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Impact of Compensated Cirrhosis Etiology on Postoperative Outcomes Following Total Knee Arthroplasty

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ABSTRACT

Background: Cirrhotics often demonstrate worse outcomes than their non-cirrhotic counterparts following orthopedic surgery; however, there are limited arthroplasty-focused data on this occurrence. Additionally, variances in postoperative outcomes among the different etiologies of cirrhosis have not been well described. The aim of this study is to evaluate the effect compensated cirrhosis had on postoperative outcomes following elective total knee arthroplasty (TKA).

Methods: In total, 1,734,568 patients who underwent primary TKA from 2006 to 2013 were identified using the Medicare Claims Database. Patients were divided into those with a history of compensated cirrhosis and those with no history of liver disease. Subgroup analysis was performed based on the etiology of cirrhosis. Multivariate logistic regression was used to evaluate postsurgical outcomes of interest.

Results: Cirrhotic patients had higher risk of developing disseminated intravascular coagulation (odds ratio [OR] 2.76, $P = .003$), encephalopathy (OR 3.00, $P < .001$), and periprosthetic infection (OR 1.79, $P < .001$) compared to controls. Following subgroup analysis, alcoholic cirrhotics had high risk of periprosthetic infection (OR 2.12, $P < .001$), fracture (OR 3.28, $P < .001$), transfusion (OR 2.45, $P < .001$), and encephalopathy (OR 7.34, $P < .001$) compared to controls. Viral cirrhosis was associated with an increase in 90-day charges ($14,941, $P < .001$) compared to controls, while cirrhosis secondary to other causes was associated with few adverse outcomes compared to controls.

Conclusion: Liver cirrhosis is an independent risk factor for increased perioperative morbidity and financial burden following TKA. Cirrhosis due to etiologies other than viral infections and alcoholism are associated with few adverse outcomes. Surgeons should be aware of these complications to properly optimize postoperative management.

Total knee arthroplasty (TKA) is one of the most successful treatment options for degenerative joint diseases [1] with over 600,000 TKAs performed annually in the United States alone. The utilization of TKA is expected to substantially increase as improvements in medical and surgical management of high-risk patients continue to improve thus expanding surgical candidacy [2,3]. In an era of cost reduction and bundled payments, the outcomes and survivorship of the previously high-risk TKA patients will continue to be scrutinized [4].

Patients with liver cirrhosis are one such group of high-risk patients that have become an eligible group for TKA due to advancement in the medical treatment of this comorbidity. Although the most common etiologies of liver cirrhosis are alcohol and viral, other less common causes include toxin-induced, autoimmune, genetic causes such as Wilson's disease, and non-alcoholic steatohepatitis [5,6].

Although it is generally accepted that the outcomes of patients with cirrhosis are worse than their non-cirrhotic counterparts following orthopedic surgery, there are limited arthroplasty-focused data in this population [7,8]. A recent study found that cirrhotic patients are more likely to experience postoperative hemorrhage and surgical site infection than non-cirrhotics

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following joint arthroplasty [9]. However, long-term data are scarce. Although few studies have investigated outcomes following joint arthroplasty among cirrhotics [9,10], very little is known about these outcomes based on the different etiologies of cirrhosis. In addition to standard predictive models such as Child-Pugh classification and model for end-stage liver disease (MELD) score, understanding how the different etiologies of cirrhosis impact postoperative outcome is imperative to better guide decision making in managing cirrhotics in the perioperative period. The goal of this study is to evaluate the outcomes and complications of cirrhotic patients following TKA and to analyze the effect of the different etiologies of cirrhosis on postoperative outcomes following TKA. We hypothesize that (1) cirrhotics, when compared to controls, are associated with increased postoperative morbidity and financial burden and (2) cirrhosis of viral and alcoholic etiology is associated with poorer outcomes when referenced to all other causes of cirrhosis.

Methods

Data Source

A retrospective database review was conducted, utilizing the commercially available PearlDiver Patient Records Database (www.pearldiverinc.com; PearlDiver Inc, Colorado Springs, CO), which 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 among others. Queried data are deidentified and Health Insurance Portability and Accountability Act compliant, therefore Institutional Review Board approval was waived for this study.

Study Population

The study population includes all Medicare patients 85 years or younger who underwent elective TKA (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] 81.54) between the years 2006 and 2013. These years were chosen to allow a minimum of 1 year of preoperative database exposure and minimum of 1 year of postoperative database exposure for all included patients. Patients undergoing same-day revision TKA (ICD-9-CM: 00.80-84, 81.55), patients with concurrent or prior ascites (ICD-9-CM: 789.59), and patients with a history of knee trauma, infection, or malignancy prior to TKA were also excluded from the population using ICD-9 diagnostic codes (Appendix Table 1). The cohort was then subdivided into patients who had a pre-existing diagnosis of liver cirrhosis without ascites prior to TKA and those without any history of liver cirrhosis (Appendix Table 1).

Postoperative Outcomes Following Total Knee Arthroplasty in Cirrhotic Patients

Cirrhotic patients were compared to controls for the following 90-day postoperative outcomes: major medical complications, minor medical complications, transfusion, encephalopathy, disseminated intravascular coagulation (DIC), and readmissions. Pooled major medical complications consisted 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. In addition, rates of 1-year complications include revision surgery, periprosthetic joint infection (PJI), periprosthetic fracture (PF), hardware failure, dislocation, manipulation under anesthesia (MUA), and knee fibrosis. To better estimate the economic burden associated with cirrhosis, length of stay (LOS), reimbursement, and charges within 90 days of index surgery were compared between the cohorts (Appendix Table 2).

Cirrhosis Subgroup Analysis

To better delineate any associations observed from the main study and draw any additional conclusions, subgroup analysis was performed for TKA cirrhotic populations. All-cause cirrhosis was divided based on etiology into the following groups: viral cirrhosis, alcoholic cirrhosis, and other cirrhotic etiology, the last of which includes lesser common causes of cirrhosis such as autoimmune, genetic, and toxin-induced, among other causes (Appendix Table 1). Subgroups were then compared to controls for the same outcomes assessed in the main analysis.

Statistical Analysis

Baseline demographics, preoperative substance use, and pre-existing comorbidities were compared using Pearson's chi-squared analysis. Pearson's chi-squared analysis was also used to perform a univariate comparison of rates of 90-day and 1-year outcomes between cirrhotic patients and controls. Multivariate logistical regression was then used to determine the isolated effect cirrhosis, including subgroups, had on postoperative outcomes following TKA after adjusting for age, gender, preoperative substance use, and pre-existing comorbidities as covariates. Mean values for LOS, reimbursement, and charges were compared using Welch's *t*-test. A linear regression was then used to determine the independent effect of cirrhosis on LOS, reimbursement, and charges using the previously mentioned covariates. All statistical analysis was performed using *R Project for Statistical Computing*, which is embedded in the PearlDiver database. Significance was determined by a *P*-value <.05.

Results

Demographics and Comorbidities

In total, 18,129 cirrhotic patients who underwent TKA were identified. They were compared to 1,716,439 control TKA patients. On initial evaluation there were significant differences in demographics and comorbidity burden between the cirrhotic population and controls. Cirrhotic patients tended to be younger (44.1% vs 10.4% under 65 years; $P < .001$), male (40.0% vs 36.1%; $P < .001$), and had higher rates of comorbidities compared to the control group. Given the significant differences between the cohorts a multivariate analysis was utilized to eliminate any potential confounding effects of these variables (Table 1).

Outcomes Following Total Knee Arthroplasty Among Cirrhotic Patients

Cirrhosis was associated with increased rates of major medical complications (3.7% vs 2.3%; odds ratio [OR] 1.23, 95% confidence interval [CI] 1.13-1.33, $P < .001$), minor medical complications (13.5% vs 7.4%; OR 1.52, 95% CI 1.45-1.59, $P < .001$), transfusion (2.8% vs 1.4%; OR 1.66, 95% CI 1.51-1.81, $P < .001$), encephalopathy (1.0% vs 0.2%; OR 3.00, 95% CI 2.55-3.51, $P < .001$), DIC (<0.1% vs <0.1%; OR 2.76, 95% CI 1.30-5.14, $P = .003$), and readmission (13.3% vs 7.9%; OR 1.39, 95% CI 1.33-1.45, $P < .001$) within 90 days. Following adjusted linear regression, cirrhosis independently increased LOS by approximately 0.28 days ($P < .001$), and it independently increased 90-day charges by $14,201 ($P < .001$) and 90-day reimbursement by $3418 ($P < .001$). No significant differences in rates of MUA (2.1% vs

Table 1
Patient Demographics.

Variable	Cirrhotics (n = 18,129)	Controls (n = 1,716,439)	*P*-Value
Age (y)			
<65	44.1%	10.4%	<.001
65-69	18.8%	30.7%	
70-74	18.6%	25.7%	
75-79	12.4%	20.9%	
80-84	6.1%	12.3%	
Male gender	40.0%	36.1%	<.001
Female gender	60.0%	63.9%	
Comorbidities			
Obesity (BMI > 30 kg/m^2)	21.2%	10.7%	<.001
PVD	8.2%	4.6%	<.001
Chronic kidney disease	12.2%	5.2%	<.001
CHF	15.1%	7.4%	<.001
CAD	28.0%	20.5%	<.001
COPD	38.1%	17.5%	<.001
Diabetes mellitus	38.5%	24.0%	<.001
Hypertension	80.6%	62.0%	<.001
Hyperlipidemia	58.3%	51.2%	<.001
Tobacco use	39.8%	13.5%	<.001
Region			
Midwest	22.7%	28.1%	<.001
Northeast	18.2%	15.7%	
South	37.9%	39.4%	
West	21.2%	16.8%	

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

1.7%, $P = .864$) and fibrosis (1.6% vs 1.2%, $P = .374$) were found between cirrhotics and controls (Table 2).

Within 1-year postoperatively, cirrhosis was associated with increased rates of revision (3.1% vs 1.3%; OR 1.41, 95% CI 1.30-1.54, $P < .001$), PJI (3.5% vs 1.2%; OR 1.79, 95% CI 1.65-1.94, $P < .001$), periprosthetic joint fracture (0.3% vs 0.1%; OR 1.77, 95% CI 1.33-2.32, $P < .001$), and hardware failure (1.6% vs 0.8%; OR 1.39, 95% CI 1.23-1.56, $P < .001$).

Viral Cirrhosis

Viral cirrhosis was associated with increased rates of major medical complications (OR 1.18, 95% CI 1.06-1.30, $P < .001$), minor medical complications (OR 1.41, 95% CI 1.33-1.49, $P < .001$), transfusions (OR 1.45, 95% CI 1.28-1.64, $P < .001$), encephalopathy (OR 2.21, 95% CI 1.75-2.75, $P < .001$), and readmissions (OR 1.36, 95% CI 1.28-1.43, $P < .001$) within 90 days compared to non-cirrhotic patients. Following adjusted linear regression, cirrhosis independently increased LOS by approximately 0.26 days ($P < .001$). Additionally, cirrhosis independently increased 90-day charges by $14,941 ($P < .001$) and 90-day reimbursements by $3649 ($P < .001$). There were no significant differences between 90-day occurrence of DIC (OR 1.97, 95% CI 0.60-4.69, $P = .186$), manipulation of anesthesia (OR 1.05, $P = .444$), and fibrosis (OR 1.08, $P = .314$) (Table 3).

Viral cirrhosis was associated with increased rates of revision (OR 1.38, 95% CI 1.23-1.53, $P < .001$), periprosthetic infection (OR 1.80, 95% CI 1.62-1.99, $P < .001$), PF (OR 1.69, 95% CI 1.16-2.36, $P = .004$), and hardware failure (OR 1.29, 95% CI 1.10-1.49, $P = .001$) within 1 year postoperatively.

Alcoholic Cirrhosis

Alcoholic cirrhosis was associated with increased rates of major medical complications (OR 1.40, 95% CI 1.13-1.72, $P < .001$), minor medical complications (OR 1.81, 95% CI 1.60-2.03, $P < .001$), transfusion (OR 2.45, 95% CI 1.97-3.02, $P < .001$), encephalopathy (OR 7.34, 95% CI 5.45-9.69, $P < .001$), and readmissions (OR 1.54, 95% CI 1.36-1.73, $P < .001$) within 90 days. Following adjusted linear regression, cirrhosis independently increased LOS by approximately 0.37 days ($P < .001$) and increased 90-day charges by $9420 ($P < .001$) and 90-day reimbursement by $2399 ($P < .001$) (Table 3).

Alcoholic cirrhosis was associated with increased rates of revision (OR 1.53, 95% CI 1.19-1.95, $P < .001$), periprosthetic infection (OR 2.12, 95% CI 1.69-2.63, $P < .001$), PF (OR 3.28, 95% CI 1.64-5.80, $P < .001$), hardware failure (OR 1.48, 95% CI 1.03-2.04, $P = .025$), MUA (OR 0.46, 95% CI 0.28-0.70, $P = .001$), and fibrosis (OR 0.54, 95% CI 0.31-0.85, $P = .013$) within 1 year postoperatively.

Other Causes of Cirrhosis

Other etiologies of cirrhosis were associated with increased rates of minor medical complications (OR 1.55, 95% CI 1.36-1.77, $P < .001$), transfusion (OR 1.74, 95% CI 1.31-2.26, $P < .001$), encephalopathy (OR 1.95, 95% CI 1.01-1.36, $P = .028$), and DIC (OR 5.32, 95%

Table 2
Comparison of Postoperative Outcomes Between Cirrhotics and Controls Following Total Knee Arthroplasty.

Variable	Cirrhotics (n = 18,129)	Controls (n = 1,716,439)	Cirrhotics vs Controls Adjusted OR (95% CI)	*P*-Value
90-d outcomes				
Major medical complication	3.7%	2.3%	**1.23 (1.13-1.33)**	**<.001**
Minor medical complication	13.5%	7.4%	**1.52 (1.45-1.59)**	**<.001**
Transfusion	2.8%	1.4%	**1.66 (1.51-1.81)**	**<.001**
Encephalopathy	1.0%	0.2%	**3.00 (2.55-3.51)**	**<.001**
DIC	0.0004%	0.0002%	**2.76 (1.30-5.14)**	**.003**
Readmission	13.3%	7.9%	**1.39 (1.33-1.45)**	**<.001**
1-y outcomes				
Revision	3.1%	1.3%	**1.41 (1.30-1.54)**	**<.001**
Periprosthetic joint infection	3.5%	1.2%	**1.79 (1.65-1.94)**	**<.001**
Periprosthetic fracture	0.3%	0.1%	**1.77 (1.33-2.32)**	**<.001**
Hardware failure	1.6%	0.8%	**1.39 (1.23-1.56)**	**<.001**
Manipulation under anesthesia	2.1%	1.7%	0.99 (0.89-1.10)	.864
Fibrosis	1.6%	1.2%	1.06 (0.94-1.19)	.374
LOS, reimbursement, and charges				
LOS	3.57 ± 2.29	3.23 ± 1.78	**0.28 (0.26-0.31)**[a]	**<.001**
Reimbursement (90 d)	$18,328 ± 32,166	$13,974 ± 9283.83	**$3418 (3276-3561)**[a]	**<.001**
Charges (90 d)	$76,082 ± 125,032	$56,940 ± 43,311	**$14,201 (13,543-14,859)**[a]	**<.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 3
Adjusted Odds Ratios Following Subgroup Analysis of Differing Cirrhotic Etiologies Among Total Knee Arthroplasty Patients.

Variable	Viral Cirrhotics vs Controls	*P*-Value	ETOH Cirrhotics vs Controls	*P*-Value	Other Cirrhotics vs Controls	*P*-Value
90-d outcomes						
Major medical complication	**1.18 (1.06-1.30)**	**.002**	**1.40 (1.13-1.72)**	**.001**	**1.36 (1.06-1.71)**	**.011**
Minor medical complication	**1.41 (1.33-1.49)**	**<.001**	**1.81 (1.60-2.03)**	**<.001**	**1.55 (1.36-1.77)**	**<.001**
Transfusion	**1.45 (1.28-1.64)**	**<.001**	**2.45 (1.97-3.02)**	**<.001**	**1.74 (1.31-2.26)**	**<.001**
Encephalopathy	**2.21 (1.75-2.75)**	**<.001**	**7.34 (5.45-9.69)**	**<.001**	**1.95 (1.01-3.36)**	**.028**
DIC	1.97 (0.60-4.69)	.186	–	–	5.32 (0.88-16.66)	.019
Readmission	**1.36 (1.28-1.43)**	**<.001**	**1.54 (1.36-1.73)**	**<.001**	**1.20 (1.04-1.39)**	**.013**
1-y outcomes						
Revision	**1.38 (1.23-1.53)**	**<.001**	**1.53 (1.19-1.95)**	**.001**	1.30 (0.93-1.76)	.106
Periprosthetic infection	**1.80 (1.62-1.99)**	**<.001**	**2.12 (1.69-2.63)**	**<.001**	1.16 (0.79-1.62)	.425
Periprosthetic fracture	**1.69 (1.16-2.36)**	**.004**	**3.28 (1.64-5.80)**	**<.001**	1.58 (0.57-3.42)	.306
Hardware failure	**1.29 (1.10-1.49)**	**.001**	**1.48 (1.03-2.04)**	**.025**	**1.62 (1.10-2.30)**	**.010**
Manipulation under anesthesia	1.05 (0.92-1.19)	.444	**0.46 (0.28-0.70)**	**.001**	1.34 (0.99-1.77)	.044
Fibrosis	1.08 (0.93-1.24)	.314	**0.54 (0.31-0.85)**	**.013**	**1.49 (1.06-2.02)**	**.015**
LOS, reimbursement, and charges						
LOS	**0.26 (0.22-0.29)**[a]	**<.001**	**0.37 (0.30-0.44)**[a]	**<.001**	0.04 (−0.04 to 0.11)[a]	.343
Reimbursement (90 d)	**$3649 (3472-3825)**[a]	**<.001**	**$2399 (2019-2780)**[a]	**<.001**	**$1677 (1275-2078)**[a]	**<.001**
Charges (90 d)	**$14,941 (14,131-15,750)**[a]	**<.001**	**$9420 (7636-11,203)**[a]	**<.001**	**$7871 (5989-9752)**[a]	**<.001**

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

CI 0.88-16.66, $P = .019$) within 90 days. In terms of 1-year outcomes, cirrhosis was associated with increased rates of hardware failure (OR 1.62, 95% CI 1.10-2.30, $P = .010$) and fibrosis (OR 1.49, 95% CI 1.06-2.02, $P = .015$). Following adjusted linear regression, cirrhosis independently increased 90-day charges and 90-day reimbursement by $7871 ($P < .001$) and $1677 ($P < .001$), respectively. No significant differences were found between LOS ($P = .343$), 90-day major medical complications (OR 1.36, $P = .011$), and readmissions (OR 1.20, $P = .013$), as well as 1-year revision (OR 1.30, $P = .106$), periprosthetic infection (OR 1.16, $P = .425$), and MUA (OR 1.34, $P = .044$) (Table 3).

Discussion

Cirrhosis is an increasingly common comorbidity among surgical candidates, likely due to advancements in the medical optimization of such high-risk patient population [11]. Although successful, TKA has its own complications in a healthy patient population. Although criteria like the MELD and Child-Pugh scores exist to evaluate surgical risk for cirrhotic patients, the outcomes following TKA require further analysis especially when compounded by an inherently sick patient population [12]. Characterizing explicit outcomes in cirrhotics undergoing TKA can ideally help streamline surgical decision-making and perioperative management. In this study, we found that all cirrhotics undergoing TKA had an increased rate of major and minor medical complications, transfusion, encephalopathy, DIC, and readmission in 90 days. Cirrhotics were at greater risk for TKA-related complications at 1 year. Additionally, our results show that viral and alcoholic cirrhotics undergoing TKA had an increased rate of major and minor medical complications, transfusion, encephalopathy, and readmission compared to non-cirrhotic patients. Furthermore, viral and alcoholic cirrhotic patients were more likely to require revision within 1 year and suffer from postoperative complications such as PJI, fracture, hardware failure, and dislocation compared to non-cirrhotic patients. Notably, cirrhotics of an etiology other than viral and alcoholism were also at a significantly greater risk for 90-day major and minor medical complications, readmission, transfusion, and encephalopathy as well as 1-year risk of hardware failure and fibrosis following TKA. Nonetheless, this patient population had no significant differences in the rate of revisions, infections, PF, and manipulation when compared to non-cirrhotic patients following TKA.

Since the liver is a vital organ for the development and maturation of proteins ranging from those involved in the coagulation cascade to acute phase reactants, there are many postoperative considerations for orthopedic surgeons involved in the care of a patient with cirrhosis. Seol et al [13] determined that cirrhotic patients were at greater risk to suffer from heavier postoperative blood loss and surgical site infection than healthy patients. Another study that evaluated TKAs determined that cirrhotic patients were more likely to experience longer hospital stays, infection, and overall higher mortality rate [10]. Compromised liver function compounded by the reduced hepatic blood flow, hypoxemia, and altered drug metabolism of cirrhosis all are potential etiologies for the poor outcome following TKA compared to non-cirrhotic patients within 90 days [14–16].

When comparing etiologies of cirrhosis, our findings suggest that viral and alcoholic cirrhosis is associated with poor outcomes when compared to non-cirrhotics. These findings are in agreement with the literature in which viral hepatitis and alcohol dependence are associated with increased mortality following non-abdominal surgery in cirrhotic patients [17]. Notably, cirrhosis from etiologies other than viral and alcohol abuse, generally had favorable outcomes within 90 days and few complications at 1 year compared to controls, thus requiring more stringent preoperative optimization and postoperative monitoring of patients with viral and alcoholic cirrhosis.

Overall, cirrhotics were more likely to have worse orthopedic-related outcomes, a finding that is well supported in the literature. The long-term outcomes of cirrhotic TKA candidates remain understudied with most contemporary results limited to less than 90 days of follow-up [9,18]. An early report on postoperative outcomes among cirrhotic TKA candidates by Shih et al [10] demonstrated that cirrhotics had a higher blood loss, longer LOS, higher rate of infection, and mortality rate. This study was limited by a sample size of 51 patients. Newman et al [18], similarly, reported higher rate of complications including anemia, hemorrhage, infections, wound complications, and other device-related complications from available in-patient data of cirrhotics following TKA. The present study addresses some of these limitations by

reporting outcomes for up to 1 year postoperatively, with additional findings such as increased revision rate, periprosthetic infection, PF, and hardware failures among cirrhotics at 1 year postoperatively. It should be noted that following the stratification of cirrhosis into different etiologies, cirrhosis due to etiologies other than viral or alcohol abuse was not an independent risk factor for revision, infection, and PF, although this patient population still maintained a higher risk of hardware failure and fibrosis at 1-year follow-up.

Cited factors for the cirrhotic patients' heightened susceptibility to infection include portosystemic shunting, cirrhosis-associated immune dysfunction, gut dysbiosis, and increased bacterial dislocation, among others [19]. Poor liver function also affects bone health and expedites demineralization through hepatic osteodystrophy, though the pathophysiology of osteodystrophy is poorly understood [20]. Other associated factors of cirrhosis including chronic steroid dependence, hypogonadism, hypoalbuminemia, among others contribute to compromised bone integrity and are responsible for the increased rates of fracture, hardware failure, among other orthopedic sequela [21,22].

Cost data from the present study demonstrate that cirrhotic patients incur greater charges and reimbursements compared to non-cirrhotic patients following TKA, with viral cirrhotics incurring high charges and reimbursements. This finding is supported by data (2000-2011) from Newman et al [18] that demonstrated that viral cirrhosis was associated with the highest average incremental cost of TKA compared to non-cirrhotics. A recent study by Mellinger et al [23], however, suggested that alcoholic cirrhotics incur the highest economic burden of cirrhosis etiologies primarily due to decompensation on admission and delayed diagnosis of cirrhosis when compared to non-alcoholic cirrhosis. It should be noted that our study excluded all decompensated cirrhotics, determined by an accompanying diagnosis of ascites. Considering the above highlighted increased cost burden and healthcare resource utilization by cirrhotics, these findings add to the growing cost discussion of excluding or modifying the inclusion of these high-risk patient populations into bundled payment models [24].

Findings from the present study, corroborated by the literature, do not discourage TKA in cirrhotic patients. Results from this study provide additional evidence to the risk benefit analysis that each surgeon must use to weigh postoperative outcomes and complications against potential benefit and individualized patient factors. These results also emphasize the added importance of including etiology of cirrhosis in surgical decision-making and perioperative management.

The major strength of this study is its large sample size and length of follow-up. Furthermore, stratification of cirrhosis based on etiology aids in providing a more tailored approach to the management of the cirrhotic patients. Finally, by creating a control cohort of non-cirrhotic patients and controlling for pertinent patient demographic factors and comorbidities through regression analysis, our study was able to resolve any confounding impact of pre-existing conditions on the independent effects of cirrhosis on knee arthroplasty outcome.

Despite these strengths, our study does have limitations. The data and conclusions drawn herein are dependent upon the accurate coding of patient information into medical records. In larger databases especially, there has been documented incidents of miscoding of diagnoses [25]. Additionally, pre-existing comorbidities are often underreported, thereby limiting the effects of controlling for identified confounding comorbidities as covariants [26]. Finally, using a stratification measure like MELD or Child-Pugh scores would have been more helpful in delineating the threshold of poor postoperative outcome following TKA in cirrhotic patients.

Conclusion

Liver cirrhosis, both viral and alcohol-related, is an independent risk factor for prolonged hospital stay, major and minor medical complications, implant-related complications, readmission, and increased costs following TKA. Cirrhosis due to etiologies other than viral infections and alcoholism, though, is associated with fewer adverse outcomes when compared to viral and alcoholic cirrhosis. Surgeons should be aware of these complications for optimized postoperative management as well as to enhance surgical decision-making when evaluating these at-risk surgical candidates in the preoperative period.

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Appendix

Appendix Table 1
Inclusion and Exclusion Codes.

All-cause cirrhosis	
Viral cirrhosis	ICD-9-CM: 070.0, 070.1, 070.20-23, 070.30-33, 070.41-44, 070.49, 070.51-54, 070.59, 070.6, 070.70, 070.71, 070.9
Alcoholic cirrhosis	ICD-9-CM: 571.10-13
Other cirrhosis	ICD-9-CM: 571.40-42, 571.49, 996.82
Knee trauma	ICD-9-CM: 716.16, 821.20-23, 821.29, 821.30-33, 821.39, 822.0-1, 823.00-02, 823.10-12, 827.0-1, 905.4, 928.11
Knee neoplasm	ICD-9-CM: 170.7, 170.9, 171.3, 213.7, 213.9
Knee infection	ICD-9-CM: 711.06, 711.46, 711.86, 711.96

Appendix Table 2
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 TKA	ICD-9-CM: 00.80-84, 81.55
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
Manipulation under anesthesia	CPT: 27570
Fibrosis	ICD-9-CM: 718.56
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; TKA, total knee arthroplasty; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; CPT, Current Procedural Terminology.