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Readmission due to infection following total hip and total knee procedures

A retrospective study

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Abstract

Policymakers have expanded readmissions penalty programs to include elective arthroplasties, but little is known about the risk factors for readmissions following these procedures. We hypothesized that infections after total hip arthroplasty (THA) and total knee arthroplasty (TKA) lead to excess readmissions and increased costs. This study aims to evaluate the proportion of readmissions due to infections following THA and TKA.

Healthcare Cost and Utilization Project–State Inpatient Databases were used for the study. Procedure codes "8151" and "8154" were used to identify inpatient discharges with THA and TKA in Florida (FL) 2009 to 2013, Massachusetts (MA) 2010 to 2012, and California (CA) 2009 to 2011. Readmission was measured by a Centers for Medicare and Medicaid Services (CMS) validated algorithm. Infections were identified by ICD-9-CM codes: 99859, 99666, 6826, 0389, 486, 4821, 00845, 5990, 48242, 04111, 04112, 04119, 0417, 99591, and 99592. Descriptive analysis was performed.

In CA, 4.29% of patients were readmitted with 33.02% of the total readmissions for infection. In FL, 4.7% of patients were readmitted with 33.39% of the readmissions for infection. In MA, 3.92% of patients were readmitted with 35.2% of readmissions for infection. Of the total number of readmissions due to infection, methicillin-resistant *Staphylococcus aureus* (MRSA) and methicillin-susceptible *Staphylococcus aureus* (MSSA) together accounted for 14.88% in CA, 13.38% in FL, and 13.11% in MA.

The rate of infection is similar across all 3 states and is a leading cause for readmission following THA and TKA. Programs to reduce the likelihood of MRSA or MSSA infection would reduce readmissions due to infection.

Abbreviations: CA = California, CJR = Comprehensive Care for Joint Replacement, CMS = Centers for Medicare and Medicaid Services, COPD = chronic obstructive pulmonary disease, FFS = fee-for-service, FL = Florida, HRRP = Hospital Readmissions Reduction Program, LOS = length of stay, MA = Massachusetts, MRSA = methicillin-resistant *Staphylococcus aureus*, MSSA = methicillin-susceptible *Staphylococcus aureus*, SSI = surgical site infection, THA = total hip arthroplasty, TKA = total knee arthroplasty.

Keywords: MRSA, readmission, surgical site infections, total hip and total knee arthroplasty

1. Introduction

The aging population has prompted an increase in the number of orthopedic procedures performed yearly in the United States. Total hip arthroplasty (THA) and total knee arthroplasty (TKA) have especially high incidence, with over 1 million total THA and TKA procedures performed each year in the US.[1] Given the success of THA and TKA in improving function and quality of life of individuals with severe arthritis, escalating demand is expected to continue; by 2030 the demand for primary and revision hip replacements is projected to more than double.[2]

Because patients who undergo THA and TKA are typically elderly, THA and TKA are the most common inpatient surgeries for Medicare beneficiaries. The 400,000 THA and TKA procedures performed in 2014 cost more than $7 billion in hospitalizations alone. The rate of complications like infections or implant failures after surgery can be more than 3 times higher at some facilities than others, increasing the chances of readmission.[3]

Surgical site infections (SSIs) are a main cause for hospital readmission. SSIs are associated with considerable morbidity and mortality among infected patients and have continued to increase in incidence despite extensive and costly infection prevention efforts.[4] Costs for SSI can range from $12,000 to $60,000, depending on the type of procedure.[5] In total, SSIs cost the US healthcare system approximately $10 billion annually.[6]

As a result of rising readmission rates, in 2010 Congress established in the Affordable Care Act the Hospital Readmissions Reduction Program (HRRP), which instructs the Centers for Medicare and Medicaid Services (CMS) to penalize hospitals with higher-than-expected readmissions for specific clinical

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conditions in order to encourage efforts to reduce those excess readmissions. The HRRP payment penalties took effect in fiscal year 2013, and in 2017, hospitals can incur a penalty of up to 3% of their Medicare part A payments.[7]

Also established through the Affordable Care Act was the Bundled Payments for Care Improvement initiative, developed by the Center for Medicare and Medicaid Innovation (Innovation Center) to reduce Medicare, Medicaid, or Children Health Insurance Program expenditures while maintaining or improving quality of care.[8] "Bundled payments" set payments to health care providers according to predetermined expected costs of a grouping of related health care services. As a result, bundled payments allow flexibility that encourages providers to allocate resources for care coordination and create a mechanism for managing shared payments for diagnosis and treatment.[9]

In 2015, CMS expanded its readmission penalties to include elective THA and TKA procedures and in April 2016 implemented the Comprehensive Care for Joint Replacement (CJR) bundled payment model for Medicare beneficiaries undergoing hip or knee replacements, under which participating providers are held financially accountable for the quality and cost of a CJR episode of care, which begins with a hospital admission of a beneficiary who is ultimately discharged under MS-DRG 469 or 470 and ends 90 days postdischarge.[10] As a result of these changes in policy, we consider an important question: how do SSIs affect readmissions to hospitals? In this study, we explore and document the proportion of readmission due to infection after index THA and TKA, and in particular, the proportion of methicillin-resistant *Staphylococcus aureus* (MRSA) and methicillin-susceptible *Staphylococcus aureus* (MSSA) among infections. This study has 3 aims: to identify and rank the top 25 diagnoses associated with readmission following THA and TKA relative to other primary diagnoses in the HRRP: pneumonia, chronic obstructive pulmonary disease, acute myocardial infarction (AMI), and heart failure; to evaluate the proportion of readmission specifically due to any type of infection, the proportion of MRSA and MSSA among infections, and the Medicare payment on index total hip and total knee procedures; and to assess the effect of MRSA and MSSA on readmission length of stay (LOS).

2. Methods

2.1. Source of data

The Healthcare Costs and Utilization Project–State Inpatient Databases (HCUP-SID) are a set of hospital databases containing all inpatient discharge abstracts from participating states, translated into a uniform format to facilitate multistate comparisons and analyses.[11]

2.2. Study population

The study population includes all patients discharged under MS-DRG 470 THA and TKA in Florida (FL) from 2009 to 2013, Massachusetts (MA) from 2010 to 2012, and California (CA) from 2009 to 2011. These states were chosen because they have large populations and are in different geographic areas of the US Index admission was defined as the discharge from which starts the 30-day potential penalty clock, excluding those patients who were discharged against medical advice, those who were discharged as dead, those who were discharged to another acute care facility, and those whose discharge code for index admission indicates nonelective THA or TKA procedures or revision/partial/resurfacing/removal of implant procedures. This study did not involve human subjects, that is, we did not obtain patient data through intervention or interaction with individuals, and we did not use indentifiable private information. Because the data in HCUP-SID are publicly available and deidentified, no IRB approval was needed.

2.3. Data analysis

To determine which index diagnosis to use in our study of SSIs and their impact on readmission, we conducted an exploratory analysis of CA, FL, and MA HCUP Medicare population data from 2009 to 2013 and determined the top primary diagnoses for readmission for each state. Specifically, we looked at the rates of readmission after index admissions for procedures included in Medicare Readmissions Reduction Program: THA and TKA, pneumonia, chronic obstructive pulmonary disease, heart failure, and acute myocardial infarction to determine which primary diagoses, if any, have a significant amount of readmission due to infection in order to quantify how much of the potential penalty under this program could be avoided if infection was prevented. Each patient readmitted due to infection following these index diagnoses is included when estimating a penalty for a hospital. For each index diagnosis, we found the total number of readmissions related to infection and ranked the type of infection by frequency in relation to all other reasons for readmission. THA and TKA, and pneumonia had among the highest rates of readmission due to infection (Table 1). Thus, we focused the study on THA and TKA as readmissions following these procedures are common and associated with high penalty costs. Procedure codes "8151" and "8154" were used to identify all inpatient discharges with THA and TKA in all 3 states. Readmission was measured by CMS' validated algorithm, which included readmitting to any acute care hospital, for any reason, with the exception of certain planned readmissions, occurring within 30 days of the discharge date of the index hospitalization. Infections were identified by the following ICD-9-CM codes: 99859, 99666, 6826, 0389, 486, 4821, 00845, 5990, 48242, 04111, 04112, 04119, 0417, 99591, and 99592. A frequency analysis was done on the 1st and 2nd aim. DRG code 470 was used to assess Medicare payment. DRG code 469 was considered for analysis but had a very low frequency and as a result an insignificant impact on the results and thus was not included. Ordinary least square regression was performed to predict the effect of MSSA and MRSA on LOS during readmission while adjusting for age, gender, race, insurance, socioeconomic status, year, and state. SAS version 9.4 statistical software was used.

3. Results

3.1. Top primary diagnoses for readmission after THA and TKA

According to HCUP Medicare population data from 2009 to 2013, THA and TKA had the highest frequency of readmissions with a primary diagnosis of "other postoperative infection" (ICD-9 code 99859) and the 2nd highest frequency of "infection and inflammation due to joint prosthesis" (ICD-9 code 99666) in CA, FL, and MA (Table 1). Thus, we determined the top 25 primary diagnoses for readmission following THA and TKA for years 2009 to 2011 in CA, 2009 to 2013 in FL, and 2010 to 2012 in MA. These years were chosen because these were the only years

Table 1

Readmission due to infection as primary diagnosis.

Primary diagnosis for readmission (ICD-9 Code)			Other postoperative infection (99859)	Infection and inflam reaction due to joint prosthesis (99666)	Unspecified Septecemia (0389)	Pneumonia, organism unspecified (486)	Pneumonia due to pseudomonas (4821)	Intestinal infection due to *Clostridium difficile* (00845)	Urinary tract infection, site not specified (5990)	Methicillian resistant pneumonia due to *S aureus* (48242)	Total readmissions due to infection	Total readmissions (top 25 dx)†	% Of top 25 dx at readmission due to infection‡
THA/TKA	CA	N	784	598	192	174	0	96	93	0	1937	5106	37.94
		Rank	1	2	10	11	NL	20	21	NL			
	FL	N	970	670	228	215	0	232	208	0	2523	6730	37.49
		Rank	1	2	12	13	NL	11	14	NL			
	MA	N	196	118	44	41	0	30	42	0	471	1157	40.71
		Rank	1	2	9	12	NL	14	11	NL			
PNEUMONIA	CA	N	0	0	2818	4196	324	601	465	424	8828	18,515	47.68
		Rank	NL	NL	2	1	16	8	11	12			
	FL	N	0	0	6021	15,818	1167	1469	2954	980	28,409	73,627	38.59
		Rank	NL	NL	2	1	23	17	7	25			
	MA	N	0	0	408	1071	74	230	142	82	2007	4902	40.94
		Rank	NL	NL	4	1	19	7	11	17			
COPD	CA	N	0	0	1137	1537	152	196	190	182	3394	19,167	17.71
		Rank	NL	NL	5	2	22	16	18	20			
	FL	N	0	0	1488	2713	272	544	509	276	5802	38,034	15.25
		Rank	NL	NL	7	3	24	15	16	23			
	MA	N	0	0	242	597	43	101	90	60	1133	7451	15.21
		Rank	NL	NL	7	2	23	14	15	20			
HF	CA	N	0	0	1917	1523	0	0	561	0	4001	35,862	11.16
		Rank	NL	NL	5	7	NL	NL	16	NL			
	FL	N	0	0	2033	1980	0	0	987	593	5593	54,319	10.30
		Rank	NL	NL	7	8	NL	NL	15	24			
	MA	N	0	0	303	420	0	142	229	0	1094	9233	11.85
		Rank	NL	NL	9	6	NL	17	11	NL			
AMI	CA	N	170	0	580	439	0	0	179	0	1368	9440	14.49
		Rank	20	NL	6	7	NL	NL	18	NL			
	FL	N	294	0	684	0	0	0	360	0	1338	17,046	7.85
		Rank	19	NL	6	NL	NL	NL	16	NL			
	MA	N	36	0	97	116	0	43	66	0	358	2422	14.78
		Rank	24	NL	10	6	NL	21	13	NL			

AMI = acute myocardial infarction, CA = California, COPD = chronic obstructive pulmonary disease, FL = Florida, HF = heart failure, MA = Massachusetts, NL = not listed, THA = total hip arthroplasty, TKA = total knee arthroplasty.

† Valid 30-days readmissions were categorized by their primary diagnoses, and the total number of readmissions falls into the top 25 most frequent diagnose categories were calculated.

‡ The proportion of readmissions caused by infection among all readmissions that fail into the top 25 readmission diagnose categories.

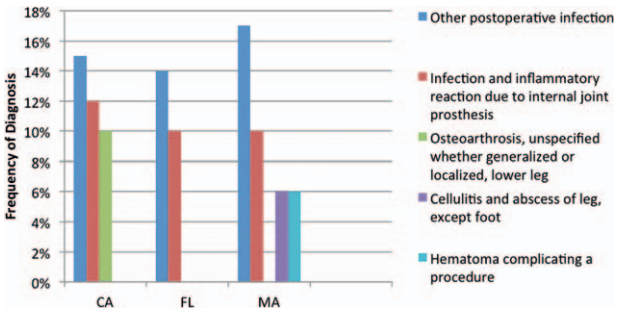

Figure 1. Top primary diagnoses for readmission after total hip athroplasty and total knee athroplasty by state.

available at the time of the study. As shown in Fig. 1, the primary diagnoses in FL with frequency above 5% are "other postoperative infection" (14%) and "infection and inflammatory reaction due to internal joint prosthesis" (10%). The primary diagnoses in CA with frequency above 5% are "other postoperative infection" (15%), "infection and inflammatory reaction due to internal joint prosthesis" (12%), and "osteoarthrosis of the lower leg, unspecified whether generalized or localized" (10%). The primary diagnoses in MA with frequency above 5% are "other postoperative infection" (17%), "infection and inflammatory reaction due to internal joint prosthesis" (10%), "cellulitis and abscess of the leg, except foot" (6%), and "hematoma complicating a procedure" (6%).

3.2. Proportion of readmission due to infection, MRSA and MSSA among infections, and Medicare payment on index THA and TKA

The distribution of diagnoses associated with readmission was extremely skewed with only a few single diagnoses resulting in a significant association with readmission, and many diagnoses associated with only 1 to 5 events out of the total number of readmissions. Table 1 shows the % of readmissions due to infection out of the top 25 diagnoses associated with readmission. Only the primary diagnoses of THA/TKA and pneumonia showed a significant portion of readmissions due to infection (>37% across all 3 states); other diagnoses showed <18% of readmissions due to infection. Table 2 shows the average readmission rate for THA and TKA in CA from 2009 to 2011 was 4.29% with 33.02% of the readmissions for infection for all diagnoses (ie, not limited to the top 25). The average readmission rate for THA and TKA in FL from 2009 to 2013 was 4.7% with 33.39% of the readmissions for infection, and the average readmission rate in MA from 2010 to 2012 was 3.92% with 35.2% of the readmissions for infection. Of those readmissions due to infection, MRSA and MSSA together accounted for 14.88% in CA, 13.38% in FL, and 13.11% in MA. The average Medicare payments for THA or TKA procedures were $14,337.00 in CA, $10,387.00 in FL, and $14,488.00 in MA for surgeries without complications or comorbidities.

3.3. Effect of MRSA and MSSA on readmission

Based on the regression analysis results shown in Table 3, MRSA and MSSA significantly increased LOS due to readmission by 3.05 and 2.79 days, respectively. Medicaid and self-pay patients were associated with slightly higher LOS compared to Medicare. Patients with private insurance had on average shorter LOS. Black and Hispanic race showed slightly higher LOS compared with White counterparts. The year 2013 showed slightly shorter LOS compared to other years, and FL showed longer LOS compared to MA and CA.

4. Discussion

The significant 30-day readmission rates due to infection following THA and TKA shown in Table 2 were similar to other reports across orthopedic procedures and demonstrate a similar proportion of readmissions due to SSI.[12] Our multivariate regression shows that, after adjusting for other confounding variables, MRSA and MSSA are significantly associated with an increased LOS due to readmission. We did not directly measure costs associated with the readmission. However, multiple studies confirm the association between infection and increased LOS, increased costs, and readmission. Typically, developing post-orthopedic SSI results in 2 to 3 times higher LOS in infected patients, and as a result, costs up to 3 times more compared with noninfected patients. Costs and LOS are compounded if SSIs result in hospital readmissions.[13,14] Specifically, postoperative MRSA leads to an average of 23 days of additional hospitalization and is independently predictive of readmission within 90 days compared to noninfected patients. Preventing SSI due to MRSA can potentially save hospitals up to $60,000 per patient.[5]

Historically, healthcare providers have been reimbursed for medical care through a fee-for-service (FFS) system that essentially permitted open-ended spending on treatment for a patient. As a result, the insurer is subject to open-ended economic risk; there is no limit to the number of services that a healthcare provider may choose to provide and receive reimbursement for. Under the traditional FFS model, hospitals are not at risk for readmissions: these would be paid as additional stays. In 2011, an admission of MS-DRG 856 "postoperative or posttraumatic infection with an OR procedure with a major complication/comorbidity" would result in an LOS of 11.2 to 15.6 and cost about $26,490, compared to MS-DRG 863 "postoperative or posttraumatic infection without surgery and MCC," which resulted in an average LOS of 4.0 to 4.9 days and cost $5056. *S aureus* infection, including MRSA, is listed as an MCC for the MS-DRGs for septicemia (870–871). If the sepsis patient requires mechanical ventilation for >96 hours, the base cost in 2011 was approximately $30,109 and the average LOS 12.8 to 15.1 days for a Medicare patient.[15] Additionally, FFS ultimately results in shifting more risks and costs to patients, who will pay higher premium rates to help insurers offset their own risk.[10]

Over the past 25 years, CMS has attempted to control healthcare costs and shift risk to providers through consolidating payments in order to place limits on payment for specific treatments or periods. The bundled payment system is an example of such a payment model that is intended to reduce costs for patients and insurers while improving quality of care. The bundled payment system incentivizes providers to manage resources and coordinate treatment efforts. Hospitals often prioritize freeing up beds over ensuring that patients have received complete care and are unlikely to be readmitted. For example, patients are often discharged without a microbiological follow-up after treatment. A study of *S aureus* infections following THA and TKA procedures found that the median time to onset of infection is 26 and 34 days after the surgical procedure for THA and TKA, respectively, where 82% and 100% of infections occurred within 90 days of the THA and

Table 2

Total hip and total knee arthroplasty readmission analysis*.

State	Year	Total nonmissing observation	Total valid index THA/TKA procedure N, %	Total valid readmission within 30 days of discharge N, %†	Total infection as primary diagnosis among readmission N, %‡	Total infection as primary and secondary diagnosis among readmissions N, %‡	MRSA as primary and secondary diagnosis among infection readmissions§ N, %‖	MSSA as primary and secondary diagnosis among infection readmissions§ N, %‖	Primary DRG	Average Medicare payment for initial admission for THA/TKA procedures
CA	2009	2,897,196	68,240 (2.36)	3,005 (4.40)	606 (20.17)	1,013 (33.71)	66 (6.52)	79 (7.80)	470	$13,381.92¶
	2010	2,914,412	72,197 (2.48)	3,136 (4.34)	669 (21.33)	1,022 (32.59)	85 (8.32)	87 (8.51)	470	$14,389.16¶
	2011	2,895,032	72,444 (2.50)	3,000 (4.14)	618 (20.60)	983 (32.77)	57 (5.80)	75 (7.63)	470	$15,242.76
	2009–2011	8,706,640	212,881 (2.45)	9,141 (4.29)	1,893 (20.71)	3,018 (33.02)	208 (6.89)	241 (7.99)	470	
FL	2009	2,182,144	50,306 (2.31)	2,555 (5.08)	533 (20.86)	882 (34.52)	86 (9.75)	34 (3.85)	470	$9,441.00¶
	2010	2,226,743	52,394 (2.35)	2,330 (4.45)	454 (19.48)	755 (32.40)	65 (8.61)	40 (5.3)	470	$10,151.61¶
	2011	2,241,241	51,325 (2.29)	2,565 (5.00)	455 (17.74)	794 (30.96)	59 (7.43)	41 (51.16)	470	$10,753.83
	2012	2,254,690	52,900 (2.35)	2,661 (5.03)	504 (18.94)	899 (33.78)	63 (7.01)	58 (6.45)	470	$10,755.76
	2013	2,250,584	56,477 (2.51)	2,265 (4.01)	505 (22.30)	802 (35.41)	59 (7.36)	48 (5.99)	470	$10,833.96
	2009–2013	11,155,402	263,402 (2.36)	12,376 (4.70)	2,451 (19.80)	4,132 (33.39)	332 (8.03)	221 (5.35)	470	
MA	2010	698,179	17,994 (2.58)	709 (3.94)	151 (20.30)	255 (35.97)	14 (5.49)	14 (5.49)	470	$13,566.40¶
	2011	699,002	18,459 (2.64)	746 (4.04)	148 (19.84)	252 (33.78)	11 (4.37)	24 (9.52)	470	$14,371.18
	2012	669,698	19,995 (2.99)	755 (3.78)	172 (22.78)	271 (35.89)	15 (5.54)	24 (8.86)	470	$15,528.74
	2010–2012	2,066,879	56,448 (2.37)	2,210 (3.92)	471 (21.31)	778 (35.20)	40 (5.14)	62 (7.97)	470	

1. Average Medicare payment data source: Centers for Medicare and Medicaid Services https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Provider-Charge-Data/Inpatient.html. 2. Medical CPI index source 2010–2011:Bureau of Labor Statistics http://www.bls.gov/news.release/cpi.t08.htm. 3. Medical CPI index source 2009 to 2010: Bureau of Labor Statistics http://www.bls.gov/cpi/cpid10av.pdf. CA = California, FL = Florida, MA = Massachusetts, MRSA = methicillin-resistant *Staphylococcus aureus*, MSSA = methicillin-susceptible *Staphylococcus aureus*, THA = total hip arthroplasty, TKA = total knee arthroplasty.

* Only the top 25 primary diagnoses were included for calculation in Table 2 because the frequency distribution among diagnoses is severely skewed.

† Denominator is the total valid index THA/TKA procedure.

‡ Denominator is the total valid readmission within 30 days of discharge.

§ Number and percent of MRSA/MSSA among readmissions due to infection based on primary and secondary diagnosis.

‖ Denominator is the total readmissions caused by infection as primary and secondary diagnosis.

¶ There is no published official average Medicare payment data for each state for year 2009 and year 2010, we used 2011 data for reference and adjusted by CPI to account for inflation.

Table 3

Multivariate Analysis of Total Hip and Total Knee Arthroplasty Length of Stay.

Characteristics	Regression Coefficient (days) (95% Confidence Interval)	P-value
MRSA		
Yes	3.05 (2.65, 3.46)	<.001
No	(Reference)	
MSSA		
Yes	2.79 (2.35, 3.22)	<.001
No	(Reference)	
Age	0.02 (0.01, 0.02)	<.001
Gender		
Female	0.05 (−0.09, 0.18)	0.500
Male	(Reference)	
Homeless		
Yes	2.95 (−0.12, 6.02)	0.060
No	(Reference)	
Primary payer		
Medicaid	0.54 (0.18, 0.90)	0.003
Private Insurance	−0.29 (−0.49, −0.10)	0.003
Self pay	1.26 (0.24, 2.29)	0.016
No charge	−1.14 (−2.82, 0.53)	0.180
Other	0.04 (−0.41, 0.49)	0.863
Medicare	(Reference)	
Race		
Black	0.66 (0.41, 0.91)	<.001
Hispanic	1.47 (1.26, 1.67)	<.001
Asian or Pacific Islander	0.26 (−0.30, 0.82)	0.362
Native American	−0.87 (−2.94, 1.20)	0.411
Other	0.36 (−0.19, 0.92)	0.198
White	(Reference)	
Year		
2010	−0.14 (−0.33, 0.05)	0.149
2011	−0.02 (−0.21, 0.17)	0.856
2012	0.22 (−0.01, 0.45)	0.063
2013	−0.42 (−0.68, −0.17)	0.001
2009	(Reference)	
State		
Florida	0.72 (0.56, 0.87)	<.001
Massachusetts	0.01 (−0.25, 0.28)	0.918
California	(Reference)	

MRSA = methicillin-resistant *Staphylococcus aureus*, MSSA = methicillin-susceptible *Staphylococcus aureus*.

TKA procedure, respectively, and 18% of infections occurred more than 90 days after TKA. As a result, readmission due to infection may likely fall outside of the 90 day period that begins when a patient is first diagnosed.[16] Bundled payments, intended to cover acute and postacute treatment 90 days following the main procedure, encourage hospitals to control quality and screen appropriately for SSIs and other causes for readmission during posttreatment care within the period covered in the bundle and implement infection control procedures to minimize their occurrence. Hospitals must take more responsibility for the coordination of care after discharge to avoid readmission after the period covered by the bundle payment ends. As providers are encouraged to improve postacute care and reduce readmissions, they additionally benefit from potential reduction in penalty payments to CMS. Many providers already have the necessary infrastructure in place to treat and monitor patients throughout the entire "continuum of care," from inpatient admission to rehabilitative services.

THA and TKA already may require lengthy and costly rehabilitation, particularly for elderly patients. Patients infected with MRSA or MSSA post-THA or TKA further compound cost, LOS, and readmission rate. Thus, providers, whose resources are limited by the CJR model, would benefit economically by implementing programs to prevent SSIs. In particular, a program aimed at Medicare and Medicaid populations would have a greater impact in reducing costs related to readmissions. As seen in our results, Medicare and Medicaid patients had a higher LOS due to readmission and thus show a greater cost burden. Other programs could include coordinating care and streamlining communication within and between providers, ensuring compliance with antibiotics, inpatient and outpatient screening for MRSA or MSSA posttreatment, decolonization, and intraoperative optimization of air quality.[12] Data from several large studies from the US, Europe, and Canada indicate that active surveillance testing with contact precautions or universal decolonization of patients provides the lowest rate of MRSA infection in healthcare settings.[17] A single-center study testing the implementation of an institution-wide prescreening program for the identification and eradication of MRSA in orthopedic surgery patients found that such a program is feasible and can lead to significant 59% reduction in rates of SSI.[18] An observational study evaluating the efficacy of a screening and decolonization protocol observed that none of the MSSA and MRSA colonized patients that had undergone the screening and decolonization intervention developed an SSI postarthroplasty. Additionally, a simple cost analysis performed found that reduced incidence of infection during the intervention period resulted in an economic gain of $231,741 compared with the preintervention period.[19] Successful implementation of an institution-wide screening program could significantly lower costs and help providers better distribute resources limited by bundle payment models and reduce costly readmissions.

Our study had several limitations. We were only able to ascertain 30-day readmission rates and were not able to extend to 90-day rates as covered by bundled payments. However, as discussed previously, most infections have an onset time of 26 to 34 days.[16] Thus, it is within reason to assume that over the 90-day period covered by the CJR bundle, an even greater portion of readmissions would be due to infection. Although our study utilized a regression model to control confounding factors such as age, gender, and race, we suspect that bias caused by unobservable confounders may still not be fully adjusted. Due to the fact that MRSA and MSSA infections occur commonly in TKA and THA patients with different characteristics, it is possible that there are additional comorbidities that are associated with both higher infection rates and longer LOS that have not yet been explored in other literature and thus were not assessed in this analysis. Additionally, HCUP only contains inpatient records and as a result limited our ability to differentiate infections that occurred within the hospital from infections that occurred outside of the hospital.

Our results in conjunction with published literature illustrate the economic burdens SSIs currently have on the healthcare system and thus suggest the importance of monitoring and controlling SSIs to reduce associated increases in LOS and readmission. These study findings will inform health policy studies to address additional study questions: how will CMS policies implemented affect the rate of readmissions related to SSI? Specifically, how will bundled payment models change providers' actions toward SSI-related readmissions going forward?

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