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Primary Hip

Compensated Cirrhosis Is Associated With Increased Risk of Complications Following Total Hip Arthroplasty in a Large Medicare Database

Sean B. Sequeira, BS [a], Lawal A. Labaran, MD [a], Joshua E. Bell, MD [a], Raj M. Amin, MD [b], Sandesh S. Rao, MD [b], Brian C. Werner, MD [a,*]

[a] Department of Orthopaedic Surgery, University of Virginia, Charlottesville, VA
[b] Department of Orthopaedic Surgery, Johns Hopkins Hospital, Baltimore, MD

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ABSTRACT

Background: The aim of this study is to evaluate medical and surgical complications of liver cirrhosis patients following total hip arthroplasty (THA), with attention to different etiologies of cirrhosis and their financial burden following THA.

Methods: In total, 18,321 cirrhotics and 722,757 non-cirrhotics who underwent primary elective THA between 2006 and 2013 were identified from a retrospective database review. This cohort was further subdivided into 2 major etiologies of cirrhosis (viral and alcoholic cirrhosis) and other cirrhotic etiology. Cirrhotics were compared to non-cirrhotics for hospital length of stay, 90-day mean total charges and reimbursement, hospital readmission, and major medical and arthroplasty-specific complications.

Results: Cirrhosis was associated with increased rates of major medical complications (4.3% vs 2.4%; odds ratio [OR] 1.20, $P < .001$), minor medical complications, transfusion (3.4% vs 2.1%; OR 1.16, $P = .001$), encephalopathy, disseminated intravascular coagulation, and readmission (13.5% vs 8.6%; OR 1.18, $P < .001$) within 90 days. Cirrhosis was associated with increased rates of revision, periprosthetic joint infection, hardware failure, and dislocation within 1 year postoperatively (3.1% vs 1.6%; OR 1.37, $P < .001$). Cirrhosis independently increased hospital length of stay by 0.14 days ($P < .001$), and it independently increased 90-day charges and reimbursements by $13,791 ($P < .001$) and $1707 ($P < .001$), respectively. Viral and alcoholic cirrhotics had higher rates of 90-day and 1-year complications compared to controls—other causes only had higher rates of 90-day medical complications, encephalopathy, readmission, and 1-year revision, hardware failure, and dislocation compared to controls.

Conclusion: Cirrhosis, especially viral and alcoholic etiologies, is associated with higher risk of early postoperative complications and healthcare utilization following elective THA.

Total hip arthroplasty (THA) has one of the best long-term survivorships of any orthopedic surgery [1]. Estimates suggest that the number of THAs performed in the United States is expected to increase to 635,000 by 2030 for several reasons, including at-risk patient populations becoming eligible for the procedure [2]. The success of THA and advancements in medical management have broadened inclusion criteria to several at-risk patient populations.

Due to enhanced medical treatment and stabilization, patients with liver cirrhosis are an at-risk patient population that may more frequently undergo orthopedic surgery. Liver cirrhosis is a chronic condition which is characterized by fibrotic and nodular changes to its lobular organization and compromised liver function, traditionally by viruses or alcohol [3]. Other less common etiologies of cirrhosis include autoimmune mechanisms, genetic conditions, and non-alcoholic fatty liver disease [3].

The various etiologies of liver cirrhosis differ in how rapidly they progress and their associated outcomes following surgery. For example, alcoholic cirrhosis is thought to be one of the most rapidly progressive forms of liver cirrhosis due to the substantial damage the

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* Reprint requests: Brian C. Werner, MD, Department of Orthopaedic Surgery, University of Virginia, 400 Ray C Hunt Dr, Charlottesville, VA 22908.

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Table 1
Inclusion Codes.

All-cause cirrhosis	
Viral cirrhosis	ICD-9-CM: 070.22, 070.23, 070.32, 070.33, 070.44, 070.54
Alcoholic cirrhosis	ICD-9-CM: 571.12
Other cirrhosis	ICD-9-CM: 571.5, 571.6, 571.8, 571.9
Non-cirrhotic liver disease	ICD-9-CM: 070.0-21, 070.30, 070.31, 070.41-43, 070.49, 070.51-53, 070.59, 070.6, 070.70, 070.71, 070.9, 571.0, 571.1, 571.3, 571.40-42, 571.49

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

ethanol metabolites have on hepatocytes [4]. In a study that utilized US Census Bureau data to evaluate liver cirrhosis mortality, alcoholic cirrhosis was found to have the highest annual increase in cirrhosis related mortality, which may have implications for these at-risk patients undergoing orthopedic surgery [5]. Furthermore, previous studies have demonstrated that liver cirrhosis surgical candidates have poor outcomes following orthopedic surgery and the severity of outcomes are different for each etiology of cirrhosis [6].

Patients with liver cirrhosis typically have poor outcomes following orthopedic surgery, although literature examining outcomes following THA in this population is limited. Some studies suggest that liver cirrhosis increases the risk of blood loss, readmission, and mortality following arthroplasty, but these studies either analyzed a small sample of patients or had short follow-up periods [3,7–9]. Additionally, there is very limited investigation to stratify outcomes following THA using liver cirrhosis etiology or analyze the financial burden of cirrhosis on healthcare following THA. As such, the goal of this study is to evaluate medical and surgical complications of liver cirrhosis patients following THA, with specific attention to different etiologies of cirrhosis and financial burden of THA in this at-risk population.

Methods

Data Source

A retrospective database review was conducted using the commercially available PearlDiver Patient Records Database (www.pearldiverinc.com; PearlDiver Inc, Colorado Springs, CO). The PearlDiver database contains all Medicare patient records from 2005 to 2014 from the 100% Standard Analytical Files, searchable by International Classification of Diseases (ICD) and Current Procedural Terminology codes. Institutional Review Board approval was waived for this study as data obtained from the database are de-identified and Health Insurance Portability and Accountability Act compliant.

Study Population

All Medicare patients aged 85 years or younger who underwent an elective THA (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM]: 81.51) between 2006 and 2013 were included. Indications for elective THA were degenerative hip pathologies. This allowed a minimum of 1 year of preoperative and postoperative database exposure for all included patients. The included patient cohort was further divided into patients with a diagnosis of liver cirrhosis and non-cirrhotic patients using ICD-9 coding for cirrhosis, the latter of which included patients with non-cirrhotic liver disease (Table 1). Exclusion criteria were the following: patients undergoing revision THA (ICD-9-CM: 00.70-73, 81.53), a concurrent or prior diagnosis of ascites (ICD-9 CM: 789.59), and patients with a history of hip trauma, infection, or malignancy prior to THA (Table 2).

Postoperative Outcomes Following Total Hip Arthroplasty Among Cirrhotic Patients

The rate of major and minor medical complications, transfusion, encephalopathy, disseminated intravascular coagulation (DIC), and readmissions were compared between cirrhotics and non-cirrhotics within 90 days following THA. Aggregated major medical complications included a diagnosis of pulmonary embolism, pneumonia, myocardial infarction, cerebrovascular accident, sepsis, and mortality. Minor medical complications included acute kidney injury, urinary tract infection, wound complications, transfusion, thrombocytopenia, and deep vein thrombosis. Major and minor criteria were defined by the Dindo classification, which has previously been utilized in general surgery outcome literature, and orthopedic literature [6,7]. The rates of arthroplasty-specific complications including revision THA, periprosthetic joint infection (PJI), periprosthetic fracture, hardware failure, and dislocation within 1 year following THA were determined (Appendix Table 1). The economic burden associated with THA among cirrhotics was also determined by patient length of stay and hospital reimbursement and charges within 90 days of index surgery.

Cirrhosis Subgroup Analysis

The resulting study cohort of cirrhotics was further subdivided into the 2 major etiologies of cirrhosis: viral and alcoholic cirrhosis. The remaining patients were grouped into “other cirrhotic etiology” to better highlight the effects of each etiology on outcomes following THA. Other cirrhotic etiologies include lesser common causes of cirrhosis such as autoimmune, genetic, and toxin-induced, among others (Table 1). Each subgroup was separately compared to the control group for the same postoperative outcomes highlighted in the main study analysis.

Statistical Analysis

Baseline demographics, substance use history, and pre-existing comorbidities between groups were compared using Pearson's chi-squared analysis. Additionally, the rates of 90-day and 1-year postoperative outcomes were compared using Pearson's chi-

Table 2
Exclusion Codes.

Hip trauma	ICD-9-CM: 716.5, 820.00-03, 820.09-13, 820.19-22, 820.30-32, 820.80, 820.90, 821.00-01, 821.10-11, 827.0-1, 928.00-01, 905.3-4
Hip neoplasm	ICD-9-CM: 170.7, 170.9, 171.3, 213.7, 213.9
Hip infection	ICD-9-CM: 711.05, 711.45, 711.85, 711.95

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

Table 3
Patient Demographics.

Variable	Total Hip Arthroplasty		
	Cirrhosis (n = 18,321)	Controls (n = 722,757)	*P*-Value
Age (y)			
<65	30.4%	10.2%	
65-69	19.8%	28.4%	
70-74	23.5%	24.4%	<.001
75-79	17.1%	21.7%	
80-84	9.2%	15.3%	
Male gender	41.7%	40.2%	<.001
Female gender	58.3%	59.8%	
Comorbidities			
Obesity (BMI >30 kg/m^2)	22.4%	8.5%	<.001
PVD	9.9%	5.0%	<.001
Chronic kidney disease	13.2%	5.4%	<.001
CHF	15.5%	7.4%	<.001
CAD	32.0%	20.2%	<.001
COPD	38.6%	17.8%	<.001
Diabetes mellitus	39.7%	19.1%	<.001
Hypertension	81.8%	58.6%	<.001
Hyperlipidemia	67.1%	49.4%	<.001
Tobacco use	38.3%	16.1%	<.001
Region			
Midwest	27.1%	28.1%	<.001
Northeast	18.5%	18.6%	
South	36.6%	34.7%	
West	17.7%	18.6%	
Pre-existing hip pathology			
Osteoarthritis	89.7%	94.7%	<.001
Avascular necrosis	17.0%	7.2%	<.001
SLE	1.1%	0.5%	<.001
Psoriatic arthritis	0.4%	0.2%	<.001
Ankylosing spondylitis	0.2%	0.2%	.193
Rheumatoid arthritis	4.8%	3.4%	<.001

CAD, coronary artery disease; BMI, body mass index; PVD, peripheral vascular disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; SLE, systemic lupus erythematosus.

squared analysis. Multivariate logistical regression was utilized to analyze the independent effect of cirrhosis, including subgroups, on postoperative outcomes following THA, adjusting for age, gender, substance use history, and pre-existing comorbidities as covariates. Welch's *t*-test was utilized to test for significant differences in the mean values of LOS, reimbursement, and charges between cirrhotics and non-cirrhotics. The independent effect of cirrhosis on LOS, hospital reimbursement, and charges was determined using a linear regression, adjusting for previously highlighted covariates. All statistical analyses were performed using R Project for Statistical Computing. Significance was determined by a *P*-value <.05.

Results

Patient Demographics and Comorbidities

In total, 18,321 cirrhotic patients and 722,757 non-cirrhotic patients who underwent a primary elective THA were identified. There were significant differences between cirrhotic and non-cirrhotic patients for each comorbidity and patient demographic subgroup, which were controlled for in subsequent multivariate analysis. There were patient demographic and comorbid condition differences between the cirrhosis and non-cirrhosis cohorts—most notably, these differences included cirrhotic patients who were younger, male, and had higher rates of comorbidities (Table 3).

Outcomes Following Total Hip Arthroplasty in Cirrhotic Patients

Cirrhosis was independently associated with increased rates of major medical complications (4.3% vs 2.4%; odds ratio [OR] 1.20, 95% confidence interval [CI] 1.11-1.30, $P < .001$), minor medical complications (13.7% vs 8.0%; OR 1.30, 95% CI 1.25-1.36, $P < .001$), transfusion (3.4% vs 2.1%; OR 1.16, 95% CI 1.06-1.26, $P < .001$), encephalopathy (0.9% vs 0.2%; OR 2.37, 95% CI 1.99-2.80, $P < .001$), DIC (0.0% vs 0.0%; OR 2.28, 95% CI 1.05-4.37, $P = .021$), and readmission (13.5% vs 8.6%; OR 1.18, 95% CI 1.13-1.24, $P < .001$) within 90 days following THA (Table 4). Cirrhosis was also associated with increased rates of revision (3.4% vs 1.9%; OR 1.25, 95% CI 1.15-1.36, $P < .001$), PJI (2.3% vs 1.1%; OR 1.23, 95% CI 1.11-1.36, $P < .001$), hardware failure (1.7% vs 1.0%; OR 1.29, 95% CI 1.14-1.45, $P < .001$), and dislocation (3.1% vs 1.6%; OR 1.37, 95% CI 1.25-1.49, $P < .001$). Linear regression demonstrated that cirrhosis independently increased hospital LOS by 0.14 days ($P < .001$), and cirrhosis independently increased 90-day charges by $13,791 ($P < .001$) and 90-day reimbursement by $1707 ($P < .001$) (Table 4).

Table 4
Comparison of Postoperative Outcomes Between Cirrhotic Arthroplasty Patients and Controls.

Variable	Total Hip Arthroplasty			
	Cirrhosis (n = 18,321)	Controls (n = 722,757)	Cirrhosis vs Controls Adjusted OR (95% CI)	*P*-Value
90-d outcomes				
Major medical complication	4.3%	2.4%	**1.20 (1.11-1.30)**	**<.001**
Minor medical complication	13.7%	8.0%	**1.30 (1.25-1.36)**	**<.001**
Transfusion	3.4%	2.1%	**1.16 (1.06-1.26)**	**.001**
Encephalopathy	0.9%	0.2%	**2.37 (1.99-2.80)**	**<.001**
DIC	0.0%	0.0%	**2.28 (1.05-4.37)**	**.021**
Readmission	13.5%	8.6%	**1.18 (1.13-1.24)**	**<.001**
1-y outcomes				
Revision	3.4%	1.9%	**1.25 (1.15-1.36)**	**<.001**
Periprosthetic joint infection	2.3%	1.1%	**1.23 (1.11-1.36)**	**<.001**
Periprosthetic fracture	0.7%	0.5%	1.20 (0.99-1.43)	.057
Hardware failure	1.7%	1.0%	**1.29 (1.14-1.45)**	**<.001**
Dislocation	3.1%	1.6%	**1.37 (1.25-1.49)**	**<.001**
LOS, reimbursement, and charges				
LOS	3.63 ± 2.59	3.30 ± 2.08	**0.14**[a] **(0.11 ≤ β ≤ 0.17)**	**<.001**
Reimbursement (90-d)	$17,604 ± 13,437	$14,251 ± 10,245	**$1707**[a] **(1557 ≤ β ≤ 1858)**	**<.001**
Charges (90-d)	$74,820 ± 66,425	$60,167 ± 47,207	**$13,791**[a] **(6743 ≤ β ≤ 8142)**	**<.001**

Values in bold denote significance determined as $P < .05$.
OR, odds ratio; CI, confidence interval; DIC, disseminated intravascular coagulation; LOS, length of stay.
[a] Standardized beta coefficient.

Table 5
Adjusted Odds Ratios Following Subgroup Analysis of Differing Cirrhotic Etiologies Among Total Hip Arthroplasty Patients.

Variable	Viral Cirrhosis (n = 2959) vs Controls	*P*-Value	ETOH Cirrhosis (n = 379) vs Controls	*P*-Value	Other Cirrhosis (n = 13,271) vs Controls	*P*-Value
90-d outcomes						
Major medical complication	**1.42 (1.19-1.67)**	**<.001**	1.15 (0.66-1.84)	.591	**1.12 (1.02-1.22)**	**.016**
Minor medical complication	**1.30 (1.16-1.45)**	**<.001**	**1.77 (1.32-2.32)**	**<.001**	**1.22 (1.16-1.29)**	**<.001**
Transfusion	**1.29 (1.07-1.55)**	**.007**	**2.21 (1.40-3.30)**	**<.001**	1.02 (0.92-1.13)	.691
Encephalopathy	**1.97 (1.25-2.94)**	**.002**	**3.60 (1.28-7.88)**	**.005**	**1.89 (1.51-2.33)**	**<.001**
DIC	**6.28 (1.85-16.08)**	**.001**	–	–	1.41 (0.43-3.41)	.506
Readmission	**1.33 (1.21-1.47)**	**<.001**	**1.72 (1.32-2.22)**	**<.001**	**1.08 (1.02-1.14)**	**.008**
1-y outcomes						
Revision	**1.47 (1.23-1.75)**	**<.001**	1.45 (0.82-2.34)	.163	**1.13 (1.01-1.25)**	**.027**
Periprosthetic infection	**1.38 (1.10-1.69)**	**.003**	**1.94 (1.08-3.19)**	**.016**	1.09 (0.96-1.24)	.186
Periprosthetic fracture	1.23 (0.76-1.86)	.371	**3.14 (1.24-6.44)**	**.006**	0.97 (0.76-1.22)	.805
Hardware failure	**1.52 (1.17-1.93)**	**.001**	1.42 (0.61-2.78)	.359	**1.24 (1.07-1.42)**	**.003**
Dislocation	**1.78 (1.49-2.11)**	**<.001**	**2.48 (1.54-3.77)**	**<.001**	**1.17 (1.04-1.30)**	**.007**
LOS, reimbursement, and charges						
LOS	**0.54**[a] **(0.46-0.61)**	**<.001**	**0.47**[a] **(0.27-0.68)**	**<.001**	−0.01[a] (−0.04 to 0.03)	.689
Reimbursement (90-d)	**$4310**[a] **(3944-4677)**	**<.001**	**$3140**[a] **(2129-4151)**	**<.001**	**$760**[a] **(586-934)**	**<.001**
Charges (90-d)	**$16,394**[a] **(14,694-18,095)**	**<.001**	**$21,186**[a] **(16,495-25,876)**	**<.001**	**$3645**[a] **(2836-4454)**	**<.001**

Values in bold denote significance determined as $P < .05$.
ETOH, alcohol; DIC, disseminated intravascular coagulation; LOS, length of stay.
[a] Standardized beta coefficient.

Viral Cirrhosis

Viral cirrhosis was significantly associated with increased rates of major medical complications (OR 1.42, 95% CI 1.19-1.67, $P < .001$), minor medical complications (OR 1.30, 95% CI 1.16-1.45, $P < .001$), transfusion (OR 1.29, 95% CI 1.07-1.55, $P = .007$), encephalopathy (OR 1.97, 95% CI 1.25-2.94, $P = .002$), DIC (OR 6.28, 95% CI 1.85-16.08, $P = .001$), and readmissions (OR 1.33, 95% CI 1.21-1.47, $P < .001$) within 90 days following THA compared to controls. Viral cirrhosis was also associated with increased rates of revision (OR 1.47, 95% CI 1.23-1.75, $P < .001$), PJI (OR 1.38, 95% CI 1.10-1.69, $P < .001$), hardware failure (OR 1.52, 95% CI 1.17-1.93, $P = .001$), and dislocation (OR 1.78, 95% CI 1.49-2.11, $P < .001$) compared to non-cirrhotics. Linear regression demonstrated that cirrhosis independently increased LOS by 0.54 days ($P < .001$), and it increased 90-day charges and reimbursements by $16,394 ($P < .001$) and $4310 ($P < .001$), respectively (Table 5).

Alcoholic Cirrhosis

Alcoholic cirrhosis was associated with increased rates of minor medical complications (OR 1.77, 95% CI 1.32-2.32, $P < .001$), transfusion (OR 2.21, 95% CI 1.40-3.30, $P < .001$), encephalopathy (OR 3.60, 95% CI 1.28-7.88, $P = .005$), and readmissions (OR 1.72, 95% CI 1.32-2.22, $P < .001$) within 90 days following THA compared to controls. Alcoholic cirrhosis was also associated with increased rates of PJI (OR 1.94, 95% CI 1.08-3.19, $P = .016$), periprosthetic fracture (OR 3.14, 95% CI 1.24-6.44, $P = .006$), and dislocation (OR 2.48, 95% CI 1.54-3.77, $P < .001$). Linear regression demonstrated that alcoholic cirrhosis independently increased hospital LOS by 0.47 days ($P < .001$) and it independently increased 90-day charges and reimbursement by $21,186 ($P < .001$) and $3140 ($P < .001$), respectively. No significant differences were found between 90-day major medical complications (OR 1.15, $P = .591$), as well as 1-year revision (OR 1.45, $P = .163$) and hardware failure (OR 1.21, $P = .346$) among alcoholic cirrhotics following THA.

Other Causes of Cirrhosis and Hip Arthroplasty

Other etiologies were associated with increased rates of major medical complications (OR 1.12, 95% CI 1.02-1.22, $P = .016$), minor medical complications (OR 1.22, 95% CI 1.16-1.29, $P < .001$), encephalopathy (OR 1.89, 95% CI 1.51-2.33, $P < .001$), and readmission (OR 1.08, 95% CI 1.02-1.14, $P = .008$) within 90 days following THA. Other cirrhosis was also associated with increased rates of revision (OR 1.13, 95% CI 0.82-2.34, $P = .027$), hardware failure (OR 1.24, 95% CI 1.07-1.42, $P = .003$), and dislocation (OR 1.17, 95% CI 1.04-1.30, $P = .007$). Following adjusted linear regression, other etiologies of cirrhosis independently increased 90-day charges by $3645 ($P < .001$) as well as $760 in 90-day reimbursement ($P < .001$). No significant differences were found between 90-day transfusion (OR 1.02, $P = .691$) and DIC (OR 1.41, $P = .506$), as well as 1-year periprosthetic infection (OR 1.09, $P = .186$) or periprosthetic fracture (OR 0.97, $P = .805$). Following adjusted linear regression, there was no significant difference in LOS between other etiologies of cirrhosis and controls.

Discussion

As the acute and chronic care of cirrhosis improves, more patients with this comorbidity will be eligible for surgery including THA. Although successful in a healthy population, there are scarce data on the outcomes following THA in an at-risk patient population like cirrhosis. Characterizing such outcomes could have important ramifications in preoperative planning, perioperative decision-making, and postoperative management. In the present study, we found that cirrhotics undergoing THA had an increased rate of 90-day major medical complications, minor medical complications, transfusion, encephalopathy, DIC, and readmission, even when controlling for associated comorbidities. Cirrhotics were at greater risk of implant-related complications at 1 year postoperatively as well. Viral and alcoholic cirrhotics had increased rates of 90-day complications and 1-year orthopedic-related complications—notably, other etiologies of cirrhosis only had increased rates of 90-day major and minor medical complications, as well as 90-day readmission, 1-year revision, hardware failure, and dislocation.

The liver is an imperative component of the body's response to major surgery and, therefore, compromise often worsens outcome following surgery. Our study determined that cirrhotic patients had poorer outcomes following THA compared to their healthy counterparts, an association supported in the literature. Liao et al [10] reported on liver cirrhosis following instrumented lumbar surgery and concluded that cirrhosis was associated with poor outcome

following lumbar surgery especially if Child-Pugh score was greater than 6. Several prior studies have concluded that cirrhotic patients suffer from increased postoperative complications including infection, revision, fracture, mortality, among others following joint arthroplasty [3,7,8,11,12]. Splanchnic vasodilation, diastolic dysfunction, coagulopathies, chronic malnutrition, among others are likely responsible for the association between cirrhosis and poor postoperative outcome [13–15]. Our results also demonstrated worse outcomes for viral and alcoholic cirrhotics compared to both their non-cirrhotic counterparts, findings also supported in the literature [16]. Notably, other etiologies of cirrhosis had few complications and better outcome following THA compared to controls which suggests heightened and aggressive management should be implemented for viral and alcoholic cirrhosis patients undergoing THA.

In the present study, viral and alcoholic cirrhosis patients not only suffer poor 90-day postoperative outcomes, but also higher rates of 1-year arthroplasty-specific complications. Although no study examines outcome to 1 year postoperatively with a similar sample size, most prior literature agrees that cirrhosis is a risk factor for poor orthopedic-related outcome. Hsieh et al [17] evaluated 45 THAs among cirrhotics and concluded that cirrhosis was associated with an increased risk of 30-day complications and 5-year periprosthetic infection. Deleuran et al [7] evaluated 210 cirrhosis patients who underwent THA and concluded that cirrhosis was also associated an increased risk of periprosthetic infection and revision within 1 year. Our study builds upon Deleuran et al with a larger sample size and the inclusion of 1-year complications such as periprosthetic fracture, hardware failure, and dislocation. Additionally, to our knowledge, no study has stratified cirrhosis based upon etiology and determined that non-alcoholic and non-viral cirrhotic patients only suffer from increased periprosthetic infection at 1 year, but, notably, are not at increased risk for revision, fracture, dislocation, or hardware failure. The mechanism behind poor orthopedic-related outcome in cirrhosis, especially of viral or alcoholic origin, is likely through hepatic osteodystrophy, which quickens bone demineralization [18]. Studies suggest that liver cirrhosis can also cause osteomalacia and osteoporosis further hindering postoperative rehabilitation [18–20]. Cirrhosis was also associated with increased risk of infection at 1 year—one study suggested that chronic liver disease was the strongest risk factor for deep prosthetic infection [21]. Hsieh et al [22] determined that debridement with retention of the prosthesis was minimally successful in resolving prosthetic hip infection in cirrhotic patients following THA. Increased susceptibility to infection is likely attributable to complement deficiencies, aberrant conduction of the reticuloendothelial system, poor acute phase reactant production, and impaired cellular immune defense inherent to liver cirrhosis [23].

It is interesting to note that the alcoholic and viral groups of cirrhosis sustain worse arthroplasty-related outcomes than other cirrhotics when each group was compared to the control group following THA. A similar set of findings was found when etiologies of cirrhosis were evaluated following TKA and may be explained by the inherent pathogenesis of these forms of cirrhosis as well as the patients who are at greater risk of these etiologies of cirrhosis [6]. Alcoholic cirrhosis has been shown to demonstrate the fastest progression of fibrosis among etiologies of cirrhosis which may therefore explain these cirrhotic patients' greater risk of poor outcome and complication following THA when compared to controls [4].

Viral cirrhotics may suffer from poor outcome following THA when compared to controls due to their poor access to healthcare since regular access to healthcare helps to prevent the transmission of viruses highly associated with hepatitis, primarily hepatitis B and C [24]. Conventional healthcare practices such as blood product screening, hepatitis B vaccination, counseling on safe sex and sexually transmitted infection testing, among others are routinely performed in healthcare settings. Therefore, it is also reasonable to presume that these patients may also have had poor follow-up and/or access to physical therapy and conventional postoperative management following their THA, thus influencing their outcome and causing a poor outcome following THA. Regardless, further research is necessary to expound upon the findings we present here as well as more specifically evaluate the different etiologies of cirrhosis against each other to draw conclusions regarding prognosis following joint replacement.

Cost analysis yielded important results regarding the greater financial impact of cirrhosis on contemporary payment models. Notably, viral cirrhosis had the highest costs of all cirrhosis etiology, a conclusion consistent with Newman et al [25]. However, other studies suggest that alcoholic cirrhosis incurs the most expense of all etiologies of cirrhosis, owing to its proclivity toward decompensation and often late diagnosis [26]. Nevertheless, these results advocate for a re-evaluation of cirrhosis as a medical condition managed under bundled payment models.

Although this study demonstrates that cirrhotic patients have worse outcomes following THA, surgeons should still include them as eligible candidates for THA but adjust preoperative counseling and management in order to optimize outcomes in light of this study's findings. These results also advocate for including etiology of cirrhosis in preoperative counseling and perioperative/postoperative management of these at-risk patients in order to tailor care appropriately to the individual patient. The major strength of this study is its length of follow-up and large sample size—this study is one of the largest that examines outcome following THA in cirrhosis patients as well as extends analysis to 1-year postoperation. Additionally, the stratification of cirrhosis based upon etiology allows conclusions to be drawn regarding more refined and individualized treatment of the cirrhotic patient. Finally, controlling for comorbid conditions and patient demographic factors through regression analysis allowed for mitigation of any confounding impact that those conditions or factors had on THA outcome. Nevertheless, our study did have its limitations. Conclusions drawn from this study are contingent upon the accuracy of the medical database used—other studies have determined that large medical databases can often miscode diagnoses [27]. However, the likelihood of miscoding in large administrative databases has been found to be around 1.1% [28]. Furthermore, pre-existing comorbid conditions can also be miscoded or simply left out, compromising the effects of our controls [29]. Additionally, PearlDiver does not provide information regarding individual institutional or surgical practice, including perioperative antibiotic regimens, surgical technique, bearing material, implant design or fixation method, or preoperative optimization of cirrhosis, all of which may affect the presence or absence of postoperative complications and mortality. Finally, cirrhosis was not stratified based upon severity—the use of conventional scoring criteria like MELD or Child-Pugh might have further contextualized the conclusions presented herein. Nevertheless, our study's findings and conclusions substantially add to the existing literature by evaluating cirrhotic patients based upon the etiology of their cirrhosis and greatly expanding upon previously reported medical and arthroplasty-related complications of these at-risk patients following THA.

Conclusion

Cirrhosis is associated with a higher risk of complications following elective THA. Alcoholic and viral etiologies of cirrhosis were independent risk factors for prolonged hospital stay, major

and minor medical complications, readmission, increased cost, and poorer 1-year orthopedic-related outcomes following THA.

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Appendix

Appendix Table 1
Postoperative Outcome Codes.

Major medical complication	
Pulmonary embolus	ICD-9-CM: 415.11-415.13, 415.19
Pneumonia	ICD-9-CM: 480.0-3, 480.8-9, 481, 482.0-2, 482.30-32, 482.39-42, 482.49, 482.81-84, 482.89, 482.9, 483.0-1, 483.8, 485, 486, 997.31-32
CVA	ICD-9-CM: 434.01, 434.11, 434.91, 436, 997.02
Myocardial infarction	ICD-9-CM: 410.00-01, 410.10-11, 410.20-21, 410.30-31, 410.40-41, 410.50-51, 410.60-61, 410.70-71, 410.80-81, 410.90-91, 997.1
Sepsis	ICD-9-CM: 995.91-92
Minor medical complication	
AKI	ICD-9-CM: 584.5, 584.9
UTI	ICD-9-CM: 599.0
Wound complications	ICD-9-CM: 998.12-13, 998.30-32, 998.51, 998.59, 998.83
Transfusion	ICD-9-CM: 99.00-09
DVT	ICD-9-CM: 453.40-42
Thrombocytopenia	ICD-9-CM: 287.49, 287.5
Encephalopathy	ICD-9-CM: 348.30, 348.31, 349.82, 572.2
DIC	ICD-9-CM: 286.6
Revision THA	ICD-9-CM: 00.70-73, 81.53
Periprosthetic infection	ICD-9-CM: 996.66
Periprosthetic fracture	ICD-9-CM: 996.44
Hardware failure	ICD-9-CM: 996.41, 996.43, 996.46, 996.47
Dislocation	ICD-9-CM: 718.35, 835.00-03, 996.42, 79.75, 79.85

DVT, deep vein thrombosis; CVA, cerebrovascular accident; UTI, urinary tract infection; AKI, acute kidney injury, DIC, disseminated intravascular coagulation; THA, total hip arthroplasty; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.