



Open inguinal hernia repair outcomes in liver transplant recipients versus patients with cirrhosis

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Received: 19 June 2020 / Accepted: 18 August 2020 / Published online: 28 August 2020
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Abstract

Purpose Patients with liver cirrhosis (LC) are at an increased risk for postoperative complications after open inguinal hernia repair (OIHR). It is possible that orthotopic liver transplant (OLT) recipients may have better outcomes, given reversal of liver failure pathophysiology. Therefore, we sought to compare mortality risk, complications, length of stay (LOS), and cost associated with OIHR in OLT recipients versus LC.

Methods From the National Inpatient Sample (NIS), using ICD-9 codes, we found 83 OLT recipients and 764 patients with LC who underwent OIHR between 2002 and 2014. We used logistic, negative binomial, and multiple linear regression models to compare peri-operative mortality risk, postoperative complications, and LOS, and cost associated with OIHR in OLT recipients versus LC patients. Models were adjusted for patient demographic and clinical characteristics, and hospital factors.

Results OLT recipients were younger (58 vs 61, $p=0.02$), more likely to be privately insured (42.0% vs 24.6%, $p=0.006$), less likely to have ascites at time of surgery (5.1% vs 18.9%, $p=0.003$), and have surgery at large (84.3% vs 65.2%, $p=0.01$) and teaching hospitals (84.2% vs 47.9%, $p<0.001$). There were no mortalities among OLT recipients, but 19 (2.5%) deaths among LC patients. OLT recipients had a similar risk of overall complications (adjusted odds ratio aOR = 0.71 1.30 2.41) and hospital-associated costs (adjusted cost ratio = 0.71 0.88 1.09). However, LOS was significantly different with OLT recipients having shorter LOS (adjusted LOS ratio = 0.56 0.70 0.89).

Conclusion Delaying OIHR in patients with LC until after OLT decreases LOS and may carry decreased mortality.

Keywords Inguinal hernia · Hernia repair · Liver transplant · Cirrhosis

Introduction

In the United States, hernia repair is one of the most common surgical procedures performed, with approximately 770,000 outpatient repairs being performed in 2010 [1]. Though hernia repair is a common procedure, there is evidence that patients with liver cirrhosis (LC) have worse outcomes. Specifically, the risk of poor postoperative outcomes

increases as MELD increases, and in the presence of ascites [2–7]. For every 1-point increase in MELD greater than the mean, there is a 7.8% increase in complications [2]. Furthermore, decompensated cirrhosis has been associated with 3.11-fold increased odds of postoperative wound infections [3]. As such, if a patient is awaiting liver transplant, in the absence of strong contraindications to repair, surgeons may delay this elective operation until after transplant, when ascites is resolved.

Orthotopic liver transplant (OLT) recipients represent a unique population that share the risk for the development of inguinal hernias, but in whom liver failure pathophysiology has reversed following transplantation. While it is possible that OLT recipients are a lower risk group for inguinal hernia repair compared to patients with LC, OLT recipients may not fair better as they are immunosuppressed, which increases their risk for postoperative complications, especially infections [8–10]. Prior research has found that transplant recipients undergoing common general surgery procedures, such

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s10029-020-02290-8>) contains supplementary material, which is available to authorized users.

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as cholecystectomy and colectomy, have greater morbidity and mortality as well as longer lengths of stay and higher costs than their non-transplanted counterparts [11, 12]. These findings may be attributed to the immunosuppressed state of transplant recipients which impacts post-transplant wound healing and infection [13–16]. However, it is unclear if the benefits of reversal of physiology outweigh the risks of immunosuppression after liver transplantation after inguinal hernia repair. We hypothesized that delay of repair until after transplant might be associated with improved post-repair outcomes.

Therefore, we studied the differences in peri-operative mortality, complications, length of stay (LOS), and cost in OLT recipients versus LC patients after open inguinal hernia repair (OIHR) using the National Inpatient Sample (NIS).

Materials and methods

Data source

The National Inpatient Sample (NIS) is a publicly available database that was developed as part of the Healthcare Cost and Utilization Project (HCUP). Each entry in the database represents one hospitalization and contains information regarding patient demographics, diagnostic, and procedural International Classification of Disease, Ninth Revision (ICD-9) codes and hospital characteristics. The NIS contains data from approximately 7 million hospital stays yearly and approximates a 20% stratified sample of all discharges in non-federal hospitals in the United States. The stratified sample is self-weighted to allow for population-based estimates [17]. Data include patient-level hospital discharge data such as demographics, and diagnostic and procedural ICD-9 codes for the index hospital admission. All study methods were approved by the Institutional Review Board.

Study population

We used International Classification of Disease, Ninth Revision (ICD-9) procedure code for open inguinal hernia repair to identify adult orthotopic liver transplant recipients (OLTs) and patients with LC who had undergone OIHR between January 1, 2002 and December 31, 2014. ICD-9 codes were similarly used to identify history of OLT or cirrhosis diagnosis. We excluded patients who underwent both OLT and hernia repair during the same hospitalization. Patients were also excluded from the analysis if they had a history of non-liver organ transplants, a concurrent non-liver organ transplant, or graft dysfunction as ascertained by ICD-9 codes (Appendix A).

Patient, hospital, and procedure characteristics

Basic demographic characteristics were examined including age, sex, race, and insurance status. Hospital and procedure characteristics included standard NIS categories such as location (e.g. rural or urban), size based on number of beds (e.g. small, medium, large), teaching status, region (e.g. Northeast, Midwest, South, or West) and case status (elective vs urgent/emergent).

Clinical outcomes

We defined peri-operative mortality as death during the primary surgical hospital admission. Morbidities, defined as intraoperative or postoperative complications during the index hospital admission, were identified by ICD-9 code and categorized into system-based groups as established in previous studies (Appendix B). Incidence in peri-operative mortality and morbidity was modeled using hierarchical multivariable logistic regression. Length of stay was examined using hierarchical binomial regression. Mixed linear regression was used to examine log-transformed costs, which were determined using the NIS cost-to-charge ratio files.

Multivariable models for each outcome included random intercepts for each hospital and were adjusted for patient characteristics (e.g. age, sex, race, insurance status, and presence of ascites), hospital factors (location, size, region, and teaching status), and surgical urgency (elective vs urgent/emergent). Multilevel models were used as they have the advantage of accounting for variance structures (correlations between patients within hospitals or clustering).

Statistical analyses

Descriptive analyses were performed using Student's *t* tests for continuous variables and χ^2 for categorical variables to compare OLT recipients to patients with LC. For all analyses, a two-tailed *p* value of <0.05 was considered statistically significant. Statistical analyses were performed using Stata/IC 15.1.

Sensitivity analysis: multiple imputation analysis

We used multiple imputation by chained equations to impute missing values and repeated the same analysis on imputed population to examine whether excluding candidates for missing values might have introduced a selection bias into our study. All inferences remained the same even after data

imputation analysis; therefore, only the non-imputed results are reported.

Results

Study population

Among the 840 patients who underwent OIHR, 76 (9.0%) were previous OLT recipients. OLTs were comparable to LC patients in terms of sex (11.4% vs 9.3% female, $p=0.58$), race (Caucasian 80.2% vs 74.8%, $p=0.26$), and case urgency (Emergency/urgent 50.1% vs 61.7%, $p=0.13$). OLTs were more likely to be younger (58 [IQR 52–66] vs 61 years [IQR 52–71], $p=0.02$) and privately insured (42.0% vs 24.6%, $p=0.006$) and less likely to have ascites at time of surgery (5.1% vs 18.9%, $p=0.003$) (Table 1). OLTs were also more likely to undergo OIHR at large (84.2% vs. 65.2%, $p=0.01$) and teaching hospitals (84.2% vs. 47.9%, $p<0.001$). It was common for both groups to receive treatment at hospitals in an urban location (98.8% vs. 90.1%, $p=0.01$) (Table 1).

Peri-operative mortality and morbidity

There were no postoperative deaths in OLTs, but there were 19 (2.5%) deaths in LC patients. Crude and adjusted differences in overall complications were not statistically different between OLTs and LC patients (aOR $_{0.71}1.30_{2.41}$ $p=0.39$) (Table 2). The only variable predictive of overall complications was ascites (aOR $_{1.01}1.62_{2.62}$ $p=0.047$). There were no differences found between OLTs and LC patients with respect to wound (5.3% vs 5.5%, $p=0.95$), infectious (1.4% vs 1.3%, $p=0.93$), cardiac (2.6% vs 1.6%, $p=0.52$), pulmonary (0% vs 2.5%), gastrointestinal (3.8% vs 2.7%, $p=0.60$), urinary (2.7% vs 2.0%, $p=0.68$), and intraoperative (1.2% vs 1.6%, $p=0.78$) complications (Table 2).

Length of stay and cost

Median LOS was shorter in OLTs compared to patients with cirrhosis (3 vs 4 days, $p<0.001$, Table 2). After adjusting for patient and hospital factors, LOS was 30% shorter for OLTs in comparison to patients with cirrhosis (LOS ratio = $_{0.56}0.70_{0.89}$, $p=0.004$, Table 2). African American race (ratio = $_{1.13}1.40_{1.73}$, $p=0.02$), emergent/urgent admissions (ratio = $_{1.37}1.57_{1.79}$, $p<0.001$), and ascites (ratio = $_{1.13}1.33_{1.57}$, $p=0.01$) were associated with increased LOS (Table 3).

Median cost of OIHR was \$24,849 (IQR \$15,866–40,646) in OLTs compared to \$25,222 (IQR \$14,708–45,322) in LC patients, $p=0.25$. On univariate analysis, OIHR was 20% less expensive in OLTs compared

Table 1 Characteristics of the study population and hospital details for orthotopic liver transplant recipients (OLT) and patients with liver cirrhosis (LC) undergoing open inguinal hernia repair

	OLT recipients (N=76)	Patients with LC (N=764)	p value
<i>Patient-related characteristics</i>			
Age, median (IQR)	58 (52–66)	61 (52–71)	0.02
Sex female, n (%)	9 (11.4)	72 (9.3)	0.58
Race, n (%)			0.26
Caucasian	61 (80.3)	572 (74.8)	
African American	9 (11.9)	74 (9.6)	
Hispanic	6 (7.8)	91 (12.0)	
Other	0 (0)	27 (3.6)	
Insurance, n (%)			0.006
Medicare	36 (47.6)	372 (48.7)	
Medicaid	5 (6.4)	132 (17.4)	
Private	32 (42.0)	187 (24.6)	
Other	3 (3.9)	73 (9.3)	
Admission, n (%)			0.13
Emergency/Urgent	38 (50.1)	471 (61.7)	
Elective	38 (49.9)	293 (38.3)	
Ascites, n (%)	4 (5.0)	144 (18.9)	0.003
<i>Hospital-related characteristics</i>			
Bed size, n (%)			0.01
Small	1 (1.2)	64 (7.8)	
Medium	11 (14.5)	206 (27.0)	
Large	64 (84.3)	494 (65.2)	
Location, n (%)			0.01
Rural	1 (1.2)	76 (9.8)	
Urban	75 (98.8)	688 (90.2)	
Region, n (%)			0.79
Northeast	20 (27.2)	216 (28.9)	
Midwest	14 (18.9)	96 (12.9)	
South	36 (46.3)	383 (49.4)	
West	6 (7.7)	69 (8.8)	
Teaching status, n (%)			<0.001
Nonteaching	12 (15.8)	399 (52.1)	
Teaching	64 (84.2)	365 (47.9)	

Bold values signifies statistical significance

to LC patients ($_{0.65}0.80_{0.99}$, $p=0.05$). After adjusting for multiple patient and hospital factors, OIHR cost was similar in OLTs and LC patients (cost ratio = $_{0.71}0.88_{1.09}$, $p=0.23$). African American race (ratio = $_{1.08}1.31_{1.60}$, $p=0.007$), emergent/urgent admissions (ratio = $_{1.27}1.44_{1.62}$, $p<0.001$), hospital size (medium (ratio = $_{0.04}1.34_{1.73}$, $p=0.023$ and large (ratio = $_{1.10}1.40_{1.78}$, $p=0.006$)), urban location (ratio = $_{1.10}1.37_{1.71}$, $p=0.005$), and ascites

Table 2 Outcomes following open inguinal hernia repair in orthotopic liver transplant recipients (OLT) vs. patients with liver cirrhosis (LC)

Outcome	OTL (N=76)	LC (N=764)	Unadjusted OR	Adjusted OR
Peri-operative mortality, n (%)	0 (0)	19 (2.5)	–	–
Overall complications, n (%)	12 (15.8)	103 (13.4)	0.69 ^{1.20} _{2,10}	0.71 ^{1.30} _{2,41}
System-specific complications, n (%)				
Mechanical wound	4 (5.3)	42 (5.5)	0.36 ^{0.97} _{2,61}	0.34 ^{0.91} _{2,42}
Infectious	1 (1.4)	10 (1.3)	0.16 ^{1.08} _{7,14}	0.12 ^{0.84} _{6,02}
Cardiac	2 (2.6)	12 (1.6)	0.35 ^{1.68} _{7,99}	0.36 ^{2.23} _{13,8}
Pulmonary	0 (0)	19 (2.5)	–	–
Gastrointestinal	3 (3.8)	21 (2.7)	0.40 ^{1.39} _{4,82}	0.43 ^{1.71} _{6,75}
Urinary	2 (2.7)	15 (2.0)	0.29 ^{1.38} _{6,53}	0.29 ^{2.00} _{13,8}
Intraoperative	1 (1.2)	12 (1.6)	0.12 ^{0.76} _{4,97}	0.08 ^{0.61} _{3,58}
Cost, median \$ (IQR)	24,849 (15,866–40,646)	25,222 (14,708–45,322)	Ratio = ^{0.65} 0.80 _{0,99}	Ratio = ^{0.71} 0.88 _{1,09}
LOS, median days (IQR)	3 (1–5)	4 (2–8)	Ratio = ^{0.49} 0.62 _{0,78}	Ratio = ^{0.56} 0.70 _{0,89}

Bold values signifies statistical significance

Table 3 Adjusted cost and length of stay (LOS) of orthotopic liver transplant recipients (OLT) vs. patients with liver cirrhosis (LC) by patient characteristics and hospital factors following open inguinal hernia repair

Characteristic	Cost ratio	LOS ratio
OLT	0.71 ^{0.88} _{1,09}	^{0.56} 0.70 _{0,89}
Race		
Caucasian (ref)	1	1
African American	^{1.08} 1.31 _{1,60}	^{1.13} 1.40 _{1,73}
Hispanic	0.82 ^{0.99} _{1,20}	0.70 ^{0.86} _{1,06}
Other	0.74 ^{1.03} _{1,44}	0.79 ^{1.13} _{1,61}
Emergency/urgent	^{1.27} 1.44 _{1,62}	^{1.37} 1.57 _{1,79}
Hospital size		
Small (ref)	1	1
Medium	^{1.04} 1.34 _{1,73}	0.84 ^{1.11} _{1,47}
Large	^{1.10} 1.40 _{1,78}	0.80 ^{1.05} _{1,36}
Location (urban)	^{1.10} 1.37 _{1,71}	0.88 ^{1.12} _{1,43}
Ascites	^{1.34} 1.56 _{1,82}	^{1.13} 1.33 _{1,57}

Bold values signifies statistical significance

(ratio = ^{1.34}**1.56**_{1,82}, $p < 0.001$) were associated with increased costs (Table 3).

Discussion

In a nationally representative study of patients undergoing OHIR, we found that while complication rates and cost were comparable between OLT recipients and LC patients, OHIR in patients with LC was associated with more mortalities. While the cost of care was similar in both groups, OLT recipients had a shorter LOS. Thus, OHIR can be safely performed in OLT recipients with reduced lengths of stay as compared to cirrhotic patients, supporting delay of OHIR until after OLT when possible.

While our study found no difference in complications between OLT and patients with LC undergoing inguinal surgery repair, we observed no postoperative deaths in the OLT group. Prior research has shown greater morbidity and mortality in transplant recipients undergoing general surgery procedures compared to their non-transplanted counterparts [11, 12], which may be attributed to the immunosuppressed states of transplant recipients [13–16]. It is possible that the immunosuppressed state of OLTs confers an equal risk of postoperative complications as the liver failure pathophysiology of their LC patient counterparts. However, the liver failure pathophysiology of patients with LC may portend an increased mortality following inguinal surgery repair.

We found that the presence of ascites was an important risk factor for postoperative complications, which is consistent with prior studies. Cho et al. also demonstrated increased complication rates following umbilical hernia repair in patients with signs of portal hypertension, ascites, and esophageal varices. Furthermore, they showed an increase in mortality following elective repair of 11.1% vs 1.3% when MELD scores were higher than 15 [7]. Fleming et al. showed increased risk of postop complications and mortality in inguinal hernia repairs with the presence of ascites for every MELD score category relative to a reference group of low MELD without ascites [6]. Additional literature has further validated the presence of ascites with increased complications and mortality [4, 5]. However, our study is the first multi-center investigation investigating the complication risk of inguinal hernia repair associated with ascites in OLT recipients.

While ascites appears to be an important variable in evaluating future risk of complications, Oh et al. has shown no difference in complication rates following hernia repair between patients with liver cirrhosis compared to those without cirrhosis [18]. Our rate of complications in patients

with LC is consistent with the literature. Recent literature of postoperative complications including infection, reoperation, bleeding, pulmonary, renal, and cardiovascular showed complications rates in cirrhotic patients ranging from 2.7 to 30% [19–21]. In addition to severity of liver disease, emergency surgery, as opposed to an elective procedure, is associated with worse outcomes after open hernia repair [4, 7, 22, 23]. Prior studies have advocated for elective repair of abdominal hernias in patients with LC instead of “watchful waiting” to avoid emergency repair which carries increased risks and complications [18, 19, 24–26]. However, we observed no difference in acuity admission status between OLTs and LC patients ($p=0.13$). Additionally, the Denmark hernia registry showed increased mortality in patients with LC even in an elective setting when compared to patients without LC [27]. Lastly, OLTs had decreased LOS compared to LC patients. The increasing complexity of care associated with more comorbidity may explain the increased length of stay in the cirrhotic group. Kuabara et al. showed that more comorbidity and complications increase the length of stay across every major diagnostic category expect for pediatric disease [28].

There are limitations of this study that warrant further discussion. One limitation inherent in the NIS is that only a single inpatient visit is captured. Therefore, this prevents interpretation of complications in the context of readmissions or those diagnosed on outpatient follow-up. Patients with shorter hospital stays have less time to develop in-hospital complications, which may underestimate complication rate. In addition, OIHR can be performed as an outpatient procedure. Given that our population was an inpatient sample, these patients may be a non-random sample in that they have inherently higher risk than average candidates for surgery. We may have also biased our patient sample by identifying them through the use of ICD codes, which relies on the validity of the coding system to accurately reflect the patient admission. Since OLT recipients should have reversal of their liver failure pathophysiology and resolution of any portal hypertension symptoms such as ascites, one would expect better outcomes in the OLTs than the cirrhotic patients. However, we were not able to include MELD scores in risk assessment, as the NIS data do not provide the required information to calculate MELD scores, and it is uncertain in which direction it would bias our estimates. It might be that MELD score is a significant confounding variable that we are unable to control for in this study.

Conclusion

Open inguinal hernia repair can be performed safely in OLT recipients and with a shorter LOS than patients with LC. OLT recipients and LC patients have similar risk of

in-hospital postoperative complications, whereas LC patients may have increased risk of death after OHIR. As such, these findings combined with a similar rate of emergency repair between these two patient populations support “watchful waiting” in transplant-eligible candidates until after liver transplantation when ascites resolves.

Funding No author received any funding for this investigation.

Code availability Statistical analyses were performed using Stata/IC 15.1 via the authors’ custom code.

Compliance with ethical standards

Conflict of interest All the authors declare no conflict of interest with the investigation.

Ethical approval The Institutional Review Board of Johns Hopkins University reviewed and approved this study.

Human and animal rights This study does not include any animal trial. For this type of article, informed consent is not required.

Consent to participate For this study, formal consent was not required.

Consent for publication For this study, formal consent was not required.

Availability of data and material All the obtained data were deidentified. All procedures performed in this study were in accordance with the ethical standards of the institutional committee and the HCUP-AHRQ data user agreement.

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