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Incidence, Causes, and Timing of 30-Day Readmission Following Total Knee Arthroplasty

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ABSTRACT

Background: It is important to study the incidence and causes of readmissions in order to understand why they occur and how to reduce them. This study looks at a national sample of patients following total knee arthroplasty (TKA) to identify incidences, trends, causes, and timing of 30-day readmissions.

Methods: Patients undergoing primary TKA from 2012 to 2016 in the American College of Surgeons National Surgical Quality Improvement Program database were identified (n = 197,192). Patients with fractures (n = 177), nonelective surgery (n = 2234), bilateral TKA (n = 5483), and cases with unknown readmission status (n = 1047) were excluded, leaving a total of 188,251 cases. Linear regression analysis was used to determine trends over time.

Results: The incidence of overall 30-day readmission following primary TKA from 2012 to 2016 was 3.19% (6014/188,251), with significant decreases in readmission rates during this time ($\beta = -0.001$, $P < .001$). The top 5 causes of readmission included superficial surgical site infection (SSI; 9.7%), non-SSI infection (9.5%), cardiovascular complications (CV; 9.3%), gastrointestinal complications (8.8%), and venous thromboembolisms (8.8%). The most common cause of readmission during postoperative week 1 was CV complications (12.2%), week 2 was superficial SSI (11.6%), week 3 was deep SSI (11.4%), and week 4 was deep SSI (12.4%).

Conclusion: Overall, 30-day readmissions following TKA were found to significantly decline from 2012 to 2016. The most common causes of overall readmission included superficial SSI, non-SSI infection, CV complications, gastrointestinal complications, and venous thromboembolisms. However, the most common causes of readmission changed from week to week postoperatively. This data may help institutions develop policies to prevent unplanned readmissions following TKA.

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The rate of total knee arthroplasty (TKA) procedures performed in the United States is expected to dramatically increase as the population ages [1]. Although this is a highly successful surgery, the Center for Medicare and Medicaid Services has begun penalizing healthcare institutions for unplanned readmissions following TKA

and total hip arthroplasty (THA). In 2013, Clement et al [2] estimated that a healthcare institution would lose approximately \$11,500 per episode of care with an associated unplanned readmission following THA under this reimbursement model.

As financial pressures mount, current literature has sought to identify incidences, risk factors, and causes of unplanned readmission following TKA and THA. However, many of these studies are conducted at single institutions, which may not reflect national averages [2–8]. In addition, studies that have analyzed large databases to identify incidences and causes of readmission have reported data limited to a single year, thus not exposing trends over time [9–11]. Furthermore, there is no literature, to our knowledge, that describes the timing of postoperative complications that lead

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to unplanned readmissions. It is imperative to study the incidence, causes, trends, and timing of readmissions following TKA in order to understand why they occur and formulate plans on how to reduce them.

This study looks at a national sample of patients following TKA to identify incidences and causes of 30-day readmissions over multiple years. Additionally, this study will describe the trends in readmission over that timeframe and the timing of postoperative complications that results in unplanned readmission.

Methods

Database

The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database was accessed for this study. The ACS NSQIP database receives contributions from over 500 healthcare systems in the United States which must use trained reviewers to prospectively collect data [12,13]. The variables reported by the ACS NSQIP database include demographics, comorbidities, preoperative laboratory values, and 30-day adverse events, such as readmission. Previous literature has widely discussed the methodology used by the ACS NSQIP database [14,15].

Patient Selection

Using Current Procedural Terminology code 27447, a total of 197,192 patients who underwent primary TKA from 2012 to 2016 were identified. The following exclusion criteria were applied: preoperative fracture diagnosis ($n = 177$), nonelective surgery ($n = 2234$), bilateral TKA ($n = 5483$), and unknown readmission status ($n = 1047$). This left 188,251 cases that were included in the final analysis. In ACS NSQIP, nonelective cases were those surgeries performed on (1) patients who were inpatients at an acute care hospital before surgery, (2) patients who were transferred from an emergency department, (3) patients who were transferred from a clinic, (4) patients who underwent an emergent/urgent surgical case, and (5) patients who were admitted to the hospital on the day prior to a scheduled procedure for any reason [16].

Causes of Unplanned Readmission

Causes of readmission were grouped into 14 categories based on International Classification of Diseases, Ninth or Tenth revision

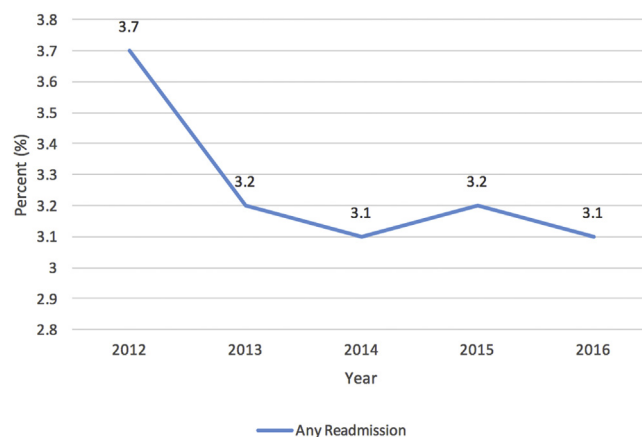


Fig. 1. Overall 30-day readmission rates following total knee arthroplasty from 2012 to 2016 ($\beta = -0.001$, $P < .001$).

codes. Infections were categorized as superficial surgical site infection (SSI), deep SSI, and non-SSI infections. Non-SSI infections included readmission for urinary tract infections, pneumonia, sepsis, *Clostridium difficile* colitis, and other infections. System-based causes of readmission were categorized as central nervous system complications, cardiovascular (CV) complications, gastrointestinal (GI) complications, genitourinary complications, respiratory complications, and musculoskeletal (MSK) complications. The remaining categories included pain, venous thromboembolism (VTE), wound complications (non-infectious), prosthesis complications, and other complications. "Other" complications included diagnoses that did not fall into one of the 13 defined categories.

Outcome Measurements

The primary outcome of this study was the incidence of overall 30-day readmission. Secondary outcome measurements included overall readmission trends from 2012 to 2016, major causes of readmission, and timing of causes leading to readmission stratified by postoperative week. Readmissions were categorized as occurring in week 1 (postoperative days 0-7), week 2 (postoperative days 8-14), week 3 (postoperative days 15-21), or week 4 (postoperative days 22-30). Trends in the timing of readmission causes, and differences between the years were also identified.

Table 1
Incidence and Causes of 30-d Readmission Following Total Knee Arthroplasty From 2012 to 2016.

Complication	Number of Readmissions	Percent (%) of Total Readmissions (N = 6014)	Percent (%) of Total Cases (N = 188,251)
Central nervous system complication	134	2.2	0.07
Cardiovascular complication	560	9.3	0.30
Deep SSI	387	6.4	0.21
Gastrointestinal complication	532	8.8	0.28
Genitourinary complication	215	3.6	0.11
Non-SSI infection	574	9.5	0.30
Musculoskeletal complication	399	6.6	0.21
Pain	149	2.5	0.08
Prosthesis complication	76	1.3	0.04
Respiratory complication	98	1.6	0.05
Superficial SSI	584	9.7	0.31
Venous thromboembolism	531	8.8	0.28
Wound complication	248	4.1	0.13
Other complications	1527	25.4	0.81
Total	6014	100	3.19

SSI, surgical site infection.

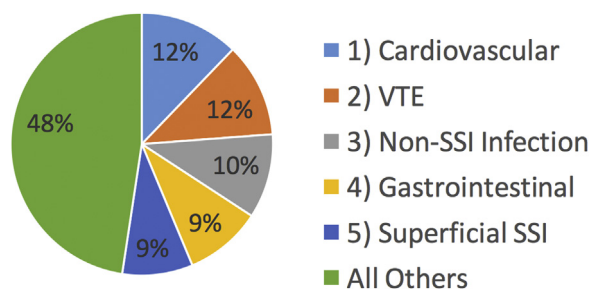


Fig. 2. Most common causes of readmission in the first week (postoperative days 0-7) following total knee arthroplasty. VTE, venous thromboembolism; SSI, surgical site infection.

Statistical Analysis

Linear regression models were used to determine trends in causes of readmission over time. This included overall readmission from year to year and cause-specific readmission from week to week. *P*-values less than .05 were considered significant. Statistics were performed on IBM SPSS Statistics 23 for Mac (IBM Corp, Armonk, NY).

Results

Overall Readmission Incidence, Trends, and Causes

The incidence of overall readmission following primary TKA from 2012 to 2016 was found to be 3.19% (6014/188,251; Table 1). Linear regression revealed a significant decrease in readmission rates during this time period (Fig. 1; $\beta = -0.001, P < .001$). The top 5 causes of unplanned readmission during this period included superficial SSI (9.7%), non-SSI infection (9.5%), CV complications (9.3%), GI complications (8.8%), and VTE (8.8%). There was no difference in superficial SSI rate within 30 days between patients discharged to home vs patients discharged to a skilled nursing facility (0.5%, $P > .05$).

Timing of Causes for Readmission

The most common causes of readmission during postoperative week 1 (Fig. 2) were CV complications (12.2%), VTE (11.6%), non-SSI infection (10.4%), GI complications (9.5%), and superficial SSI (8.7%). During postoperative week 2 (Fig. 3), the most common causes of readmission were superficial SSI (11.6%), non-SSI infection (10.6%), GI complications (9.5%), CV complications (8.8%), and VTE (7.8%). In week 3 (Fig. 4), the most common causes of readmission were deep SSI (11.4%), superficial SSI (9.3%), VTE (8.9%), non-SSI infection

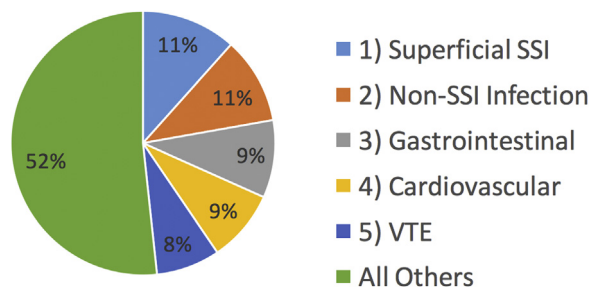


Fig. 3. Most common causes of readmission in the second week (postoperative days 8-14) following total knee arthroplasty. VTE, venous thromboembolism; SSI, surgical site infection.

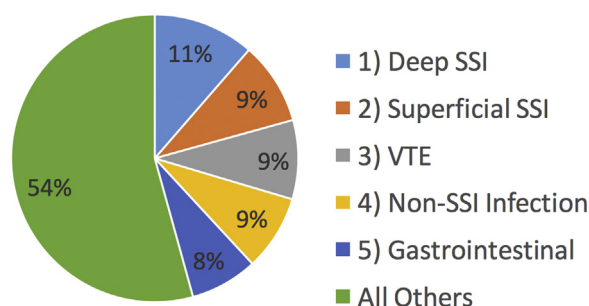


Fig. 4. Most common causes of readmission in the third week (postoperative days 15-21) following total knee arthroplasty. VTE, venous thromboembolism; SSI, surgical site infection.

(8.5%), and GI complications (7.6%). Finally, the most common causes of readmission during postoperative week 4 (Fig. 5) were deep SSI (12.4%), superficial SSI (9.4%), MSK complications (8.8%), CV complications (8.2%), and GI complications (8.1%). Following linear regression, readmissions for CV complications ($P < .001$), non-SSI infections ($P = .003$), pain ($P < .001$), respiratory complications ($P < .013$), and VTEs ($P < .001$) significantly decreased from postoperative week 1 to week 4 (Table 2). In contrast, causes of readmission that significantly increased from postoperative week 1 to week 4 included deep SSI ($P < .001$), MSK complications ($P < .001$), and wound complications ($P < .001$; Table 2). When we stratified by year, superficial SSI remained the most common cause of readmission in weeks 1 and 2 across all years analyzed, with CV complications being the second most commonly reported (Table 3). Deep SSI was the most commonly reported cause of readmission for weeks 3 and 4 across all years analyzed (Table 3).

Discussion

Readmission rates are an important quality control metric in the setting of TKA, and institutions are being financially penalized when they occur. To contribute to the discussion of how to reduce readmissions following TKA, this study adds a large, contemporary cohort to identify the incidence and causes of readmission. In addition, this study offers novel data in regards to readmission trends over time and timing of readmission stratified by postoperative week that has not been described in prior literature.

This study has several limitations. The ACS NSQIP database only reports a 30-day follow-up window, so it does not capture all potential readmissions that may be related to the episode of care. Additionally, large database studies are subject to data collection errors [17]. Though, the ACS NSQIP database has been shown to be reliable in its methodology [18–20]. Another limitation to this study is that it does not adjust for potential confounders, such as patient age, when reporting the trends in readmission from year to

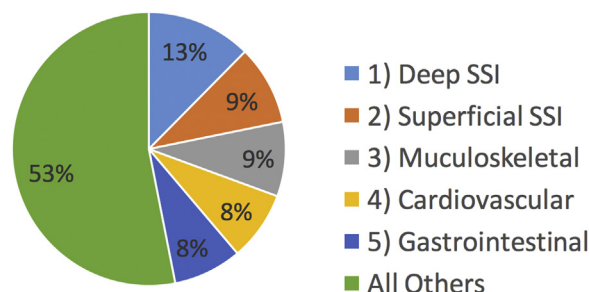


Fig. 5. Most common causes of readmission in the fourth week (postoperative days 22-30) following total knee arthroplasty. SSI, surgical site infection.

Table 2
Trends in Causes of Readmission Stratified by Postoperative Week Following Total Knee Arthroplasty.

Cause (%)	Wk 1	Wk 2	Wk 3	Wk 4	B (95% CI)	P-Value
Any readmission	1922 (100)	1685 (100)	1205 (100)	1153 (100)	N/A	N/A
Central nervous system complication	44 (2.3)	41 (2.4)	21 (1.7)	26 (2.3)	−0.001 (−0.004 to 0.003)	.624
Cardiovascular complication	235 (12.2)	149 (8.8)	80 (6.6)	95 (8.2)	−0.016 (−0.022 to −0.009)	<.001
Deep SSI	31 (1.6)	74 (4.4)	137 (11.4)	143 (12.4)	0.040 (0.034 to 0.045)	<.001
Gastrointestinal complication	183 (9.5)	160 (9.5)	92 (7.6)	93 (8.1)	−0.006 (−0.013 to 0.000)	.060
Genitourinary complication	66 (3.4)	67 (4.0)	42 (3.5)	40 (3.5)	0.000 (−0.004 to 0.004)	.936
Non-SSI infection	199 (10.4)	178 (10.6)	102 (8.5)	87 (7.5)	−0.010 (−0.017 to −0.003)	.003
Musculoskeletal complication	100 (5.2)	110 (6.5)	87 (7.2)	101 (8.8)	0.011 (0.006 to 0.017)	<.001
Pain	70 (3.6)	47 (2.8)	20 (1.7)	12 (1.0)	−0.009 (−0.013 to −0.005)	<.001
Prosthesis complication	20 (1.0)	31 (1.8)	16 (1.3)	9 (0.8)	−0.001 (−0.003 to 0.002)	.515
Respiratory complication	40 (2.1)	28 (1.7)	21 (1.7)	9 (0.8)	−0.004 (−0.007 to −0.001)	.013
Superficial SSI	167 (8.7)	195 (11.6)	112 (9.3)	108 (9.4)	0.001 (−0.006 to 0.008)	.814
Venous thromboembolism	223 (11.6)	132 (7.8)	107 (8.9)	66 (5.7)	−0.017 (−0.024 to −0.011)	<.001
Wound complication	34 (1.8)	63 (3.7)	78 (6.5)	73 (6.3)	0.017 (0.012 to 0.021)	<.001
Other complications	510 (26.5)	410 (24.3)	290 (24.1)	291 (25.2)	−0.005 (−0.015 to 0.005)	.308

CI, confidence interval; N/A, not applicable; SSI, surgical site infection.

year. However, this is simply a descriptive study and is not meant to identify risk factors for readmission. With regards to the reporting of complications, NSQIP does not account for location, that is, if a complication was diagnosed in a same-day emergency room discharge or a clinic visit. NSQIP does not also account for possible complication management at non-NSQIP participant hospitals. Despite these limitations, this study adds a sizable cohort to the discussion of readmission after TKA and reports novel information.

The primary outcome of this study is to identify the incidence of overall readmission following TKA. The rate of 30-day readmission from 2012 to 2016 was found to be 3.19%.

These findings are similar to what has been recently published in the literature. Readmission rates have been reported to fall between 2.2% and 6.6% 30 days after total joint arthroplasty (TJA) and between 5.3% and 9.7% 90 days after TJA [2–8,11,21,22]. Although this study falls on the lower end of the reported readmission rate spectrum, we also found that readmissions have decreased from 2012 to 2016. These findings could reflect the heightened awareness of readmissions as a quality metric and the drive to reduce readmission rates to avoid financial penalization.

A secondary outcome of this study is to identify the most common causes of readmission after TKA. This study found superficial SSI, non-SSI infection, CV complications, GI complications, and VTE to be the most common causes of overall readmission. These findings coincide with previously reported causes for readmission. Specifically, SSI, CV complications, VTE, and non-SSI infections (eg, sepsis) have all been previously identified as primary causes of readmission following TJA [2–4,11]. However, a unique finding of this study was that certain causes of readmission, such as deep SSI, increase in frequency as time from surgery increases, while other causes of readmission decrease. Pugely et al [11], in their analysis of causes of 30-day incidence and risk factors of SSI found in the NSQIP database, found that body mass index >40, hypertension, history of wound infection, an operative time of >2 hours, and electrolyte disturbances were independent risk factors for SSI at 30 days. The authors found that discharge disposition

did not affect superficial SSI rate within 30 days, similar to our findings. In studies that examine 90-day readmissions following TKA, arthrofibrosis has been identified as one of the primary causes [6,8]. Although this study did not find MSK complications to be one of the overall primary causes of readmission, we did show that it was a major cause for readmission in postoperative week 4 and that readmissions related to MSK complications significantly increased as time from surgery passed. These findings may help physicians recognize who is at risk of readmission based on postoperative day.

Identifying who is at risk of readmission following TKA is complicated due to the multifactorial nature of a patient's health status. Although comorbidities have been commonly reported as readmission risk factors, Oronce et al [21] also found that race, health insurance payer, and socioeconomic status contribute to a patient's risk of readmission after TJA. Furthermore, in 2015, Merkow et al [9] concluded that readmissions after surgery are more likely to be related to a new post-discharge complication rather than an exacerbation of medical complications that occurred during the index hospitalization. Because of the complexity involved, strategies should be adopted to optimize patient health prior to surgery. Medical complications are preventable in the postoperative course; therefore aggressive use of preventative medicine is warranted before discharge. Preventative measures against CV complications, GI complications, and VTE would capture most of the complications, demonstrated by Table 2. Yu et al [23] suggest that addressing potential modifiable risk factors (eg, *Staphylococcus aureus* colonization) and strict coordination of post-discharge care can help prevent postoperative complications that lead to readmission after TJA.

To conclude, overall unplanned 30-day readmission following TKA was found to be 3.19% and significantly declining from 2012 to 2016. The most common causes of overall readmission include superficial SSI, non-SSI infection, CV complications, GI complications, and VTE. However, it was found that the most common causes of unplanned readmission change over time. These data may help institutions develop policies to prevent unplanned readmissions following TKA.

Table 3
Most Common Causes of Readmission per Week per Year From 2012 to 2016.

	Wk 1	Wk 2	Wk 3	Wk 4
2012	Superficial SSI (10.1%)	Superficial SSI (9.3%)	Deep SSI (11.2%)	Deep SSI (11.6%)
2013	CV (18.6%)	Non-SSI infection (13.7%)	Deep SSI, VTE, and GI (tie 9.4%)	CV (13.2%)
2014	CV (12.3%)	Superficial SSI (11.1%)	MSK and non-SSI infection (tie, 11.5%)	Deep SSI (11.3%)
2015	VTE (14.3%)	Superficial SSI (14.7%)	Deep SSI (10.1%)	Deep SSI (12.9%)
2016	Non-SSI infection (11.7%)	GI related (11.2%)	Deep SSI (15.3%)	Deep SSI (14.3%)

SSI, surgical site infection; CV, cardiovascular; VTE, venous thromboembolism; GI, gastrointestinal; MSK, musculoskeletal.

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