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Low conversion rate during minimally invasive major hepatectomy: Ten-year experience at a high-volume center

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ABSTRACT

Background: Minimally invasive approaches for major hepatectomy have been marred by significant rates of conversion and associated morbidity. This study aimed to determine risk factors for conversion as well as postoperative morbidity in patients undergoing minimally invasive right-sided hepatectomy (MIRH).

Methods: Data for patients undergoing MIRH between 2008 and 2017 at Emory University were reviewed. Risk factors for conversion were determined using multivariate regression analysis. Outcomes of conversion patients were compared with those who underwent successful MIRH or elective open surgery.

Results: Unplanned conversion occurred in 7 (6.25%) of 112 patients undergoing MIRH. Primary reason for conversion was difficult dissection secondary to inflammation and severe adhesions. No preoperative clinical factor was identified that predicted conversions. Converted cases had higher EBL and pRBC transfusion compared to non-converted cases however morbidity was similar to those undergoing primary open surgery.

Conclusion: Difficult dissection and adhesions remained the only clinically applicable parameter leading to unplanned conversions. While these did offset benefits of a successful minimally invasive approach, it did not increase risk of postoperative complications compared with planned open surgery.

Introduction

First reported in 1991,[1] the laparoscopic approach to liver surgery has gained popularity, with several centers across the US adopting a minimally invasive approach.[2] Laparoscopic liver resection (LLR) has been associated with less blood loss and intraoperative transfusions, lower postoperative morbidity and shorter length of stay compared to open approach[3,4,5] Minimally invasive liver resection has expanded from minor segmental resections to major hepatectomies[6,7,8,9]. Laparoscopic major hepatectomy (LMH) is defined as resection of ≥3 liver segments.[10] Major hepatectomy is considered the most challenging LLR procedure,[11,12] the technical difficulty being higher for posterosuperior hepatic segments[13] (I, IVa, VII, VIII) and especially for surgeons without adequate experience in LLR.

Conversion rates have traditionally been reported between 10 and 20%.[14,15] NSQIP data for hepatectomy targeted Participant Use Data Files (PUFs) was utilized by Dickson et al.,[16] who demonstrated similar outcomes. However, the conversion cases were associated with significantly higher rates of bleeding requiring transfusion and a higher incidence of UTIs compared to open procedures. Another study utilizing the NSQIP database[10] demonstrated a 15.8% rate of unplanned conversions to open in 539 laparoscopic approaches of partial hepatectomy. Studies conducted in the past have reported raised BMI, large sized lesions and need for biliary reconstruction,[12] surgeon expertise and institution volume,[17] and resection of posterosuperior segments[18] to be risk factors for conversion.

However, specific data for conversions in major hepatectomy is limited and in small numbers to date. Keeping in mind the historically higher unplanned conversion rate for minimally invasive

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hepatectomy and its associated morbidity, we studied our institutional data over the last ten years.

Methods

Data Collection. We reviewed medical records for all consecutive patients who underwent minimally invasive right-sided hepatectomy (MIRH) at Emory University Hospital, Atlanta, GA from 2008 to 2017. All operations were performed independently by the senior author (JMS). Electronic medical records were analyzed for demographics, comorbidities, indication for surgery, operative details, pathology results, postoperative complications and readmissions. Complications of hepatectomy were recorded if occurring within 30 days of surgery and reported utilizing the Clavien-Dindo classification system. Conversion was defined as the requirement for laparotomy at any time of the procedure, except for extraction of the resected specimen. Reasons for conversion to open operation were ascertained using operative reports.

Operative Technique. MIRH is standardized involving seven key steps. After trocars and midline hand port are placed, intraoperative hepatic ultrasound is performed; 1) The right hepatic artery is dissected and divided; 2) The right portal vein is dissected and divided; 3) Mobilization of the right lobe triangular ligaments is performed; 4) The inferior vena cava is dissected; 5) The right hepatic vein is dissected and divided; 6) Marking and division of the right lobe parenchyma is performed along the line of ischemia and the right hepatic duct is taken intra-parenchymally and 7) Hemostasis is obtained. Another important aspect to note is that our technique does not include the use of the pringle maneuver routinely (in fact, it was not used for any of the minimally invasive cases in this series). We also do not divide the falciform ligament for our right hepatectomies. All patients were preferentially offered the minimally invasive approach if they met physiologic parameters to be able to undergo pneumoperitoneum. Tumor close to right anterior or posterior pedicle and large exophytic type tumors (>10 cm) were the only exclusions factors.

Data analysis

Data analysis was performed using SPSS version 24 (IBM Corp). Comparisons of proportions between 2 groups were made utilizing chi-square or Fisher's exact test. Continuous data was analyzed using 2-sample t-tests for means. Univariate analysis was used to compare comorbidities and operative outcomes between MIRH and unplanned conversion patients, as well as planned open and conversion patients. All statistical tests were two sided and homogeneity of samples was confirmed. Data is presented as mean values with standard deviations, medians with ranges, or as counts. All data is complete except where noted within the text.

Results

A total of 112 patients underwent minimally invasive right-sided hepatectomy at our institute from 2008 to 2017 by the senior author (JMS). Of these 75 cases were formal right hepatectomy (segments 5–8), 10 cases were extended right hepatectomies (segments 4–8), 9 cases were right anterior sectorectomies (segments 5 and 8) and 12 cases were right posterior sectorectomies (segments 6–7). Conversion to open procedure was required in 7 patients. Table 1 lists the patient demographics and pre-operative data for both MIRH and conversion groups. There were 69 men (61.6%) and 43 women (38.4%). Mean age was 52 (37.3–66.7%) years in the MIRH group and 56.2 (43.3–69.1%) years in the conversion group. Median BMI was higher in the successful MIRH group (31 ± 14.5) compared to the conversion group (29 ± 6.0). Preoperative Alkaline Phosphatase levels were significantly higher in the conversion group (95.8 U/L in MIRH, 170 U/L in conversion, $p = 0.002$).

Table 2 lists the operative details and pathologic data on both groups. Estimated blood loss and units of RBCs transfused intraoperatively were significantly higher in the conversion group (764 ml and 1 unit in conversion, 258 ml and 0 unit in MIRH $p < 0.001$). A review of the operative notes of these unplanned conversions demonstrated that this bleeding was not from the liver parenchyma but in fact was from oozing omental adhesions in all cases.

Table 3 lists post-operative outcomes in both groups, with conversions showing longer length of stay (8 days in conversion group, 5 in MIRH group $p = 0.007$). However, when compared to planned open there was no difference in the length of stay of the unplanned conversion patients. The conversion group also had a significant increase in readmission rate (33.3% compared to 15.6% $p = 0.001$). Table 4 compares postoperative course and complications between elective open hepatectomies and conversions, with no significant difference demonstrated in terms of LOS, ICU stay, 30-day morbidity, readmission and mortality between the two groups.

Table 5 lists the indications of surgery and reason for conversion in the open procedure group. Four patients required hepatic resection for intractable benign disease, while three required surgery for malignancy. All seven patients were converted to open due to difficult dissection, with secondary concerns of potential uncontrollable bleeding and positive oncologic margins. None of the conversions were during parenchymal or hilar dissection. Supplementary Tables 1 and 2 compare patient demographics, preoperative, operative and pathologic data between planned open operations ($n = 45$) and unplanned conversion to open ($n = 7$). There is no significant difference in morbidity or mortality between the two groups.

Discussion

During the past 8 years, a total of 112 patients underwent minimally invasive major right-sided hepatectomy at our institution, all performed by the senior author (JMS). 105 patients had successful minimally invasive surgery, while 7 patients (6.25%) underwent unplanned conversion to open resection. This rate is much lower than that traditionally quoted in literature.[29,30] A study by Gamblin et al.[19] used data from the 2014 NSQIP dataset to study 2884 patients, demonstrated an overall rate of 20% (115 of 549) unplanned conversions in minimally invasive approaches for liver resection. In the same study however, for formal right lobectomy patients this conversion rate was 39% (13 of 33). Similarly, in the study by Dickson et al.[25] using the same NSQIP database but with an additional year (2014–2015) the conversion rate for major hepatectomy was 44% (44 of 99). Yet another study[10] from the same NSQIP database does mention 138 major hepatectomies were approached laparoscopically, though these were excluded from further analysis. We have previously reported a 10.4% (5 of 48) conversion rate in a cost analysis where we only analyzed anatomic right hepatectomies.[20] We included right anterior and posterior sectorectomies in this analysis as they follow the same operative steps in our standardized protocol. Additionally, we believe these are technically more challenging than a pure right hepatectomy due to two lines of transection compared to one for a pure formal right or an extended right hepatectomy.

We hypothesize that the possible reasons for our exceedingly low conversion rate are a standardized approach to these cases, possibly good patient selection and adherence to good surgical technique. Additionally, our overall particularly high bar for

Table 1
Patient demographics and pre-operative data.

	MIRH (n = 105)	Conversion (n = 7)	p-value
Indication (malignant), n (%)	58 (55.2%)	3 (42.9%)	0.406
Tumor/lesion number on imaging, n (%)			0.470
1	37 (35.9%)	2 (40.0%)	
2	21 (20.4%)	2 (40.0%)	
≥3	45 (43.7%)	1 (20.0%)	
Largest diameter on imaging, mean (SD)	6.33 (±4.4)	6.80 (±3.2)	0.830
Age, mean (SD)	52.05 (±14.7)	56.29 (±12.9)	0.458
Sex (female), n (%)	41 (39.0%)	2 (28.6%)	0.581
Race, n (%)			0.688
White	62 (59.0%)	5 (71.4%)	
African American	35 (33.3%)	2 (28.6%)	
Other	8 (7.6%)	0	
BMI, kg/m2, mean (SD)	31 (±14.5)	29 (±6.0)	0.843
Comorbidities, n (%)			
HTN	53 (50.5%)	3 (42.9%)	0.696
Smoker	35 (33.3%)	2 (28.6%)	0.795
DM	12 (11.4%)	0	0.381
CVA	3 (2.9%)	0	0.675
CAD	4 (3.8%)	1 (16.7%)	0.140
CKD	1 (1.0%)	0	0.810
COPD	2 (1.9%)	0	0.733
Cirrhosis	4 (3.8%)	0	0.626
Previous abdominal surgery, n (%)	53 (50.5%)	1 (14.3%)	0.064
Liver biochemistry profile, mean (SD)			
Hemoglobin, g/dL	12.9 (±1.5)	11.9 (±1.8)	0.153
Platelets, x10^3/mcl	259 (±117.2)	237 (±46.0)	0.643
Prothrombin time, s	11.6 (±1.3)	12.3 (±0.7)	0.167
International normalized ratio	1.00 (±0.1)	1.05 (±0.0)	0.090
Creatinine, mg/dL	0.85 (±0.2)	0.87 (±0.4)	0.864
Aspartate aminotransferase, U/L	33 (±28.6)	37 (±27.1)	0.710
Alanine aminotransferase, U/L	30 (±23.3)	35 (±35.0)	0.626
Alkaline phosphatase, U/L	95.8 (±47.3)	170.0 (±132.2)	0.002*
Total bilirubin, mg/dL	0.7 (±0.5)	0.7 (±0.2)	0.933
MELD, median (range)	6.00 (6–7.2)	6.00 (6–6.4)	0.286
ASA class, n (%)			0.446
1	3 (2.9%)	0	
2	44 (41.9%)	1 (14.3%)	
3	57 (54.3%)	6 (85.7%)	
4	1 (1.0%)	0	
Neoadjuvent chemotherapy, n (%)	10 (13.3%)	0	0.339

exclusion from minimally approach meant we are doing more cases in this manner. This may be key for other institutes where low volumes of minimally invasive surgery are possibly driven by stringent patient selection, perhaps seeking the perfect surgical candidate for MIH procedures. Due to a lack of similar high volume (or low volume) comparison group from other surgeons, we are unable to do a comparative analysis within our own institution to truly determine if surgeon experience or volume[21] is a driver of conversion to open procedures. However, this is an area open to further exploration.

Table 2
Operative and pathologic data.

	MIRH (n = 105)	Conversion (n = 7)	p-value
Operative room time, min, mean (SD)	239 (±78.9)	242 (±46.5)	0.937
Case time (incision to close), min, mean (SD)	178 (±74.9)	182 (±45.1)	0.893
Estimated blood loss, mL, mean (SD)	258 (±311.4)	764 (±533.6)	<0.001*
Urine output, mL, mean (SD)	234 (±197.8)	288 (±210.9)	0.524
Transfusion requirements, mean (SD)	2552 (±1141.1)	3400 (±938.1)	0.082
Crystalloid, mL	1936 (±962.6)	2317 (±825.6)	0.350
Colloid, mL	671 (±521.8)	1083 (±664.6)	0.072
Red blood cells, units	0 (±0.6)	1 (±1.6)	<0.001*
Platelets, units	0	0	
Fresh frozen plasma, units	0 (±0.2)	0	0.781
Invasive Monitoring, n (%)	16 (20.8%)	2 (33.3%)	0.472
Arterial Line	13 (16.9%)	1 (16.7%)	0.989
Central Venous Line	4 (5.2%)	1 (16.7%)	0.255
Pathology tumor size diameter, mean (SD)	5.93 (±4.1)	7.22 (±4.3)	0.495
Pathology specimen size diameter, mean (SD)	17.9 (±3.9)	17.3 (±2.5)	0.698
Pathology specimen weight grams, mean (SD)	668 (±321.3)	606 (±371.8)	0.655
Steatosis, n (%)	39 (37.1%)	3 (42.9%)	0.762
Cirrhosis, n (%)	3 (2.9%)	0	0.650
Margin status, positive, n (%)	10 (17.2%)	1 (33.3%)	0.480

Table 3
Post-operative course and complications.

	MIRH (n = 105)	Conversion (n = 7)	p-value
Length of stay, days mean (SD)	5 (±2.9)	8 (±1.9)	0.007*
ICU days, mean (SD)	0 (±0.9)	0 (±0.4)	0.678
Postoperative complications			
Clavien I-II, n (%)	33 (31.4%)	4 (57.1%)	0.225
Clavien III-V, n (%)	5 (4.8%)	0 (0.0%)	0.528
30-day emergency room visit, n (%)	13 (12.4%)	1 (14.3%)	0.968
30-day readmission, n (%)	2 (1.9%)	2 (28.6%)	0.001*
30-day mortality, n (%)	1 (1.0%)	0 (0.0%)	0.776

Table 4
Post-operative complications compared between elective ORH and unplanned conversions.

	ORH (n = 45)	Conversion (n = 7)	p-value
Length of stay, days mean (SD)	9 (±8.3)	8 (±2.0)	0.705
ICU days, mean (SD)	2 (±6.1)	0 (±0.4)	0.444
Postoperative complications			
Clavien I-II, n (%)	37 (82.2%)	5 (71.4%)	0.510
Clavien III-V, n (%)	9 (20.0%)	0 0	0.201
30-day emergency room visit, n (%)	9 (20.0%)	1 (14.3%)	0.728
30-day readmission, n (%)	7 (15.6%)	2 (28.6%)	0.407
30-day mortality, n (%)	3 (6.7%)	0 0	0.491

Table 5
Indication for surgery and reason for conversion in patients undergoing laparoscopic major hepatectomy. Case number refers to chronological serial number of the patient in this series (n = 112). Overall number refers to chronological serial number of the patient in the list of all laparoscopic hepatectomies (n = 193 till last date of inclusion) performed by senior author.

Patient ID	Diagnosis/Indication for Surgery	Surgical Procedure	Operative Reason for conversion	Detailed Reason for conversion
Patient 1 (Case 23, Overall 42)	Giant Hemangioma of Right Liver Lobe	Right Hepatectomy	Difficult Dissection	Inability to mobilize Right lobe of liver due to adhesions; risk of uncontrollable bleeding
Patient 2 (Case 39, Overall 64)	Polycystic Disease of The Liver	Right Hepatectomy	Difficult Dissection	Inability to separate omentum from undersurface of liver and diaphragm, right lobar cyst from diaphragm
Patient 3 (Case 47, Overall 82)	Right Hepatic Duct Stricture	Right Hepatectomy	Difficult Dissection	Inability to separate omentum from liver surface
Patient 4 (Case 48, Overall 83)	Right Liver Lobe Chronic Abscess	Right Hepatectomy	Difficult Dissection	Inability to mobilize Right lobe of liver due to adhesion to diaphragm
Patient 5 (Case 63, Overall 105)	Colorectal Metastasis to Liver	Right Hepatectomy	Difficult Dissection	Inability to place trocars due to severe adhesions to abdominal wall at start of case
Patient 6 (Case 65, Overall 107)	Cholangiocarcinoma Bismuth 3a	Extended Right Hepatectomy	Difficult Dissection	Inability to safely excise liver lobe due to adhesions
Patient 7 (Case 80, Overall 136)	Colon Cancer Metastasis to Liver	Right Hepatectomy	Difficult Dissection	Avoid IVC injury during dissection (tumor surrounds IVC), increase chance of negative margin

Along similar lines of surgeon experience and learning curve[22] a closer look at Table 5, which lists the conversion in chronological order of occurrence demonstrates that we had only one conversion in the last 50 cases compared to 6 conversions in the first 72 cases of this series. Table 5 also lists the chronological serial number of that patient in terms of all laparoscopic hepatectomies performed by the senior author. If we look at the overall number, we had 6 conversions for major right sided resections in the first 107 attempted laparoscopic cases but only 1 conversion for a major right sided resection in the next 86 cases. Similar to previously published literature we agree that approximately 40–50 major complex cases are needed to gain proficiency in using the minimally invasive approach for major hepatic resection[23,24,25].

Another interesting aspect of our institutional data demonstrates that none of the conversions occurred in patients with cirrhosis, a surprising contrast to the association between cirrhosis and conversion previously documented in literature.[26] Similarly, while previous studies have reported BMI as a risk factor for conversion,[12] our study showed conversion patients to have lower mean BMIs than successful MIRH patients. We believe that high BMI is in fact a favorable reason to approach these resections laparoscopically as ligamentous dissection is easier. Further, the effect of pneumoperitoneum to expand the abdominal cavity volume leads to better visualization during laparoscopic approaches. Preoperative testing revealed Alkaline Phosphatase levels to be significantly higher in the conversion group, which may be related to inflammatory reactions eventually leading to severe adhesions. The use of LFTs to determine risks of unplanned conversion or prediction of difficult dissection during surgery needs further study in a larger cohort of patients. We believe that patient 7 (Table 5) was likely a selection issue and probably not a good candidate for laparoscopic approach due to tumor encasing IVC. Hemodynamic issues were not a factor for conversion and notably none of our conversions occurred during hilar dissection or parenchymal transection.

While unplanned conversions did result in higher morbidity and longer lengths of stay in comparison to successful MIRH patients, more importantly they demonstrated no difference in outcomes compared to planned open procedure in our cohort. This leads to the provocative question of 'why not start with a laparoscopic approach for all patients?'[31]. One advantage we have discovered with starting laparoscopically is the ability to continue the

remaining operation via a midline incision for right hepatectomy as opposed to a chevron or subcostal type incision which have higher rates of short-term post-operative morbidity[27,28].[29] Another advantage of starting laparoscopically is the ability to identify occult peritoneal metastasis and save patients the morbidity of a long midline laparotomy incision which is risk factor for hernia development.[30]

This surge in popularity of laparoscopic liver surgery has been marred by a historically high rate of conversion to open procedure intraoperatively. Our data demonstrate that though conversion offsets benefits of laparoscopic surgery, it does so without posing greater health risks than a primary open operation. In our study, the sole reason for conversion in six cases were difficulty in dissection due to adhesions and in one case poor patient selection.

Our study has several limitations. Due to its retrospective nature and the relatively small number of cases, the possibility of a type II error cannot be excluded. Additionally, due to the limited number of patients that required conversions, generalizable conclusions regarding postoperative morbidity cannot be drawn.

Author disclosures

The authors have no disclosures.

Author contributions

MRJ, JMS designed and conceived the study. MRJ, DM did primary analysis. MRJ, MT wrote initial draft. MRJ, DM, MT, SSH, EL, JMS did secondary analysis, data tabulation, contributed to manuscript preparation and final approval.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.amjsurg.2018.08.014.

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