cardiopulmonary optimization could play a role in reducing severe complications in patients undergoing liver resection.

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None.

Conflicts of interest

None.

Author Contribution

Design of the work: EC, VV, GMS, AD, RG. Analysis and interpretation of data: EC, VV, GMS, RG. Manuscript drafting and critical revision: EC, VV, PE, FM, GMS, AD, LT, RG. Final approval of the version to be published: EC, VV, PE, FM, GMS, AD, LT, RG.

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