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Health Policy & Economics

Selective Early Hospital Discharge Does Not Increase Readmission but Unnecessary Return to the Emergency Department Is Excessive Across Groups After Primary Total Knee Arthroplasty

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ABSTRACT

Background: There has been much attention paid to the ability to optimize outcomes, limit complications, and reduce costs within the episode of care after total joint arthroplasty. Limiting the duration of postoperative hospitalization as well as reducing emergency department (ED) visits and readmissions are additional considerations in the paradigm of cost containment. Our purpose was to evaluate the safety of early hospital discharge after primary total knee arthroplasty (TKA) and to identify the diagnoses responsible for ED visits and readmissions in the postoperative period.
Methods: We investigated risk factors for readmission in 995 patients undergoing primary TKA. We compared 2 groups: length of hospital stay (LOS) ≤2 or ≥3 days. Analysis included LOS, Charlson score, history of DVT, discharge disposition, and postdischarge ED visits.
Results: Patients who stayed ≤2 postoperative days had a significantly lower mean Charlson score and more likely discharged home. Charlson score and history of DVT were predictive of return events. Patients discharged to home were less likely to have return events. More than half of the patients evaluated in the ED were not readmitted.
Conclusion: Among patients undergoing primary TKA, it is the health of the patient, and not their resultant LOS, that correlates to return events. The ED is overused for complaints that may otherwise be managed as effectively and more cost efficiently in outpatient settings. Cost containment must include unnecessary utilization of the ED.

More than 600,000 total knee arthroplasties (TKAs) are performed yearly in the United States [1]. This number is expected to increase by 673 percent by the year 2030 [2]. The increasing volume as well as increased pressure for optimizing outcomes, limiting complications, and reducing costs through the entire episode of care requires careful assessment of a variety of procedures and protocols [3-5]. Shortening the duration of postoperative hospitalization after joint arthroplasty is one consideration for achieving these goals. Even outpatient joint arthroplasty is being considered more commonly as our understanding of risk stratification evolves [6,7].

Reducing emergency department (ED) visits and hospital readmissions after total joint arthroplasty are additional considerations in the paradigm of cost containment. The Centers for Medicare and Medicaid Services is using readmissions as a surrogate measure of performance and an indirect measure of surgical quality, with penalties being levied for such readmissions [8,9]. To be clear then, any programmatic efforts to reduce length of hospital stay (LOS) should not be at the expense of readmission, which would paradoxically increase the costs of care. Importantly, patient education, appropriate risk stratification, and optimization of perioperative health status of the patients are necessary to ensure successful early discharge, and even outpatient surgery, while reducing the risks of postoperative readmission within the 90-day time frame.

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There is general agreement within the growing body of literature examining readmission rates after total joint arthroplasty that decreasing the LOS after TKA is not associated with increased readmission rates [10-17]. However, the presently available readmission data may underestimate the overall unplanned hospital return event rates after TKA in as much as they do not account for patients who present to the ED with a TKA-related complaint and are sent home without a hospital readmission [10-17]. ED visits should be considered in the analysis because they reflect further the postoperative medical status of the patient and add to the total cost of care.

The purpose of this study was to evaluate the safety of early hospital discharge after primary TKA. Our objectives were to compare return event data between patients who were discharged early (LOS ≤2 days) and those who were discharged ≥3 days after TKA and to evaluate LOS within the context of other possible predictors of unplanned return events. We also evaluated diagnoses that were responsible for ED visits in the postoperative period and determined if ED visits affected readmission rates. We hypothesized that readmission rate would not be higher in patients who are discharged early. We also hypothesized that LOS would not be as predictive as other factors for unplanned postoperative return events.

Materials and Methods

After institutional review board approval, a query of institutional procedure records identified 1220 consecutive patients admitted for TKA between January 1, 2011 and July 31, 2013 in a community hospital setting. Multiple surgeons within the same health system performed the procedures. Patients were excluded if they underwent bilateral TKAs, revision TKA, or partial knee arthroplasty. This reduced the cohort to 995 patients. The authors abstracted data from the institution's electronic medical records and followed them out to 90 days postoperatively.

There were 348 (35%) males and 647 (65%) females. The mean age was 65.3 years (range, 36-90 years). There were 459 (46%) right-sided and 536 (54%) left-sided procedures. No patients died during the study period.

An unplanned return event was defined as any unplanned visit to our hospital's ED or hospital readmission. The primary diagnosis documented at the time of a return event was considered to be the primary reason for the return event. Any planned events, such as an elective contralateral TKA or routine unrelated medical screening visit such as mammography, were excluded from the study.

A descriptive univariate analysis was made of the study group and other parameters. Two subgroups were established based on LOS ≤2 days and LOS ≥3 days. These 2 groups were compared using the Wilcoxon signed rank test for nonparametric variables and Fisher exact test for categorical variables. Multivariate logistic regression was used to discern which patient factors affected ED visits and readmissions. Factors that were compared included LOS, Charlson Comorbidity Score (CCS), age, gender, past medical history of deep vein thrombosis (DVT) or pulmonary embolism, discharge disposition (eg, to home, rehabilitation facility, and so forth), and postoperative ED visits [18]. Bivariate analysis was used to look for a correlation between ED events and readmissions. Only the medical comorbidity subcomponent of the CCS was used, which avoided including the effect of age twice. Statistical significance was established at $P \leq .05$.

Results

The overall mean LOS was 2.8 days (range, 1-17 days). Three hundred forty-two patients stayed ≤2 days, and 653 patients stayed ≥3 days. The mean CCS was 0.88 (range, 0-8). A total of 18 patients (1.8%) had a previous history of DVT, and 8 patients (0.8%) had a previous history of pulmonary embolism. Ninety-one percent of patients discharged ≤2 days after TKA were discharged directly home; 32% of patients discharged ≥ 3 days after TKA went to an inpatient subacute rehabilitation center ($P < .01$; Table 1).

Subgroup analysis revealed that patients with LOS ≥3 days were significantly older, more commonly female, had a higher CCS, and experienced more return events (Table 1). When the CCS was plotted against return events, we found that, regardless of LOS, as comorbidity burden increased, the unplanned return event rate also increased (Fig. 1).

In total, 128 patients (12.9%) had 154 unplanned return events within 90 days of the index surgery. Overall, the data revealed that irrespective of LOS, return events increased with increasing comorbidity (CCS). Increased LOS (≥ 3 days) does not significantly change the odds of readmission over patients who stayed ≤ 2 days (odds ratio [OR] = 0.418, confidence interval [CI] = 0.125-1.400, $P = .157$) when controlling for patient factors such as age, gender, DVT, and CCS. Simple comparison of readmit rates, without controlling for patient factors, was also not significant (4.39% for ≤ 2 days vs 7.04% for ≥ 3 days, $P = .125$).

One hundred nineteen patients (12.0%) had a total of 155 ED events. Postoperative pain or swelling (25.2%) was the most common diagnosis that prompted ED visits (Table 2). Of the patients who presented to the ED with postoperative pain and swelling, 67% were sent from a subacute rehabilitation facility, and only 10% were readmitted.

With respect to ED events, regression analysis confirmed the association between CCS (OR = 1.244, 95% CI = 1.058-1.462, $P = .008$) and increased return events. In addition, history of DVT (OR = 2.944, 95% CI = 0.979-8.849, $P = .055$) trended toward but did not reach statistical significance for increased return events. Discharge to home (OR = 0.643, 95% CI = 0.386-1.069, $P = .089$) approached significance and demonstrated a negative correlation with ED events.

Nearly half of the patients who visited the ED (46%) were readmitted, whereas less than 1% of patients without an ED event were readmitted. Of patients presenting to the ED with pain and swelling of the lower extremity, only 10% were readmitted. When ED visits (OR = 197.285, 95% CI =65.327-595.793, $P < .0001$) were included as a predictor of return events in multivariate analysis, there was an overwhelming statistically significant increase in readmission over the other variables studied.

Sixty-one patients (6.1%) had a total of 86 hospital readmissions. Cellulitis was the most common readmission diagnosis (Table 3). With respect to readmissions, age (OR = 1.038, 95% CI = 1.008-1.070, p = .014) demonstrated a small but statistically significant

Table 1
Length of Stay Subgroup Comparison.

Comparisons	LOS ≤ 2 d	LOS ≥ 3 d	*P* Value
n	342	653	N/A
LOS (mean, SD)	1.80 (0.40)	3.32 (1.16)	N/A
Age (mean, SD)	62.94 (9.14)	66.51 (9.92)	<.01[a]
Female (%)	57.02	69.22	<.01[a]
Prior DVT	2	16	.04[a]
Prior PE	1	7	.27
CCS (mean, SD)	0.68 (1.06)	1.00 (1.09)	<.01[a]
Discharged home (%)	90.64	31.39	<.01[a]
Overall return rate (%)	11.00	15.90	.04[a]
ED event rate (%)	9.36	13.94	.04[a]
Readmission rate (%)	4.39	7.04	.12

The table shows the statistical difference between the 2 subgroups in the study.
LOS, length of stay; SD, standard deviation; DVT, deep vein thrombosis; PE, pulmonary embolus; CCS, Charlson Comorbidity Score; ED, emergency department; NA, not applicable.
[a] Statistical significance established at $P \leq .05$.

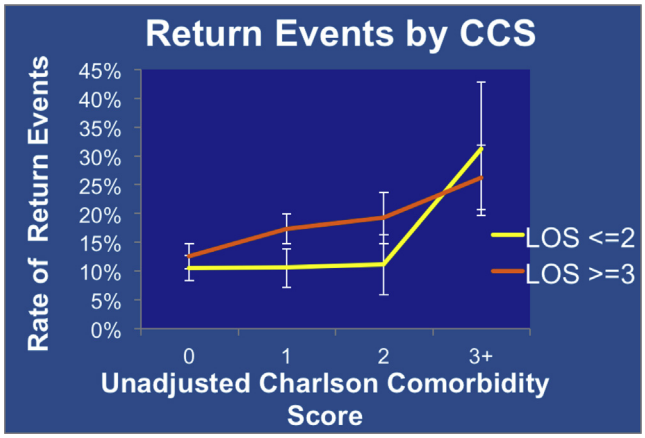

Fig. 1. Regardless of LOS, the rate of return events increases as the CCS increases. LOS, length of stay; CCS, Charlson Comorbidity Score.

correlation to return events. In this analysis, the effect of CCS (OR = 1.205, 95% CI = 0.968-1.499, $P = .095$) was weaker and only trended toward significance. In addition, discharge to home (OR = 0.340, 95% CI = 0.153-0.751, $P = .008$) had an even greater statistically significant negative correlation with return events. The breakdown for return events by systems is listed in Figure 2.

Discussion

The current care paradigm involves optimizing patient outcomes, limiting complications and controlling costs within the entire episode of patient care before and after TKA. Decreasing LOS is one component of controlling costs in TKA. Readmissions are currently used by the Centers for Medicare and Medicaid as a surrogate for judging quality. Therefore, rapid rehabilitation and early discharge must not come at the expense of postdischarge costs or increased use of the ED or readmissions.

We found our overall 90-day readmission rate of 6.1% to be comparable to previously reported studies (range, 3.5%-15.6%) [12,13,15,17,19]. Our common reasons for readmission were infection (24.4%) and cardiac complaints (24.4%; Fig. 2). These findings are similar to those of Zmistowski et al, who reported that infection (35.9%) was the most common reason for readmission after TKA, and Vorheis et al, who reported that among Medicare patients, the most common reason for readmission was cardiac in etiology [15,17]. Unlike prior studies which have not shown a clear link between medical comorbidities and readmissions after TKA, the present study shows a clear link, irrespective of LOS.

Stratifying patients with regard to their appropriateness for short-stay TKA requires a reliable preoperative risk assessment. The CCS was originally designed to predict 10-year mortality based on a patient's comorbidities and age. It has been used in the orthopedic literature to predict postoperative complications, mortality, blood transfusion, discharge to nursing home, LOS, and hospital charges [18,20,21]. We found that both comorbidity burden and age were predictive of return events.

As predicted, our study shows that younger patients with less medical comorbidities and who can be discharged from the hospital sooner to home will have less return events. In addition, regardless of LOS, the rate of return events increases as the CCS increases (Fig. 1). The apparent association between longer LOS and adverse outcomes arises because patient health factors affect them both.

Unlike our study, previous studies of readmissions after TKA have not included data regarding ED visits occurring within the same 90-day postoperative period [12,13,15,17]. Our data indicated that ED events were common (12% of patients) and contributed to an overall return event rate of 12.8%. However, ED events were significantly less common among patients who were discharged earlier and who were discharged to home. Including ED return events in our analysis provides a more complete view of the collective postoperative experience, as well as a more accurate assessment of the safety and potential costs of a shorter postoperative stay. It also highlights the importance of controlling patient disposition as well as optimizing perioperative care and communication.

In reviewing our ED data, we found that there was a high incidence of potentially unnecessary ED visits. The most common reason for return to the ED in this series was knee pain or swelling; however, 90% of these patients were sent home from the ED and did not require readmission. This highlights the unnecessary burden imposed on patients (regardless of LOS) who are referred to the ED with pain or swelling after TKA. A system facilitating timely assessment of patients experiencing postoperative knee pain or swelling by the treating orthopedic physician, rehabilitation staff, or ancillary providers rather than ED providers would be both

Table 2
Some of the Common Reasons for Return to the Emergency Department and Their Percentage of the Total Number of Events.

Common ED Return Events	155 Events	Percentage
Postoperative pain and/or swelling	39	25.2
Cellulitis	16	10.3
Cardiac chest pain/EKG abnormality	9	8.4
Fall	8	5.2
Periprosthetic infection	6	3.9
Drug coagulopathy (ie, coumadin or rivaroxaban)	5	3.2
Deep vein thrombosis	4	2.6

There were 119 patients with a total of 155 events.

Table 3
Some of the Common Reasons for Readmission to the Hospital and Their Percentage of the Total Number of Events.

Common Readmission Events	86 Events	Percentage
Cellulitis	10	11.6
Periprosthetic infection	8	9.3
Wound dehiscence	4	4.4
Hemarthrosis	4	4.4
Deep vein thrombosis	4	4.4
Dislocated patella	3	3.3

There were 57 patients with a total of 86 events.

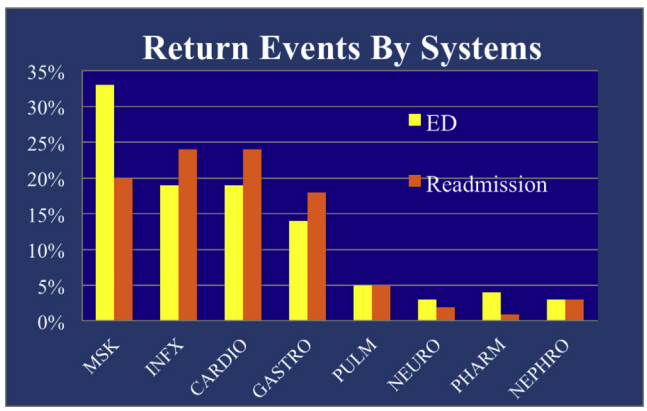

Fig. 2. The percentage of return events by systems. Most events for the ED and readmission involve MSK, INFX, or cardiac etiology. ED, emergency department; MSK, musculoskeletal; INFX, infectious.

better for patients and more cost effective. In addition, preoperative and postoperative patient education is of the utmost importance. Patients should have an understanding of the postoperative complications that can occur after TKA, as well as a clear line of communication with the surgeon's staff. Given the frequent unnecessary return events from subacute rehabilitation facilities, educating care providers at theses centers and minimizing the disposition of patients to these care centers are important considerations. Given the growing emphasis on cost containment, overutilization of the ED should be minimized [22].

The successful implementation of short-stay TKA, with its attendant cost savings and apparent safety, should also prioritize discharge to home and minimize discharge to rehabilitation or skilled nursing facilities. This will optimize surgeon control of patient care and minimize hospital return events. Schairer et al reported an association between post-TKA hospital readmission and patients having more medical comorbidities, LOS greater than 5 days, and having been discharged to skilled nursing facility [23]. Bini et al showed that discharge to sub-acute rehab after TKA was associated with an increased readmission rate compared to discharge home [19]. Similarly, we found that patients who were discharged to a rehabilitation facility were generally older had more medical comorbidities, more commonly female, had longer LOS, and experienced more return events. It is our opinion that return events among these patients are in part attributable to their generally poorer health, but also at times related to limited experience, training, or initiative by inpatient rehabilitation caregivers.

Limitations of this study include its retrospective nature, as well as the inability to account for unplanned return events occurring at other health care facilities, such as outside hospitals or urgent care facilities. Taking into account that all of these surgeries were performed in a community hospital setting as opposed to a tertiary care hospital, we think that patients are more apt to return to their local community hospital in which the procedure was performed. In a recent study, Bini et al showed that 2-day LOS did not increase readmissions compared with 3-day LOS after TKA [24]. Like theirs, our study shows that with sound selection and protocols, readmissions can be reduced in either a tertiary hospital or a community hospital. In addition, patient selection, operative technique, methods of communication, and postoperative protocols were not unified between treating surgeons. Patient expectations and education were not addressed uniformly in this study. In addition, surgeon protocols for the time of initiation of in-hospital physical therapy and scripting regarding early discharge varied. Finally, the study did not stratify whether preoperative medical optimization plays a beneficial role in decreasing readmission rates. This might be performed using CCS in a prospective manner while evaluating readmission rates.

Conclusions

Overall, these data demonstrated that among patients undergoing primary TKA, it is the health of the patient, and initial discharge disposition, and not their LOS, that correlates to return events. When reasons for ED visits are considered in this context, it appears that the ED is overused for complaints that may otherwise be managed as effectively and more cost efficiently in outpatient settings. Cost containment must include reduced utilization of the ED. Effective strategies should include risk stratification of patients preoperatively, reduced utilization of subacute rehab facilities, nursing education, patient education, and most importantly a clear line of communication between the patient and the physician in the postoperative period.

References

1. Cram P, Lu X, Kates SL, et al. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991–2010. JAMA 2012;308:1227.
2. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780.
3. Bosco JA, Karkenny AJ, Hutzler LH, et al. Cost burden of 30-day readmissions following Medicare total hip and knee arthroplasty. J Arthroplasty 2014;29:903.
4. Bozic KJ, Maselli J, Pekow PS, et al. The influence of procedure volumes and standardization of care on quality and efficiency in total joint replacement surgery. J Bone Joint Surg Am 2010;92(16):2643.
5. Centers for Medicare and Medicaid Services. *Fact sheet: bundled payments for care improvement initative*. 2013. http://www.cms.gov/Newsroom/MediaReleaseDatabase/Fact-Sheets/2013-Fact-Sheets-Items/2013-01-31.html [accessed 01.08.15].
6. Berger RA, Kusuma SK, Sanders SA, et al. The feasibility and perioperative complications of outpatient knee arthroplasty. Clin Orthop Relat Res 2009;467(6):1443.
7. Berger RA, Sanders S, Gerlinger T, et al. Outpatient total knee arthroplasty with a minimally invasive technique. J Arthroplasty 2005;20(3):33.
8. Readmissions reduction program. 2012 (http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html). [accessed 01.08.15].
9. Tsai TC, Joynt KE, Orav EJ, et al. Variation in surgical-readmission rates and quality of hospital care. N Engl J Med 2013;369:1134.
10. Aram V, Petruccelli D, Winemaker M, et al. Total joint arthroplasty readmission rates and reasons for 30-day hospital readmission. J Arthroplasty 2014;29(3):465.
11. Daily EA, Cizik A, Kasten J, et al. Risk factors for readmission of orthopaedic surgical patients. J Bone Joint Surg Am 2013;95(11):1012.
12. Husted H, Otte KS, Kristensen BB, et al. Readmissions after fast-track hip and knee arthroplasty. Arch Orthop Trauma Surg 2010;130:1185.
13. Mahomed NN, Barrett J, Katz JN, et al. Epidemiology of total knee replacement in the United States Medicare population. J Bone Joint Surg Am 2005;87:1222.
14. Mesko N, Bachmann K, Kovacevic D, et al. Thirty-day readmission following total hip and knee arthroplasty-A preliminary single institution predictive model. J Arthroplasty 2014;29:1532.
15. Vorhies JS, Wang Y, Herndon JH, et al. Decreased length of stay after TKA is not associated with increased readmission rates in a national Medicare sample. Clin Orthop Relat Res 2012;470(1):166.
16. Vorheis JS, Wang Y, Herndon J, et al. Readmission and length of stay after total hip arthroplasty in a national Medicare sample. J Arthroplasty 2011;26(6 Suppl):119.
17. Zmistowski B, Restrepo C, Hess J, et al. Unplanned Readmission after total joint arthroplasty: rates, reasons, and risk factors. J Bone Joint Surg Am 2013;95-A:1869.
18. Charlson ME, Pompeii P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Chronic Dis 1987;40(5):373.
19. Bini SA, Fithian DC, Paxton LW, et al. Does discharge disposition after primary total joint arthroplasty affect readmission rates? J Arthroplasty 2010;25(1):114.
20. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 1992;45:613.
21. Januel JM, Chen G, Ruffieux C, et al. Symptomatic In-hospital deep vein thrombosis and pulmonary embolism following hip and knee arthroplasty among patients receiving recommended prophylaxis: a systematic review. JAMA 2012;307(3):294.
22. Courtney PM, Rozell JC, Melnic CM, et al. Who should not undergo short stay hip and knee arthroplasty? Risk factors associated with major medical complications following primary total joint arthroplasty. J Arthroplasty 2015;30(9 Suppl):1.
23. Schairer WW, Vail TP, Bozic KJ. What are the Causes of Hospital Readmission after Total Knee Arthroplasty? Clin Orthop Relat Res 2014;472(1):181.
24. Bini S, Inacio M, Cafri G. Two-day length of stay is not inferior to 3 days in total knee arthroplasty with regards to 30-day readmissions. J Arthroplasty 2015;30(5):733.

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Winner of the Dorr Award

Risk Factors, Causes, and the Economic Implications of Unplanned Readmissions Following Total Hip Arthroplasty

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ABSTRACT

In order to identify risk factors for readmissions following total hip arthroplasty (THA) and the causes and financial implications of such readmissions, we analyzed clinical and administrative data on 1583 consecutive primary THAs performed at a single institution. The 30-day readmission rate was 6.51%. Increased age, length of stay, and body mass index were associated with significantly higher readmission rates. The most common re-admitting diagnoses were deep infection, pain, and hematoma. Average profit was lower for episodes of care with readmissions ($1548 vs. $2872, $P = 0.028$). If Medicare stops reimbursing for THA readmissions, the institution under review would sustain an average net loss of $11,494 for episodes of care with readmissions and would need to maintain readmission rates below 23.6% in order to remain profitable.

The 30-day readmission rate has become a pervasive quality indicator for hospital care. The Medicare Payment Advisory Commission (MedPAC) estimated that, in 2005, 17.6% of patients were readmitted to the hospital within 30 days of discharge. This resulted in $15 billion in annual spending, 80% of which was related to potentially preventable readmissions [1]. With growing national attention on cost containment, payors and providers alike are focused on readmissions as a target for cost cutting and quality improvement.

Section 3025 of the Patient Protection and Affordable Care Act of 2010 grants the Centers for Medicare & Medicaid Services (CMS) the authority to penalize hospitals with excessive 30-day readmission rates [2]. In October 2012, CMS began recouping hundreds of millions of dollars from hospitals with high rates of readmission following hospitalization for heart failure, acute myocardial infarction, and pneumonia [3]; the government may extend this policy in the coming years to include a broader range of conditions [1,4].

Over 300,000 total hip arthroplasty (THA) operations are performed in the United States annually, with Medicare paying for the majority of cases [5]. By one recent estimate, 8.5% of primary and 14.1% of revision THA patients are readmitted within 30 days of discharge [6]. Furthermore, annual THA volume has been predicted to expand to 570,000 by the year 2030, partially as a result of an aging population and the growing prevalence of obesity [7]. National spending on THAs is thus likely to continue increasing into the future and may soon be a focus of regulatory scrutiny.

In this changing healthcare environment, with increasing pressures for cost-containment and quality improvement, it is critical that hospitals identify the risk factors and quantify the costs of unplanned readmissions; thus allowing healthcare institutions to prevent these episodes and remain financially viable. The purpose of this study is to identify risk factors for readmissions following THA and the causes and financial implications of such readmissions should CMS revoke reimbursements for them.

Methods

This is a retrospective cohort study examining 1583 consecutive primary THA procedures performed between July 1, 2009, and June 30, 2011, at an urban tertiary academic hospital network serving over 70,000 inpatients annually. The investigation received approval from the health system's institutional review board. Subjects were identified for inclusion from the pool of all inpatient admissions on the basis of the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedures code indicating primary THA (81.51); revision procedures were not included. The outcome of interest was unplanned readmissions within 30 days of discharge from the inpatient stay when THA was performed. Readmissions were

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included only if occurring for unforeseen causes; planned readmissions for inpatient rehabilitation or skilled nursing care were excluded from the analysis. In accordance with CMS policies, returns to the emergency department were not considered readmissions without subsequent admission to a hospital floor or intensive care bed.

Readmitted and non-readmitted patients were compared based on demographic, clinical and financial parameters. Demographic and clinical data, including patient age, gender, race, length of stay (LOS), height, weight, procedure codes, and readmitting diagnoses (if applicable) were collected from the institution's data warehouse. Height and weight were used to calculate body mass index (BMI). Financial data, including actual costs and calculated reimbursements, were obtained from a cost accounting database maintained by the institution's Finance Department. Reimbursement calculations were performed using Medicare reimbursement rates for all patients regardless of the actual insurer in order to enhance the study's generalizability as private reimbursement rates vary widely based on geography and bargaining power in local markets. These calculations were carried out in accordance with CMS policy as a function of the Medicare Severity Diagnosis Related Group (MS-DRG) associated with the admission. Profit (or loss) was calculated for each patient by subtracting total cost from reimbursement revenue. Financial analysis was also performed to model the hypothetical scenario in which unplanned readmissions following THA are no longer reimbursed. Breakeven analysis was preformed to assess the impact of potential reimbursement changes on the THA program's profitability.

For all calculations, statistical significance was defined by P values of less than 0.05. Continuous variables were tested for normality. Parametric variables were compared using the Student's t-test and are represented as mean and standard deviation. Non-parametric variables were compared using the Mann–Whitney U-test and are represented as median and interquartile range (IQR). Categorical variables were analyzed as proportions using chi-squared testing and are represented as percents. Odds ratio (OR), 95% confidence interval (CI), and P value were calculated using bivariate and multivariate logistic regression.

Results

The average age and standard deviation of the 1583 THA patients enrolled in our study were 60.7 ± 13.3 years (Table 1). Fifty-three percent were female, and average BMI was 30.3 ± 7.0. Sixty-nine percent of patients were white, 27% black, 0.6% Asian, 0.1% Native American, and 3.3% classified racially or ethnically as "other" or "unknown." Ninety-seven patients (6.13%) were readmitted to the hospital comprising 103 readmissions (6.51% readmission rate).

Table 1
Patient Characteristics.

	All Patients (N = 1583)		Readmitted (N = 97)		Not Readmitted (N = 1486)		
	N or Mean	% or SD	N or Mean	% or SD	N or Mean	% or SD	*P* Value
Age (y)	60.7	13.3	64.5	14.7	60.5	13.1	0.004
Gender							0.368
Female	844	53.3%	56	57.7%	788	53.0%	
Male	739	46.7%	41	42.3%	698	47.0%	
Race							
White	1093	69.0%	65	67.0%	1028	69.2%	0.654
Black	426	26.9%	30	30.9%	396	26.6%	0.357
Native American	2	0.1%	0	0.0%	2	0.1%	0.718
Asian	10	0.6%	0	0.0%	10	0.7%	0.418
Other	30	1.9%	1	1.0%	29	2.0%	0.519
Unkown	22	1.4%	1	1.0%	21	1.4%	0.755
BMI	30.3	7.0	32.7	7.9	30.1	6.9	<0.001
LOS (d)	4.0	2.5	4.9	3.4	4.0	2.4	<0.001

Table 2
Bivariate Logistic Regression (Readmitted vs Non-Readmitted Patients).

	OR	95% CI	*P* Value
Age	1.02	1.01–1.04	0.004
≤55	1.00	–	–
56–65	0.90	0.50–1.62	0.74
66–75	1.51	0.87–2.61	0.14
≥76	2.02	1.14–3.60	0.017
Gender			
Female	1.00	–	–
Male	0.83	0.55–1.25	0.37
Race			
White	1.00	–	–
Black	1.20	0.77– 1.88	0.43
Other	0.39	0.05–2.85	0.35
LOS	1.09	1.03–1.16	0.003
BMI	1.05	1.02–1.07	0.001
<25	1.00	–	–
25–<30	0.66	0.33–1.31	0.23
30–<35	1.42	0.77–2.62	0.27
≥ 35	2.28	1.27–4.09	0.006

Increased age ($P = 0.004$), LOS ($P < 0.001$), and BMI ($P < 0.001$) were correlated with readmissions. The rate of readmission was not found to be correlated with gender ($P = 0.368$) or race ($P = 0.357$–0.755).

Bivariate logistic regression revealed similar correlations (Table 2). Prolonged LOS ($P = 0.003$) was associated with an OR of 1.09 for risk of readmission (95% CI: 1.03–1.16). Age ≥76 ($P = 0.017$) demonstrated an OR of 2.02 when compared with age <55 (95% CI: 1.14–3.60), and BMI ≥35 ($P = 0.006$) demonstrated an OR of 2.28 when compared with BMI <25 (95% CI: 1.27–4.09). Again, gender ($P = 0.37$) and race ($P = 0.35$–0.43) were not associated with unplanned readmissions. A multivariable logistic regression model adjusted for gender and race confirmed these correlations between unplanned thirty-day readmissions and age ($P = 0.003$), BMI ($P < 0.001$), and LOS ($P = 0.020$).

The most common ICD-9 diagnosis code associated with readmissions was 998.59 signifying "Other postoperative infection" and accounting for 19 readmissions (18.3%). This code is typically used for operative site infections other than infected seromas and cellulitis. Other common codes associated with readmission were "Infection and inflammatory reaction due to internal joint prosthesis" (996.66) accounting for 12 readmissions (11.5%), and "Hematoma complicating a procedure" (998.12) accounting for seven readmissions (6.7%). For an expanded list, see Table 3.

Table 3
Most Common Principal Diagnosis Code Descriptions for Readmission.

Rank	ICD-9 Code	Readmitting Diagnosis	Count	% of Complications
1	998.59	"Other postoperative infection"	19	18.3%
2	996.66	"Infection and inflammatory reaction due to internal joint prosthesis"	12	11.5%
3	998.12	"Hematoma complicating a procedure"	7	6.7%
4	719.45	"Pain in joint, pelvic region and thigh"	6	5.8%
5	996.42	"Dislocation of prosthetic joint"	5	4.8%
5	729.5	"Pain in limb"	5	4.8%
7	996.77	"Other complications due to internal joint prosthesis"	3	2.9%
7	729.81	"Swelling of limb"	3	2.9%
9	453.41	"Acute venous embolism and thrombosis of deep vessels of proximal lower extremity"	2	1.9%
9	780.97	"Altered mental status"	2	1.9%
9	682.9	"Cellulitis and abscess of unspecified sites"	2	1.9%
9	682.6	"Cellulitis and abscess of leg, except foot"	2	1.9%
9	786.5	"Chest pain"	2	1.9%
9	780.6	"Fever and other physiologic disturbances of temperature regulation"	2	1.9%
9	486	"Pneumonia, organism unspecified"	2	1.9%

Table 4
Economic Analysis Under Current Reimbursement Scheme.

	Avg THA Episode	Avg Episode Without Readmission	Avg Episode With Readmission(s)	Difference With & Without Readmission	*P* Value
Revenue	$21,613 ($16,257–$25,333)	$21,285 ($16,234–$25,333)	$34,481 ($24,860–$48,298)	−$13,196	<0.001
Cost	$17,636 ($15,741–$21,363)	$17,454 ($15,643–$20,505)	$31,755 ($26,099–$44,253)	−$14,301	<0.001
Profit	$2828 (−$1751–$8217)	$2872 (−$1524–$8188)	$1548 (−$9153–$8645)	$1323	0.028

Note: Profit values do not exactly equal revenue less cost because these are median observed values from the study sample, not calculated figures.

The median (IQR) hospital revenue, cost, and profit of THA in this study were $21,613 ($16,257–$25,333), $17,636 ($15,741–$21,363), and $2828 (−$1751–$8217), respectively (Table 4). Of note, the profits described are not precisely equal to revenue less cost because these figures are median values of the sample. When compared to episodes without an unplanned readmission, episodes with readmissions were $14,301 more expensive ($P < 0.001$), were reimbursed by an additional $13,196 ($P < 0.001$), and were $1323 less profitable ($P = 0.028$).

Under the hypothetical scenario in which CMS denies reimbursement for THA readmissions, the median unplanned readmission would generate a loss of $11,494 rather than the current profit of $227 ($P < 0.001$) (Table 5). As some THA episodes result in multiple unplanned readmissions, the cumulative effect would be a median loss of $12,410 for each THA episode with at least one associated readmission. In this hypothetical scenario, the average THA episode at the institution under review would be reimbursed $328 less than the current reimbursement level ($P = 0.018$). The resultant profit would be $2457, as opposed to the profit of $2828 for the average THA episode in the current system ($P = 0.051$). The institution under review would need to maintain a readmission rate less than 23.6% to remain profitable in the absence of reimbursement for THA readmissions (Fig. 1).

Discussion

With increased attention on cost-containment in the healthcare industry, unplanned 30-day readmission rates have become a popular tool used by payors, most notably CMS, to levy reimbursement penalties. Such cost-cutting efforts are likely to spread to additional specialties and procedures, and the growing arthroplasty market may be a favorable future target. This study examines 1583 consecutive primary THA procedures performed at a large academic hospital network to elucidate the risk factors, causes, and financial implications associated with 30-day unplanned readmissions as well as the potential economic consequences of reimbursement penalties.

The 30-day readmission rate for THA at the institution under review was 6.51%, and episodes of care with unplanned readmissions generated significantly lower profit. Older age ($P = 0.004$), higher BMI ($P = 0.001$), and longer LOS ($P = 0.003$) were associated with significantly higher rates of readmission, while gender, race, and revision surgery had no influence. The most common readmission diagnoses observed in our sample were “other postoperative infection” (18.3%) and “infection and inflammatory reaction due to internal joint prosthesis” (11.5%). These codes both typically represent deep infections and are often used interchangeably for that purpose; superficial infections are normally denoted by ICD-9 codes for cellulitis and abscess (3.8%) or infected seroma (1%). Thus, 29.8% of readmissions were likely prompted by deep joint infections, though the use of administrative data, as discussed below, limits our full understanding of these readmissions. Other common causes of readmission were pain in the limb or pelvis (10.6%), hematoma (6.7%), and hip dislocation (4.8%).

The academic literature detailing the causes and rates of readmission after THA is mixed. Cram et al reviewed data on nearly two million patients undergoing THA and found that 8.5% of primary and 14.1% of revision THA patients were readmitted within 30 days of discharge [6]. A 2006 study of 769 consecutive patients undergoing primary THA in the United Kingdom observed a readmission rate of 8.5%; the main causes of readmission were DVT, atraumatic dislocation, and wound complications such as superficial infection and hematoma [8]. In contrast, 6.8% of 1809 THA patients were readmitted in a 2011 analysis of Medicare Patient Safety Monitoring System data. In this case, cardiac complications (e.g., congestive heart failure, ischemic heart disease, dysrhythmias) were the most common causes of readmission, while DVT and dislocation were not included in the top ten diagnoses [9]. These seemingly conflicting results may be the result of differences in populations studied, data recording methodologies, inclusion criteria, and definitions of readmission itself.

Despite the lack of consensus as to the predominate causes of readmissions, much work has already been done in an attempt to prevent them. Hansen et al performed a systematic review of interventions to reduce 30-day readmission and identified 43 articles evaluating initiatives aimed at reducing readmission. Interventions included strategies for enhanced patient education, discharge planning, and follow-up communication [10]. The fact that the authors were unable to identify an intervention that consistently reduced readmission risk emphasizes the need for further research on the topic. Our financial analysis demonstrates that unplanned readmissions have a significant negative impact on THA profit, providing further incentive for such research as well as process changes aimed at preventing readmissions. The elimination of payment for unplanned readmissions would greatly expand that incentive. Of note, our investigation identified a substantial number of patients with planned readmission within 30-days of THA for reasons such as inpatient rehabilitation and skilled nursing care. Future reimbursement programs, quality improvement initiatives, and research studies should thus make rigorous efforts to distinguish between planned and unplanned readmissions.

One limitation of this study is its reliance on administrative data, which may result in underestimation of morbidity rates if complications are not coded properly or do not require hospitalization [11].

Table 5
Economic analysis with hypothetical CMS policy extension revoking reimbursement for THA readmissions.

	Avg Readmission Visit in Current System	Hypothetical Readmission Without Reimbursement	Avg Difference With & Without Reimbursement	Avg THA Episode in Current System	Hypothetical Avg THA Episode Without Reimbursement for Readmissions	Avg Difference Per Episode With & Without Reimbursement for Readmissions
Revenue	$10,840	$0	$10,840 ($P < 0.001$)	$21,613	$21,285	$328 ($P = 0.018$)
Cost	$11,494	$11,494	$0 ($P = 1.000$)	$17,636	$17,636	$0 ($P = 1.000$)
Profit	$227	−$11,494	$11,721 ($P < 0.001$)	$2,828	$2,457	$371 ($P = 0.051$)

Profit values do not exactly equal revenue less cost because these are median observed values from the study sample, not calculated figures.

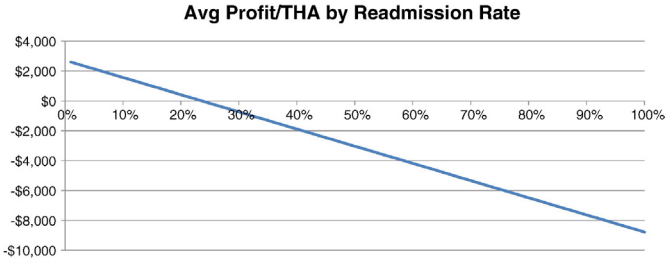

Fig. 1. Scatterplot depicting break-even analysis for readmission rate based on profits from the initial visit and from hypothetical readmission(s) without reimbursement. The X-intercept represents the break-even point, which occurs at a readmission rate of 23.6%.

The most likely negative impact on this study is potential inaccuracy in the rates of specific diagnoses associated with readmissions, which would be expected if ICD-9 codes were recorded inaccurately or inconsistently. Future research into the causes of readmissions relying solely on clinical data will be helpful in verifying our results. Still, our primary outcomes of readmission and cost should be largely immune to subjectivity in the coding process. A second limitation is the use of data from a single institution. While the hospital system under review is large and offers most of the care for the local community, it is possible that some patients presented to outside facilities for postoperative readmission; these readmissions would not have been captured in our results.

In conclusion, unplanned readmissions have become a prime target for cost cutting as the US strives to reign in health care expenditures. While current policies are limited to Medicare reimbursements for a select few conditions, financial penalties for elevated readmission rates are likely to become more widespread as additional disease states are added to the list and as private payers follow suit [1]. Demand for total hip arthroplasty, already at record-high levels, is expected to grow significantly in the coming years which may position the procedure squarely in the crosshairs of cost-cutting initiatives. If Medicare stops reimbursing for THA readmissions altogether and if our findings are generalizable to hospitals across the country, hospitals will begin sustaining a substantial net loss for each readmitted patient. In order to achieve quality improvement and to remain financially viable in this increasingly demanding reimbursement environment, it is critical for hospitals to perform similar analyses so that they can identify the risk factors for unplanned readmissions most relevant to their particular population and invest in programs to address them.

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References

1. MedPAC. Report to the Congress: promoting greater efficiency in Medicare. Available at: http://www.medpac.gov/chapters/jun07_ch05.pdf; 2007. [Accessed August 17, 2012].
2. The Patient Protection and Affordable Care Act, P.L. 111–148, 23 March 2010.
3. Centers for Medicare & Medicaid Services. Readmissions reduction program. Available at: http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html. [Accessed August 17, 2012].
4. Thomson Reuters. Preparing for readmission payment reductions: know your risk and opportunities. Available at: http://thomsonreuters.com/content/healthcare/pdf/collateral/assess_baseline_on_readmissions; 2010. [Accessed August 17, 2012].
5. Agency for Healthcare Research and Quality, Rockville, MD. HCUPnet: a tool for identifying, tracking, and analyzing national hospital statistics. Available at: http://hcupnet.ahrq.gov/. [Accessed August 17, 2012].
6. Cram P, Lu X, Kaboli PJ, et al. Clinical characteristics and outcomes of Medicare patients undergoing total hip arthroplasty, 1991–2008. JAMA 2011;305:1560.
7. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780.
8. Cullen C, Johnson DS, Cook G. Re-admission rates within 28 days of total hip replacement. Ann R Coll Surg Engl 2006;88:475.
9. Vorhies JS, Wang Y, Herndon J, et al. Readmission and length of stay after total hip arthroplasty in a national Medicare sample. J Arthroplasty 2011;26:119.
10. Hansen LO, Young RS, Hinami K, et al. Interventions to reduce 30-day rehospitalization: a systematic review. Ann Intern Med 2011;155:520.
11. Bozic KJ, Chiu VW, Takemoto SK, et al. The validity of using administrative claims data in total joint arthroplasty outcomes research. J Arthroplasty 2010;25:58.

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Health Policy and Economics

Incidence, Risk Factors, and Costs for Hospital Returns After Total Joint Arthroplasties

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ABSTRACT

Background: Unplanned hospital returns after total joint arthroplasty (TJA) reduce any cost savings in a bundled reimbursement model. We examine the incidence, risk factors, and costs for unplanned emergency department (ED) visits and readmissions within 30 days of index TJA.
Methods: We retrospectively reviewed a consecutive series of 655 TJAs (382 total knee arthroplasty and 273 total hip arthroplasty) performed between April 2014 and March 2015. Preoperative diagnosis was osteoarthritis of the hip or knee (97%) or avascular necrosis of the hip (3%). Hospital costs were recorded for each ED visit and readmission episode.
Results: Of the 655 TJAs reviewed, 55 (8.4%) returned to the hospital. Of these hospital returns, 35 patients (5.3%) returned for a total of 36 unplanned ED visits whereas the remaining 20 patients (3.1%) presented 22 readmissions within 30 days of index TJA. The 2 most common reasons for unplanned ED visits were postoperative pain/swelling (36%) and medication-related side effects (22%). Avascular necrosis of the hip was a significant risk factor for an unplanned ED visit (7.27 odds ratio [OR], 95% confidence interval [CI] 1.67-31.61, $P = .008$). Multiple logistic regression analysis revealed the following risk factors for readmission: body mass index (1.10 OR, 95% CI 1.02-1.78, $P = .013$), comorbidity >2 (2.07 OR, 95% CI 1.06-6.95, $P = .037$), and prior total knee arthroplasty (2.61 OR, 95% CI 1.01-6.72, $P = .047$). Ambulating on the day of surgery trended toward a lower risk for readmission (0.13 OR, 95% CI 0.02-1.10, $P = .061$). The 2 most common reasons for readmission were ileus (23%) and cellulitis (18%). The total cost associated with unplanned ED visits were $15,427 whereas costs of readmissions totaled $142,654.
Conclusion: Unplanned ED visits and readmissions in the forthcoming bundled payments reimbursement model will reduce cost savings from rapid recovery protocols for TJA. Identifying and mitigating preventable causes of unplanned visits and readmissions will be critical to improving care and controlling costs.

Over one million total joint arthroplasties (TJAs), at a cost of US $18.75 billion, were performed in the United States in 2012 [1]. Medicare patients were one of the largest recipients of TJA, making these procedures one of the largest procedural costs for Medicare [2]. The rising cost of health care has led to a shift in Medicare reimbursement policy, away from the traditional fee-for-service payments to reimbursements that are linked to the quality of care [3,4].

The Affordable Care Act of 2012 linked reimbursements to the quality of care by establishing the Hospital Readmissions Reduction Program [5]. Through this program, hospitals are financially penalized for select readmissions. Originally limited to only a few procedures, it was revised in 2014 to include TJA (hip and knee). Several studies have evaluated readmission causes and risk factors after TJA [6-11], yet little exists regarding economic implications of readmissions. Previous reports that have described costs for unplanned readmissions have been limited to total hip arthroplasties (THAs) [6] or to Medicare patients [12,13].

The Comprehensive Care for Joint Replacement (CJR) model expands on previous health policy, linking reimbursements to

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quality of care. Medicare's goal is to link 30% of all fee-for-service payments to alternative payment models by 2016 and 50% by 2018 [5]. Accordingly, the CJR model leverages bundled payments to require hospitals, physicians, and postacute care facilities to coordinate the care of patients for the duration of recovery (ie, 90 days post discharge) [4]. Under bundled payments, all services related to the episode of care fall under a single fixed global fee and incremental financial penalties of up to 20% are assessed for complication rates greater than national averages [14].

Expanding the onus of financial responsibility to include any complication related to the index procedure will affect approximately 800 hospitals participating in CJR [4]. Unplanned emergency department (ED) visits, regardless of readmission status, can also adversely impact cost savings from rapid recovery protocols promoting an early discharge. It has been well documented that rapid recovery protocols shorten length of stay (LOS) without consequently increasing readmissions [15-17]. However, literature is scarce on the impact of early discharge protocols on ED visits that do not result in readmission. A recent study reported excessive returns to the ED (12.8% of patients) using early discharge protocols for total knee arthroplasties (TKAs) [18]. The study did not evaluate the financial impact of such returns.

In this era of shorter LOS and bundled reimbursement models for TJAs, identifying and mitigating preventable causes for unplanned ED visits and readmissions will be critical to improving care and controlling costs. The purpose of our study was to examine the incidence and risk factors for unplanned ED visits that do not result in readmission after both THA and TKAs. Furthermore, we expand on the current body of literature by examining hospital costs for both ED visits and readmissions for all patients undergoing TJAs.

Methods

Institutional review board approval was obtained. A retrospective chart review was performed for a consecutive series of unilateral primary elective TJAs performed between April 2014 and March 2015. A total of 655 TJA (382 TKA and 273 THA) were included in this study. All procedures were performed at a single institution by one of 2 experienced surgeons, performing >450 TJA per year. Each surgeon performed approximately half of the procedures. All procedures, regardless of LOS, were performed using our early discharge protocols, which have been described in a previous report [15].

Hospital costs were obtained using an institutional cost accounting system and were retrieved using the specific encounter number for the return event (ED visit or readmission). Hospital costs were calculated using Time-Driven Activity-Based Costing methodology, with each department providing time and supply estimates for every charge code the hospital bills to the patient. Event-specific hospital costs were categorized into variable (eg, medicine, supplies) or fixed (eg, salaried labor, buildings, equipment) costs. Variable costs were defined as costs that change with output and could be saved in the short term by discontinuing service [19]. Fixed costs were defined as costs not saved in the short term by discontinuing service.

Study Population

Patient characteristics are summarized in Table 1. Sixty percent of THA procedures and 18% of TKA procedures were performed under spinal anesthesia. Seventy-one percent of the THAs were performed via the direct anterior approach, with 29% being performed via the posterolateral approach. All TKAs were performed via a standard medial patellar arthrotomy. Mean LOS was 2.2 days (2.0 days for THA and 2.3 days for TKA). Overall, 27% of patients had a 1-day LOS, 44% of patients had a 2-day LOS, and 29% had a LOS $\geq$3 days. Seventy-seven percent of patients were discharged home and 23% were transferred to a subacute rehabilitation center.

Table 1
Patient Demographics.

Variable	Mean%
N	655
Age (y)	65.6 ± 9.1
Body mass index (kg/m^2)	30.9 ± 5.9
Gender	
Male	41%
Female	59%
American Society of Anesthesiologists score	
1	2%
2	61%
3	35%
4	2%
Comorbidity	
Osteoarthritis of hip or knee	97%
Avascular necrosis of hip	3%
Hypertension	66%
Hyperlipidemia	55%
Diabetes	16%
Coronary artery disease	11%
Atrial fibrillation	10%
Chronic obstructive pulmonary disease	7%
Congestive heart failure	2%
Past medical history	
Prior total knee arthroplasty	17%
Prior total hip arthroplasty	12%
History of cerebrovascular accidents	6%
History of deep vein thrombosis/pulmonary embolism	5%
History of myocardial infarct	4%

Study Outcomes

We examined incidence, risk factors, and costs for unplanned ED visits and readmissions after TJAs. Unplanned ED visits and readmissions were defined as any unplanned patient visit to the ED or readmission within 30 days of index admission. The primary diagnosis documented in the patient chart at the time of the unplanned ED visit or readmission was considered to be the primary reason for the return event.

Statistical Analysis

Logistic regression was employed to examine the association between patient demographics, clinical characteristics, and unplanned ED visits and readmissions. Odds ratios, 95% confidence intervals, and *P* values are presented. Pearson's chi-squared test and 2-sided Fisher's exact test were used to analyze the differences in categorical variables between the readmission and no readmission cohorts. One way analysis of variance was used to explore the relationship among continuous variables such as age, body mass index (BMI), and cost. All analyses were performed using IBM SPSS Statistics version 23 (Armonk, NY). A *P* value less than or equal to .05 was treated as statistically significant.

Results

Fifty-five patients returned to the hospital within 30 days of index TJA, with 20 being readmitted. Thirty-five patients (5.3%) accounted for 36 unplanned ED visits without readmission, with 20 patients (3.1%) accounting for 22 readmissions. Patients were readmitted from the ED (n = 16), directly readmitted to the floor (n = 3) or readmitted to an outside health care facility (n = 1).

For the 35 unplanned ED visit patients, postoperative pain or swelling (36%) was the most common diagnosis (Table 2). Medication-related side effects (22%) were the second most common cause for return, with two-thirds of the visits resulting from opioid medications side effects and one-third due to anticoagulation-coagulopathy side effects. Medical complications (11%) included urinary retention, urinary tract infection, acute bronchitis, and flu-like symptoms. Logistic regression revealed that patients with a history of avascular necrosis of the hip were more likely to have an unplanned ED visit (7.27 odds ratio, 95% confidence interval 1.67-31.61, $P = .008$). We subcategorized patients into 2 groups (1-day vs 2-day LOS groups) and found no differences in ED return visits (8.0% 1-day vs 4.6% 2-day LOS, $P = .124$). There was, however, a trend for patients in the 1-day LOS group to more often return to the ED complaining of pain and/or swelling (4.0% 1-day vs 1.4% 2-day LOS, $P = .075$).

For the 20 patients who were readmitted within 30 days, postoperative ileus (23%) and wound infections (18%) were the 2 most common reasons for readmission (Table 3). Of the 3 patients presenting with wound infections, 1 was conservatively managed whereas the other 2 required a total of 3 operating room surgical-site debridement procedures. Patient demographics and perioperative factors for patients readmitted within 30 days of surgery were compared to those not readmitted (Table 4). Mean age was similar between groups. However, patients in the readmitted group, presented with higher BMIs. Readmitted patients demonstrated a greater acute decrease in hemoglobin levels after surgery, as measured on postoperative day 1. Mean LOS, operating room time, and intraoperative blood loss were comparable between groups. Multiple logistic regression identified BMI, >2 comorbidity, and previous TKA as risk factors for readmissions within 30 days of index TJA (Table 5). Ambulating on the day of surgery trended toward a lower risk for 30-day readmissions.

Institutional cost accounting systems documented hospital costs by return event, unplanned ED visit, or readmission. The total hospital cost for unplanned ED visits were $15,427 or $429 on average per return visit (Table 6). The largest aggregate costs were incurred for patients presenting with pain and/or swelling ($5381) and medical complications ($2406). Hospital costs for readmissions totaled $142,654 or $6484 per readmission (Table 7). The largest collective costs were incurred with treatments for wound infections ($33,011) and postoperative ileus ($18,517). Hospital costs for all ED visits and readmissions totaled $158,080.

Discussion

The 2016 introduction of the CJR payments model will shift the burden of cost from Medicare to health systems. In addition to assuming financially responsibility for costs associated with ED visits and readmissions, hospitals will also be penalized for quality of care below the national average [14]. The expansion of financial responsibility to all complications after TJAs necessitates an evaluation of ED visits that do not result in readmission. Literature is scarce on this, with only one study reporting that 12.8% of patients undergoing TKA procedures returned to the ED and did not require readmission [18]. The study did not assess costs for such return visits. Our study expands on the current literature by examining reasons, risk factors, and costs for unplanned ED visits and readmissions after both THA and TKA procedures.

We found that 5.3% of patients returned to the ED within 30 days of index TJA. The most common reasons for return were postoperative pain and/or swelling (36%) or medication-related side effects (22%). Our findings are similar to those of Rossman et al [18], who report that postoperative pain and/or swelling (25%) was the most common reason for return after TKA surgery. As shorter lengths of stay become the standard of care for patients undergoing TJAs, overviewing the different stages of recovery in the preoperative education class is of utmost importance to reassure patients. A clear line of communication to the surgical care team after surgery may help reduce ED overutilization. Our study found that 1-day LOS patients were more likely to present to the ED complaining of pain and/or swelling, highlighting the need for optimizing pain control, preoperative education, and communication in this subgroup of early discharge patients. Postoperative pain and swelling can be treated by a member of the surgical care team in an outpatient setting, saving costly ED resources. Based on our incidence of return visits relating to postoperative pain and/or swelling, we extrapolate an annual cost of approximately $16,500 per year to our institution.

Alcohol-induced avascular necrosis (AVN) of the hip was a risk factor for unplanned ED visits within 30 days of index THA. Patients with AVN of the hip were more likely to present to the ED complaining of pain and/or swelling, indicating the need for additional resources to be directed at these high-risk patients, all of whom had AVN as a result of alcohol abuse. At our institution, we are piloting

Table 2
Reasons for Unplanned Emergency Department Visits Within 30-D of Surgery That Did Not Result in Readmission.

Diagnosis	36 Events	%
Pain and/or swelling	13	36
Medication related	8	22
Medical complications	4	11
Syncope	4	11
Noncardiac chest pain	2	6
Cardiac chest pain	1	3
Deep vein thrombosis	1	3
Fall	1	3
Hematoma	1	3
Hypotension	1	3

There were 35 patients with 36 unplanned emergency department visits.

Table 3
Reasons for Readmission Within 30-D of Surgery.

Diagnosis	22 Events	%
Postoperative ileus	5	23
Wound infection	4	18
Pulmonary embolism	2	9
Sepsis	2	9
Altered mental status	1	5
Atrial fibrillation	1	5
Cholecystectomy	1	5
Hematoma	1	5
Hyperglycemia	1	5
Paresthesia	1	5
Prosthetic joint infection	1	5
Syncope	1	5
Urinary tract infection	1	5

There were 20 patients with 22 readmission events.

Table 4
Comparison of Patient Demographics and Perioperative Variables Between Groups.

Variable	Readmission	No Readmission	*P* Value
Patient demographics			
Age (y)	68.5 ± 8.8	65.6 ± 9.1	.153
Body mass index (kg/m^2)	34.2 ± 6.2	30.8 ± 5.8	.012
Perioperative variables			
Length of stay (d)	2.9 ± 1.9	2.4 ± 1.3	.093
Operating room time (min)	87.5 ± 12.2	82.4 ± 18.2	.216
Intraoperative blood loss (mL)	257.5 ± 137.9	243.5 ± 190.4	.744
Δ Hemoglobin after surgery[a]	−3.9 ± 2.3	−2.6 ± 1.7	.025

[a] As measured on postoperative day 1.

Table 5
Multiple Logistic Regression Identifying Risk Factors for Readmissions Within 30-D of Surgery.

Variable	Odds Ratio	95% CI	*P* Value
BMI	1.10	1.02-1.78	.013
Comorbidity >2	2.72	1.06-6.95	.037
Prior total knee arthroplasty	2.61	1.01-6.72	.047
Ambulating on the day of surgery	0.13	0.02-1.10	.061

CI, confidence interval; BMI, body mass index.

strategies such as having our nurse navigators call these higher risk patients on their first and/or second day after surgery, which is when patients tend to have the most concerns at home.

Medication-related side effects were a common reason for ED visits (22%) and readmissions (32%), with narcotic-related side effects (constipation, nausea, and vomiting) accounting for the vast majority of these returns. The use of multimodal pain management regimens can decrease the need for opioid pain medications, preventing return visits related to their adverse effects. Preoperative education focusing on hydration, stool softeners, and early ambulation may further decrease opioid-related postoperative ileus. Our institution is also reexamining our standard fasting policy (nil-by-mouth from midnight) based on a Cochrane review that reported shortened time to passage of flatus for patients receiving preoperative carbohydrate treatments when compared with fasting or placebo [20]. Regarding anticoagulation-related side effects, aspirin is a substitute for warfarin or low-molecular-weight heparin for thromboembolism prophylaxis following TJAs [21]. The use of aspirin in clinically appropriate patients may decrease return visits related to anticoagulation side effects.

With regard to readmissions, we demonstrate that 3.1% of patients were readmitted within 30 days of discharge, which is comparable to literature-reported rates of 2.2%-6.5% [6-11]. Pugely et al [7], for example, analyzed American College of Surgeons National Surgical Quality Improvement Program data and report readmission rates within 30 days of index surgery to be 4.6% and 4.2% for TKA and THA, respectively. The common reasons for readmission in our study were postoperative ileus (23%) and wound infections (18%). Other studies have also observed similar reasons for readmissions, although the exact percentages vary [6,8,9]. Zmistowski et al [8] reported that infection (35.9%) was the most common reason for readmission within 30 days, while gastrointestinal (4.9%)-related causes were less common. Avram et al [9] demonstrated that septic complications related to the joint (23.2%) and cardiovascular events (16.8%) were the common reasons for readmission in their patient population. Geographical variations in patient demographics may account for the variations between studies for the reasons for readmissions after surgery.

Risk factors for readmissions within 30 days of surgery were increased BMI status and >2 comorbidities. Our findings are consistent with the existing literature [7-10]. Saucedo et al [10], for example, found that BMI ≥30 increased the risk for 30-day readmissions after TKA. Similarly, we demonstrate that patients with a BMI ≥30 were at a 2.65 times greater risk for readmissions ($P = .062$). The risk for readmission was even greater (3.73 odds ratio, $P = .078$) in our morbidly obese (BMI ≥40) patients. In contrast to a report that found no association between number of comorbidity and 30-day readmissions [9], we demonstrate that patients with >2 comorbidities were at a greater risk for readmission within 30 days of TJA surgery. A report using National Surgical Quality Improvement Program data found that elevated American Society of Anesthesiologists (ASA) class increased the risk for readmissions after TJAs [7]. We, however, demonstrate no association between ASA rating and readmissions. Our findings are consistent with another study that reviewed 4288 TJAs and found no association between ASA rating and readmissions [9]. Readmission risk should be assessed and mitigated before admission, especially in those with increased morbidity.

Table 6
Hospital Costs for Unplanned Emergency Department Visits That Did Not Result in Readmission.

Diagnosis	35 Events	Variable Cost	Fixed Cost	Total Cost
Pain or swelling	13	$1743	$3638	$5381
Medical complications	4	$845	$1561	$2406
Drug related	8	$680	$1601	$2281
Syncope	4	$479	$1103	$1582
Noncardiac chest pain	2	$333	$652	$985
Deep vein thrombosis	1	$226	$449	$675
Cardiac chest pain	1	$188	$415	$603
Fall	1	$157	$415	$572
Hematoma	1	$182	$333	$515
Hypotension	1	$140	$286	$426
Total	36	$4972	$10,455	$15,427

Table 7
Hospital Costs for Readmissions Within 30-D of Surgery.

Diagnosis	22 Events	Variable Cost	Fixed Cost	Total Cost
Wound infection	4	$12,517	$20,494	$33,011
Postoperative ileus	5	$6721	$11,796	$18,517
Prosthetic joint infection	1	$7682	$8167	$15,849
Atrial fibrillation	1	$6130	$9394	$15,524
Sepsis	2	$4685	$8058	$12,743
Paresthesia	1	$4473	$7190	$11,663
Cholecystectomy	1	$3025	$4205	$7230
Hematoma	1	$2650	$4565	$7215
Hyperglycemia	1	$2862	$4196	$7058
Pulmonary embolism	2	$1974	$3572	$5546
Altered mental status	1	$1599	$2850	$4449
Syncope	1	$943	$1763	$2706
Urinary tract infection	1	$387	$755	$1142
Total	22	$55,647	$87,006	$142,654

The findings of this study have important financial implications for health care organizations. We demonstrate that in the new reimbursement model, our hospital would incur a loss of $158,080 for this study population (n = 655) alone. To further illustrate the financial impact of these ED visits and readmissions to our institution, we used the reasons, incidence, and costs for our study population and extrapolated the financial impact based on our TJA volume (>2000 TJA) in fiscal year 2015. With ED visits and readmissions rates of 5.3% and 3.1%, we can postulate that our health system would have incurred a loss of $47,270 for ED visits and $437,108 for readmissions, a net loss of $484,377 in fiscal year 2015. These findings highlight the importance of reducing unplanned ED visits and readmissions in a cost-sensitive health care environment that is increasingly focusing on quality-based reimbursement models.

Our study was limited in that we only examined ED visits and readmissions within 30 days of surgery. This short time frame could underestimate our ED visits, readmissions, and costs for complications related to the index procedure as compared to a 90-day follow-up. Zmistowski et al [8] examined readmissions in the 30-day and 90-day follow-up periods and found that 3.1% of patients were readmitted within 30 days of index surgery whereas 5.3% were readmitted within 90 days. They observed that the reasons for readmissions between 30 and 90 days were stiffness (55%), medical conditions (35%), and surgical-site infections (10%). While we did not track our 90-day readmissions for medical complications, we found that 3 patients in our study were readmitted during the 30- to 90-day postoperative period for surgical-site complications, 2 for stiffness requiring manipulations under anesthesia and 1 for a wound infection requiring debridement. Another limitation of our

study was that 2 high-volume surgeons were included in this retrospective review, which may have impacted the results of our study. Reports have shown that high-volume surgeons have fewer readmissions, shorter LOS, and more discharges to home [22,23]. Our study was also limited in that despite performing a detailed chart review and history at each postoperative visit, is it possible that some ED visits or readmissions to other institutions may not have been discovered. We did elicit one readmission episode to an outside facility from the patient chart and included it in our analysis.

Conclusion

Unplanned ED visits and readmissions add to the cost of TJA. The forthcoming bundled payments reimbursement model will reduce any cost savings from rapid recovery protocols for TJA. Identifying and mitigating preventable causes for unplanned visits and readmissions are critical to improving care and controlling costs in TJAs. Further study should focus on effectiveness of strategies aimed at reducing ED visits and readmissions.

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References

1. Centers for Disease Control and Prevention. Cost of hospital discharges with common hospital operating room procedures in nonfederal community hospitals, by age and selected principle procedure: United States, selected years 2000-2012. http://www.cdc.gov/nchs/data/hus/hus14.pdf#105. [accessed 25.02.16].
2. Bozic KJ, Rubash HE, Sculco TP, et al. An analysis of medicare payment policy for total joint arthroplasty. J Arthroplasty 2008;23:133.
3. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89-A(4):780.
4. Centers for Medicare & Medicaid Services. Comprehensive care for joint replacement model. https://innovation.cms.gov/initiatives/cjr. [accessed 25.02.16].
5. Centers for Medicare & Medicaid Services. Readmissions reduction program. https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html/. [accessed 7.03.16].
6. Clement RC, Derman PB, Graham DS, et al. Risk factors, causes, and the economic implications of unplanned readmissions following total hip arthroplasty. J Arthroplasty 2013;28(8):7.
7. Pugely AJ, Callaghan JJ, Martin CT, et al. Incidence of and risk factors for 30-day readmission following elective primary total joint arthroplasty: analysis from the acs-nsqip. J Arthroplasty 2013;28(9):1499.
8. Zmistowski B, Restrepo C, Hess J, et al. Unplanned readmission after total joint arthroplasty: rates, reasons, and risk factors. J Bone Joint Surg Am 2013;95-A(20):1869.
9. Avram V, Petruccelli D, Winemaker M, et al. Total joint arthroplasty readmission rates and reasons for 30-day hospital readmission. J Arthroplasty 2014;29(3):465.
10. Saucedo JM, Marecek GS, Wanke TR, et al. Understanding readmission after primary total hip and knee arthroplasty: who's at risk? J Arthroplasty 2014;29(2):256.
11. Schairer WW, Sing DC, Vail TP, et al. Causes and frequency of unplanned hospital readmission after total hip arthroplasty. Clin Orthop Relat Res 2014;472(2):464.
12. Kiridly DN, Karkenny AJ, Hutzler LH, et al. The effect of severity of disease on cost burden of 30-day readmissions following total joint arthroplasty (TJA). J Arthroplasty 2014;29(8):1545.
13. Bosco 3rd JA, Karkenny AJ, Hutzler LH, et al. Cost burden of 30-day readmissions following Medicare total hip and knee arthroplasty. J Arthroplasty 2014;29(5):903.
14. Centers for Medicare & Medicaid Services. Comprehensive care for joint replacement (CJR) model: provider and technical fact sheet. https://innovation.cms.gov/Files/fact-sheet/cjr-providerfs-finalrule.pdf. [accessed 25.02.16].
15. Sibia US, Waite KA, Callanan MA, et al. Do shorter lengths of stay increase readmissions after total joint replacements? Arthroplasty Today 2016. http://dx.doi.org/10.1016/j.artd.2016.05.001.
16. Stambough JB, Nunley RM, Curry MC, et al. Rapid recovery protocols for primary total hip arthroplasty can safely reduce length of stay without increasing readmissions. J Arthroplasty 2015;30(4):521.
17. Husted H, Otte KS, Kristensen BB, et al. Readmissions after fast-track hip and knee arthroplasty. Arch Orthop Trauma Surg 2010;130(9):1185.
18. Rossman SR, Reb CW, Danowski RM, et al. Selective early hospital discharge does not increase readmission but unnecessary return to the emergency department is excessive across groups after primary total knee arthroplasty. J Arthroplasty 2016;31:1175.
19. Roberts RR, Frutos PW, Ciavarella GG, et al. Distribution of variable vs fixed costs of hospital care. JAMA 1999;281(7):644.
20. Smith MD, McCall J, Plank L, et al. Preoperative carbohydrate treatment for enhancing recovery after elective surgery. Cochrane Database Syst Rev 2014;(8):CD009161.
21. Schousboe JT, Brown GA. Cost-effectiveness of low-molecular-weight heparin compared with aspirin for prophylaxis against venous thromboembolism after total joint arthroplasty. J Bone Joint Surg Am 2013;95(14):1256.
22. Bozic KJ, Maselli J, Pekow PS, et al. The influence of procedure volumes and standardization of care on quality and efficiency in total joint replacement surgery. J Bone Joint Surg Am 2010;92:2643.
23. Styron JF, Koroukian SM, Klika AK, et al. Patient vs provider characteristics impacting hospital lengths of stay after total knee or hip arthroplasty. J Arthroplasty 2011;26:1418.

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Health Policy & Economics

Reducing Length of Stay Does Not Increase Emergency Room Visits or Readmissions in Patients Undergoing Primary Hip and Knee Arthroplasties

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ABSTRACT

Background: Total hip and total knee arthroplasty (total joint arthroplasty [TJA]) are 2 of the most common elective surgeries. Identifying which patients are at highest risk for emergency room (ER) visits or readmissions within 90 days of surgery and the reasons for return are crucial to formulate ways to decrease these visits and improve patient outcomes.

Methods: This is a retrospective review of a consecutive series of 7466 unilateral primary TJA performed from July 2013 to June 2017; any patients who had an ER visit or readmission in the first 90 days after surgery were identified, and a detailed chart review was performed. Patients discharged home or to rehab were analyzed separately.

Results: Three hundred thirty-six (4.5%) patients had 380 ER visits and 250 (3.3%) patients had 291 readmissions in the first 90 days after TJA. Patients returning to the ER were equivalent to those who did not. Patients who went to a rehab facility on discharge were significantly more likely to be readmitted ($P = .000$). Patients who were readmitted had a higher American Society of Anesthesiologists score ($P = .000$). Length of stay decreased over the study period from 2.66 days to 1.63 days, while the number of unplanned interventions remained steady. Pain and swelling was the most common reason for return for ER visits (33.2%) and readmissions (14.1%).

Conclusion: The overall number of unplanned interventions after TJA in this population was low and remained consistent over time despite decreasing length of stay. Patients who went to rehab were more likely to experience readmission. The majority of unplanned interventions occurred in the first 4 weeks after surgery.

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are 2 of the most common surgical procedures performed in the United States, with the number of procedures performed increasing each year. In 2015, TKA and hip arthroplasty, both total and partial, were the 2 most common operations performed during inpatient hospital stay with 236 TKA and 167 hip arthroplasties performed per 100,000 stays [1]. By the year 2030, the demand for primary TKA is projected to be 3.48 million and for primary THA is 572,000 [2]. Any surgical procedure comes with an inherent risk of complications and joint arthroplasty is no exception. Owing to the large numbers of THA and TKA performed each year, even a modest occurrence of complications requiring readmission or emergency room (ER) visits will have a significant impact on the health-care system. With the advent of the Affordable Care Act and the Centers for Medicare and Medicaid Services commitment to decrease health-care costs, there is a move toward alternative payment methods including bundled payment models. While this is not yet mandatory, joint arthroplasty is one of the most common procedures to utilize a bundled payment model, which will include all costs associated with a procedure for the first 90 days, including

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readmission and ER visits [3]. Other payers are also linking quality of care to insurance payments with readmissions being a common measure of quality [4].

Unplanned interventions, ER visits, or readmissions in the first 90 days after surgery significantly add to the cost of patient care and are associated with suboptimal patient outcomes [3]. Identifying which patients are at highest risk for unplanned interventions and the causes of return are crucial to formulate ways to decrease unplanned interventions, thereby improving patient outcomes. A number of factors have been hypothesized to increase the risk and the rate of unplanned intervention in TKA and THA patients including length of stay (LOS), discharge disposition, and patient factors including comorbidities [4–8].

There have been many studies examining readmission after total joint arthroplasty (TJA) with somewhat varied conclusions [7,9–11] though few studies have examined ER visits either independently or concurrently with readmissions [12–14]. We aim with this study to add to the current body of literature by examining both readmissions and ER visits experienced by patients after TJA from one high-volume institution. We seek to identify the timing of unplanned interventions and the reasons for the visits to identify necessary areas of improvement to care pathways. We also seek to evaluate whether decreased hospital length of stay increases the rate of unplanned interventions.

Methods

The institutional review board approval was obtained. A retrospective chart review was performed for a consecutive series of all primary unilateral TJA performed at this institution between July 2013 and June 2017. Surgeries were performed by one of 11 board-certified orthopedic surgeons. Basic demographic data including age, sex, and body mass index, discharge disposition, and LOS were recorded for the entire population. American Society of Anesthesiologists (ASA) score was used to quantify preoperative health status [15]. All patients who returned to this institution via ER or readmission were identified, and a detailed chart review was performed.

Perioperative Protocol

All patients were subject to the same perioperative protocols in a coordinated Joint Replacement Center Program. Throughout the study, all patients received preoperative education consisting of written materials and a class, preoperative medical evaluation, and preoperative strengthening via a home exercise program or formal physical therapy. All patients underwent a standard decolonization protocol with intranasal mupirocin ointment twice daily for 3 days before surgery and chlorhexidine body wash for 3 days before surgery. All patients also received parenteral antibiotics per the Surgical Care Improvement Project guidelines. Before the implementation of an enhanced recovery after surgery (ERAS) protocol, patients received either general anesthesia with a femoral nerve block for TKA or spinal anesthesia and pain control via infiltrative anesthetic and patient-controlled analgesia transitioning to oral pain medication on postoperative day one. In this time period, warfarin was the primary pharmacologic prophylaxis for deep vein thrombosis (DVT) along with mechanical prophylaxis, and patients were typically mobilized in the morning of postoperative day one. Patients received group physical therapy twice daily while in the hospital and were discharged either to a skilled nursing facility (SNF) or to home health or outpatient physical therapy 3 times a week. After the implementation of the ERAS protocol in April 2015, patients received regional anesthesia wherever appropriate; femoral nerve blocks and patient-controlled analgesia were discontinued, and multimodal pain management regimens were initiated with celecoxib, acetaminophen, pregabalin and short-acting opioids. Patients also received aggressive intraoperative fluid management, tranexamic acid utilization, and day of surgery ambulation. Aspirin 325 mg bid became the primary pharmacologic DVT prophylaxis, using warfarin in selected high-risk patients. Postdischarge physical therapy protocols did not change.

Study Population

A total of 7466 patients were included in the study. All TKAs (4720 patients) were performed via a standard medial patellar arthrotomy, posterior approach THA (924 patients) in the lateral decubitus position and anterior approach THA (1822 patients) using a modern fracture table. There were a total of 671 unplanned interventions in the first 90 days postoperatively by 586 patients, 7.8% of the study group. There were 380 visits were made to the ER by 336 (4.5%) patients and 250 (3.3%) patients experienced 291 readmission events.

Study Outcomes

We examined incidence and risk factors of patients who experienced an unplanned intervention, either ER visit or readmission in the first 90 days after surgery. The entire group was analyzed, and then patients discharged home or to an SNF were analyzed separately. Unplanned ER visits or readmissions were defined as any return to the hospital within 90 days of the index admission. The primary diagnosis documented in the patient chart was considered to be the reason for the return visit.

Statistical Analysis

Pearson's chi-squared tests were used to analyze the differences in categorical variables between groups. A series of t tests and analysis of variance were used to analyze continuous variables. A P value less than or equal to .05 was treated as statistically significant. All analyses were performed using SPSS (SPSS 24.0, IBM Inc., Somers, NY).

Results

A total of 7466 patients were included in the study. Of the total sample, 5835 (78.2%) patients were discharged home and 1631 (21.8%) patients discharge to an SNF. In the group of patients that discharged home 264 (4.5%), patients experienced 303 ER visits and 169 (2.9%) patients experienced 194 readmissions. Of the patients who discharged to an SNF, 72 (4.4%) patients experienced 77 ER visits and 81 (5.0%) patients experienced 97 readmissions. The percentage of patients experiencing an ER visit was not significantly different between patients discharged to home vs an SNF ($P = .827$) though the readmission rate was ($P < .000$). There was a 47.4% decrease in patients discharged to an SNF instead of home, from 29.3% in year 1 to 15.4% in year 4 ($P < .000$).

There was a significant decrease of 38.7% in overall LOS, from 2.66 days to 1.63 days over the course of the study ($P < .000$). Patients who discharged home also experienced a decrease in LOS, from 2.38 days to 1.35 days ($P < .000$). The decrease in LOS experienced by patients discharged to an SNF was minimal (3.23 to 3.13 days, $P = .574$). An ERAS protocol was implemented at this institution halfway through the study period. There was a 23.1% increase in the overall number of patients having joint arthroplasties during the study, from 1674 the first year to 2061 by the last year. The overall number of patients experiencing unplanned interventions was unaffected by decreasing LOS or implementation of

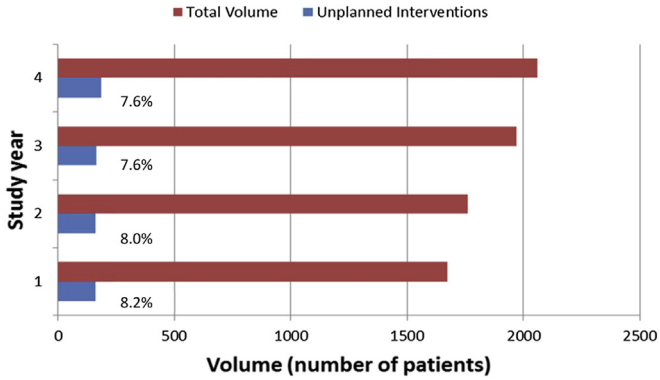

Fig. 1. Patient volume by study year.

ERAS protocols (Fig. 1) when examining the population as a whole, and this remained true when looking only at patients who were discharged home.

When examining the impact of patient variables on the risk of an ER visit for the entire population, none showed significance (Table 1). The only factor that approached significance was having a TKA (63.0% vs 67.6%, $P = .091$). Age (66.56 vs 65.92 years, $P = .288$), sex (59.2% vs 55.4% female, $P = .157$), and LOS (2.08 vs 2.17 days, $P = .262$) were all equivalent between those that returned to the ER and those that did not. Discharge to an SNF between the groups was also equivalent (21.8% vs 21.4%, $P = .877$). Table 2 compares only the patients who discharged home. In this cohort, the sex of patients became significant; 50.8% of patients returning to the ER were males compared with 44.4% of patients who did not ($P = .043$). The groups were comparable on all other measures.

Table 3 shows the impact of patient factors on the risk of readmission for the entire study population. Patients that were readmitted were older (66.45 vs 68.92 years, $P < .000$), were more likely to have an ASA score of 3 or 4 (41.3% vs 56.3%, $P < .000$), and were more likely to be male (40.7% vs 48.0%, $P = .021$). Of patients who were readmitted, a higher percentage were initially discharged to an SNF (21.4% vs 32.4%, $P = .000$). Patients who were readmitted had a longer length of stay compared with those who did not get readmitted (2.06 vs 2.67 days, $P = .000$). The percentage of patients having a TKA was equivalent between groups (63.2% vs 64.4%, $P = .694$). When looking only at the patients who discharged home, there were also significant differences (Table 4). Patients who were readmitted were still older (64.88 vs 66.77 years, $P = .020$), more likely to have an ASA score of 3 or 4 (36.6% vs 45.9%, $P = .022$), and more likely to be male (44.5% vs 53.3%, $P = .023$). These patients also had a longer initial length of stay (1.72 vs 1.95 days, $P = .015$).

The majority of unplanned interventions, both ER visits, and readmissions occurred within the first 4 weeks after surgery (Fig. 2). A total of 91% of ER visits and 83% of readmissions took place in the first 4 weeks, with 169 ER visits and 90 readmissions occurring in the first 5 days after discharge.

Table 5 compares the reasons for ER visits between patients who were discharged home and patients who were discharged to an SNF. The most common reason patients returned to the ER in both cohorts was postoperative pain and swelling (35.0% vs 26.0%, $P = .134$), though this was not significant between the groups. Other medical complications (12.2% vs 24.7%, $P = .006$) occurred in a significantly higher percentage of patients who were initially discharged to an SNF; this category included diagnoses such as pneumonia, anxiety, vertigo, and epistaxis. One other category approached significance between groups; a greater percentage of patients discharging to an SNF experienced an ER visit due to a fall (3.0% vs 7.8%, $P = .052$). The remainder of reasons for ER visits was equivalent between groups. There were 4 thromboembolic events (3 DVT and 1 pulmonary embolism) accounting for 1.1% of total visits to the ER.

Table 1
Patient Factors That Increase Risk of Emergency Room Visit for the Total Study Population.

	No ER Visit	ER Visit	Sig.
Age, y (mean ± SD)	66.56 ± 9.70	65.92 ± 10.73	.288
Sex			.157
Female (%)	59.2	55.4	
Body mass index, kg/m^2 (mean ± SD)	31.35 ± 6.23	31.52 ± 6.34	.633
ASA score 3 or 4 (%)	41.6	46.2	.116
Procedure time, min (mean ± SD)	82.99 ± 29.19	84.71 ± 21.38	.288
Total OR time, min (mean ± SD)	127.71 ± 24.71	128.90 ± 24.65	.387
Procedure type			.091[a]
THA (%)	37.0	32.4	
TKA (%)	63.0	67.6	
Discharge to SNF (%)	21.8	21.4	.877
Length of stay, d (mean ± SD)	2.08 ± 1.41	2.17 ± 1.46	.262
Length of stay, h (mean ± SD)	56.43 ± 33.66	58.79 ± 35.28	.209

ASA, American Society of Anesthesiologists; ER, emergency room; SD, standard deviation; SNF, skilled nursing facility; THA, total hip arthroplasty; TKA, total knee arthroplasty; OR, operating room.
[a] P approaches significance.

Table 2
Patient Factors That Increase Risk of Emergency Room Visit for Patients Discharged Home.

	No ER Visit	ER Visit	Sig.
Age, y (mean ± SD)	64.96 ± 9.24	64.38 ± 10.54	.377
Sex			**.043**
Female (%)	55.6	49.2	
Body mass index, kg/m^2 (mean ± SD)	31.28 ± 5.98	31.03 ± 5.85	.518
ASA score 3 or 4 (%)	36.7	41.3	.151
Procedure time, min (mean ± SD)	82.92 ± 30.58	83.90 ± 20.71	.605
Total OR time, min (mean ± SD)	127.51 ± 24.23	127.95 ± 24.04	.773
Procedure type			.332
THA (%)	37.4	34.5	
TKA (%)	62.6	65.5	
Length of stay, d (mean ± SD)	1.72 ± 0.97	1.78 ± 0.92	.287
Length of stay, h (mean ± SD)	47.72 ± 23.06	49.36 ± 22.13	.257

$P \leq .05$ are in bold.
ASA, American Society of Anesthesiologists; ER, emergency room; SD, standard deviation; THA, total hip arthroplasty; TKA, total knee arthroplasty; OR, operating room.

Table 3
Patient Factors That Increase Risk of Readmission for the Total Population.

	No Readmission	Readmission	Sig.
Age, y (mean ± SD)	66.45 ± 9.70	68.92 ± 10.65	**.000**
Sex			**.021**
Female (%)	59.3	52.0	
Body mass index, kg/m^2 (mean ± SD)	31.33 ± 6.22	32.32 ± 6.54	**.013**
ASA score 3 or 4 (%)	41.3	56.3	**.000**
Procedure time, min (mean ± SD)	82.88 ± 29.00	88.72 ± 24.45	**.002**
Total OR time, min (mean ± SD)	127.55 ± 24.57	133.90 ± 27.82	**.000**
Procedure Type			.694
THA (%)	36.8	35.6	
TKA (%)	63.2	64.4	
Discharge to SNF (%)	21.4	32.4	**.000**
Length of stay, d (mean ± SD)	2.06 ± 1.35	2.67 ± 2.60	**.000**
Length of stay, h (mean ± SD)	56.04 ± 32.16	70.73 ± 62.76	**.000**

$P \leq .05$ are in bold.
ASA, American Society of Anesthesiologists; SD, standard deviation; SNF, skilled nursing facility; THA, total hip arthroplasty; TKA, total knee arthroplasty; OR, operating room.

Table 4
Patient Factors That Increase Risk of Readmission for Patients Discharged Home.

	No Readmission	Readmission	Sig.
Age, y (mean ± SD)	64.88 ± 9.27	66.77 ± 10.37	**.020**
Sex			**.023**
Female (%)	55.5	46.7	
Body mass index, kg/m^2 (mean ± SD)	31.24 ± 5.98	31.91 ± 5.89	.153
ASA score 3 or 4 (%)	36.6	45.9	**.022**
Procedure time, min (mean ± SD)	82.83 ± 30.35	87.57 ± 24.33	**.044**
Total OR time, min (mean ± SD)	127.39 ± 24.09	132.24 ± 27.80	**.026**
Procedure Type			.195
THA (%)	37.4	32.5	
TKA (%)	62.6	67.5	
Length of stay, d (mean ± SD)	1.72 ± 0.96	1.95 ± 1.21	**.015**
Length of stay, h (mean ± SD)	47.63 ± 22.79	53.18 ± 29.45	**.016**

$P \leq .05$ are in bold.
ASA, American Society of Anesthesiologists; SD, standard deviation; THA, total hip arthroplasty; TKA, total knee arthroplasty; OR, operating room.

Table 6 compares the reasons for readmissions between patients who were discharged home and patients who were discharged to an SNF. There were several reasons that differed significantly between the 2 groups, pain and swelling (19.1% vs 4.1%, $P = .001$) and thromboembolic events (7.7% vs 1.0%, $P = .018$) were more likely to occur in patients discharging to home. All but 2 of the thromboembolic events in readmitted patients were for pulmonary embolism. Wound infection (10.3% vs 19.6%, $P = .029$) and anemia (0.5% vs 6.2%) were more likely to occur in patients discharging to an SNF. A higher percentage of patients discharged to an SNF also experienced other medical complications (9.8 vs 7.5%, $P = .059$) and urinary symptoms (2.1 vs 6.2%, $P = .069$) and these both approached significance. Other medical complications included diagnoses such as viral illnesses, renal complications, and diabetic complications.

Discussion

In this era of cost efficiency and bundled payment models, there has been concern that a decreasing length of stay after TKA and THA would increase ER visits and readmissions [5,16,17]. Similar to the study by Saucedo et al [11], we found that patients who were readmitted actually had a longer initial LOS. This held true for the entire study population and when we looked exclusively at the patients who discharged to home. This could be explained by an increased burden of medical comorbidities, though longer LOS has been linked to risk of readmission in other populations as well [18]. In addition, while our rate of unplanned interventions stayed fairly consistent, our average LOS for the entire cohort fell by >1 day over the study period. The LOS of patients discharged home also fell by >1 day over the course of the study without an increase in ER visits or readmission events.

The rate of ER visits following TJA has been documented at anywhere from 5.8% to 12.0% in the first 30-90 days after surgery [3,12,14]. In our study population, the overall rate of ER visits was 4.5% in the first 90 days, substantially lower than other published studies. When looking at patients who discharged to home and patients who discharged to an SNF, they both had a similar rate of ER visits. We also found that almost half of the visits, 45% occurred in the first 5 days after hospital discharge and 91% within 28 days. About one-third of ER visits were due to pain and swelling which is likely a preventable cause of return [19]. Returning to the ER for pain and swelling was not dependent on discharge disposition as it was the most common reason for both patients discharged to home and patients discharged to an SNF. All primary joint arthroplasty patients at our institution are included in a standardized pathway starting from the point at which surgery is scheduled and continuing into the postoperative period. One of the components of this is a preoperative education class that approximately 75% of patients take before surgery. In addition, all patients are given detailed written educational material both preoperatively and postoperatively in an attempt to reduce unnecessary unplanned interventions. With the advent of newer technology, changing the way this information is disseminated and improving access to providers before resorting to emergency care may help decrease this type of visit [20].

Readmission following TKA and THA has been more thoroughly studied with recent publications documenting a readmission rate of 2.2%-7.8% in the first 30-90 days after surgery [3,4,6,7,9,11]. Our readmission rate in this study was 3.3%. Readmissions were somewhat delayed compared with ER visits, only 31% of readmissions occurred in the first 5 days after surgery and 83% at 28 days. We found that patients who were discharged to an SNF rather than home had an increased likelihood of readmission. This is consistent with other published studies, though those studies relied primarily on large national databases rather than a single institution's data [8,21–23]. The reasons for this are not entirely clear. Ponnusamy et al [23] suggests that SNFs may have a lower threshold for transferring patients back to the hospital and that the proximity of many SNFs to the acute care facility may be a factor as

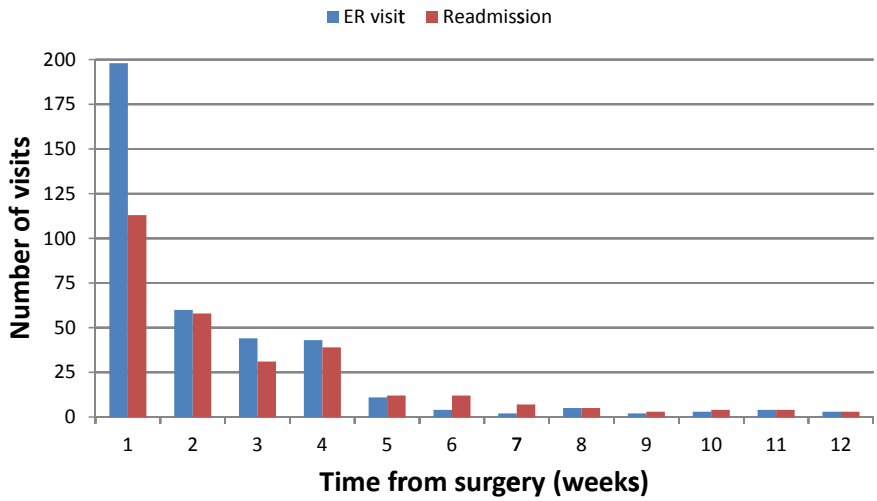

Fig. 2. ER visits and readmissions by time from discharge (by week).

Table 5
Reasons for ER Visits.

Reason for Return	Number of Visits (Discharge Home) N = 303 (%)	Number of Visits (Discharge SNF) N = 77 (%)	Sig. (Discharge Home vs SNF)	All Visits Percent (Total Population)
Pain/swelling	106 (35.0)	20 (26.0)	.134	1.7
Other medical issues	37 (12.2)	19 (24.7)	**.006**	0.75
Urinary symptoms	24 (7.9)	4 (5.2)	.414	0.36
Shortness of breath	18 (5.9)	4 (5.2)	.802	0.29
Wound infection	15 (5.0)	1 (1.3)	.154	0.21
Other orthopedic issues	12 (4.0)	5 (6.5)	.337	0.23
Nausea/vomiting/diarrhea	12 (4.0)	4 (5.2)	.630	0.21
Constipation/Ileus	11 (3.6)	2 (2.6)	.656	0.17
Syncope	10 (3.3)	2 (2.6)	.753	0.16
Medication related	10 (3.3)	2 (2.6)	.753	0.16
Fever	10 (3.3)	0	.106	0.13
Fall	9 (3.0)	6 (7.8)	.052	0.20
Cardiac complication	9 (3.0)	4 (5.2)	.338	0.17
Noncardiac chest pain	8 (2.6)	2 (2.6)	.983	0.13
Mechanical complication	7 (2.3)	2 (2.6)	.882	0.12
DVT/PE	4 (1.3)	0	.311	<0.01
Periprosthetic fracture	1 (0.3)	0	.614	<0.01

$P \leq .05$ are in bold.
DVT, deep vein thrombosis; ER, emergency room; SNF, skilled nursing facility; PE, pulmonary embolism.

well. Our institution does not have an on-site SNF, so that is not a factor in this study. Overall preoperative health status is another possible reason. Patients with a higher comorbidity burden preoperatively are more likely to discharge to an SNF and the same patients are at higher risk of adverse events after surgery [21], though in our study many of the patient characteristics associated with readmission in the population as a whole also held true when looking only at the patients discharged home.

While pain and swelling was also the most common reason for readmission in patients who discharged to home, the reasons for readmission were more evenly distributed across the categories. When comparing groups by discharge disposition, patients who were discharged home had a significantly higher rate of return for pain and swelling and for thromboembolic events. It is probable that patients discharged to an SNF who experienced similar symptoms were able to be assessed and managed in that facility rather than needing to return to an acute care facility. Patients who were discharged to an SNF had a much higher rate of infectious compared with those discharging home. While this may be related to the patient's overall health status, it also raises concerns of nosocomial infection in these patients and emphasizes the need to continue to decrease SNF admissions in THA and TKA patients [8,23]. Compared to ER visits, more readmissions were directly related to surgical complications.

The study has multiple strengths. Our study sample is large and extends over a 4- year period. We included all ER visits and readmissions that occurred in the first 90 days after surgery, rather than stopping at 30 days postoperatively. Because all the data are from one institution, we can confidently state that all patients were subjected to the same protocols preoperatively, during the hospitalization and postoperatively which decreases the risk of some confounding variables. We also examined patients discharged home and to an SNF separately.

We were unable to account for any readmissions or ER visits that may have happened outside of our institution, though our institution is geographically isolated. When examining statewide

Table 6
Reasons for Readmission.

Reason for Return	Number of Visits (Discharge Home), N = 194 (%)	Number of Visits (Discharge SNF), N = 97 (%)	Sig. (Discharge Home vs SNF)	All Visits Percent (Total Population)
Pain/swelling	37 (19.1)	4 (4.1)	**.001**	0.55
Wound infection	20 (10.3)	19 (19.6)	**.029**	0.52
Other medical issues	19 (9.8)	17 (17.5)	.059	0.48
Cardiac complications	17 (8.8)	8 (8.2)	.882	0.33
DVT/PE	15 (7.7)	1 (1.0)	**.018**	0.21
Small bowel obstruction/GI bleed	12 (6.2)	6 (6.2)	1.0	0.24
Cellulitis	10 (5.2)	7 (7.2)	.480	0.23
Neurologic complication	9 (4.6)	6 (6.2)	.574	0.20
Other orthopedic issues	8 (4.1)	3 (3.1)	.664	0.15
Periprosthetic infection	8 (4.1)	3 (3.1)	.664	0.15
Mechanical complication	7 (3.6)	4 (4.1)	.828	0.15
Periprosthetic fracture	7 (3.6)	3 (3.1)	.820	0.13
Constipation/ileus	7 (3.6)	3 (3.1)	.820	0.13
Syncope	6 (3.1)	0	.080	<0.01
Urinary symptoms	4 (2.1)	6 (6.2)	.069	0.13
Shortness of breath	4 (2.1)	1 (1.0)	.523	<0.01
Anemia	1 (0.5)	6 (6.2)	**.003**	<0.01
Medication related	1 (0.5)	0	.479	<0.01
Fever	1 (0.5)	0	.479	<0.01
Nausea/vomiting/diarrhea	1 (0.5)	0	.479	<0.01

$P \leq .05$ are in bold.
DVT, deep vein thrombosis; SNF, skilled nursing facility; GI, gastrointestinal; PE, pulmonary embolism.

readmission data from the Chesapeake Regional Information System, 85.8% of TJA patients are readmitted back to our institution. We hypothesize that the small number of unplanned interventions that we cannot account for are similar in reason and occur in a similar time frame that they did in this study so while the incidence of these events may be underestimated in this study, the data still have value in formulating strategies to improve care. In addition, because this was a retrospective study, we are unable to account for all possible confounding variables. We also limited this study to elective, unilateral primary THA and TKA.

Conclusion

The overall number of unplanned interventions experienced by this population was low. LOS decreased substantially in the total population as well as in patients discharged to home over the study period without an increase in either ER visits or readmissions. The majority of unplanned interventions occurred within the first 4 weeks after surgery. Pain and swelling was the most common reason for patients to return to the ER or be readmitted from home.

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References

[1] HCUP Fast Stats. Healthcare Cost and Utilization Project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2017. https://www.hcup-us.ahrq.gov/faststats/NationalProceduresServlet?year1=2015&characteristic1=0&included1=0&year2=&characteristic2=0&included2=1&expansionInfoState=hide&dataTablesState=hide&definitionsState=hide&exportState=hide; [accessed 12.12.17].
[2] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780–5.
[3] Navathe AS, Troxel AB, Liao JM, Nan N, Zhu J, Zhong W, et al. Cost of joint replacement using bundled payment models. JAMA Intern Med 2017;177:214–22.
[4] Weinberg DS, Kraay MJ, Fitzgerald SJ, Sidagam V, Wera GD. Are readmissions after THA preventable? Clin Orthop Relat Res 2017;475:1414–23.
[5] Sibia US, Waite KA, Callanan MA, Park AE, King PJ, MacDonald JH. Do shorter lengths of stay increase readmissions after total joint replacements? Arthroplast Today 2017;3:51–5.
[6] Zmistowski B, Restrepo C, Hess J, Adibi D, Cangoz S, Parvizi J. Unplanned readmission after total joint arthroplasty: rates, reasons, and risk factors. J Bone Joint Surg Am 2013;95:1869–76.
[7] D'Apuzzo M, Westrich G, Hidaka C, Jung Pan T, Lyman S. All-cause versus complication-specific readmission following total knee arthroplasty. J Bone Joint Surg Am 2017;99:1093–103.
[8] McLawhorn AS, Fu MC, Schairer WW, Sculco PK, MacLean CH, Padgett DE. Continued inpatient care after primary total knee arthroplasty increases 30-day post-discharge complications: a propensity score-adjusted analysis. J Arthroplasty 2017;32:S113–8.
[9] Avram V, Petruccelli D, Winemaker M, de Beer J. Total joint arthroplasty readmission rates and reasons for 30-day hospital readmission. J Arthroplasty 2014;29:465–8.
[10] Kurtz SM, Lau EC, Ong KL, Adler EM, Kolisek FR, Manley MT. Hospital, patient, and clinical factors influence 30- and 90-day readmission after primary total hip arthroplasty. J Arthroplasty 2016;31:2130–8.
[11] Saucedo JM, Marecek GS, Wanke TR, Lee J, Stulberg SD, Puri L. Understanding readmission after primary total hip and knee arthroplasty: who's at risk? J Arthroplasty 2014;29:256–60.
[12] Rossman SR, Reb CW, Danowski RM, Maltenfort MG, Mariani JK, Lonner JH. Selective early hospital discharge does not increase readmission but unnecessary return to the emergency department is excessive across groups after primary total knee arthroplasty. J Arthroplasty 2016;31:1175–8.
[13] Sibia US, Mandelblatt AE, Callanan MA, MacDonald JH, King PJ. Incidence, risk factors, and Costs for hospital returns after total joint arthroplasties. J Arthroplasty 2017;32:381–5.
[14] Finnegan MA, Shaffer R, Remington A, Kwong J, Curtin C, Hernandez-Boussard T. Emergency department visits following elective total hip and knee replacement surgery: identifying gaps in continuity of care. J Bone Joint Surg Am 2017;99:1005–12.
[15] Sankar A, Johnson SR, Beattie WS, Tait G, Wijeysundera DN. Reliability of the American Society of Anesthesiologists physical status scale in clinical practice. Br J Anaesth 2014;113:424–32.
[16] Courtney PM, Rozell JC, Melnic CM, Lee GC. Who should not undergo short stay hip and knee arthroplasty? Risk factors associated with major medical complications following primary total joint arthroplasty. J Arthroplasty 2015;30(9 Suppl):1–4.
[17] Lovald ST, Ong KL, Malkani AL, Lau EC, Schmier JK, Kurtz SM, et al. Complications, mortality, and costs for outpatient and short-stay total knee arthroplasty patients in comparison to standard-stay patients. J Arthroplasty 2014;29:510–5.
[18] Hockenberry JM, Burgess Jr JF, Glasgow J, Vaughan-Sarrazin M, Kaboli PJ. Cost of readmission: can the Veterans Health Administration (VHA) experience inform national payment policy? Med Care 2013;51:13–9.
[19] Trimba R, Laughlin RT, Krishnamurthy A, Ross JS, Fox JP. Hospital-based acute care after total hip and knee arthroplasty: implications for quality measurement. J Arthroplasty 2016;31:573–578.e2.
[20] Hallfors E, Saku SA, Makinen TJ, Madanat R. A consultation phone service for patients with total joint arthroplasty may reduce unnecessary emergency department visits. J Arthroplasty 2018;33:650–4.
[21] Keswani A, Tasi MC, Fields A, Lovy AJ, Moucha CS, Bozic KJ. Discharge destination after total joint arthroplasty: an analysis of postdischarge outcomes, placement risk factors, and recent trends. J Arthroplasty 2016;31:1155–62.
[22] Bini SA, Fithian DC, Paxton LW, Khatod MX, Inacio MC, Namba RS. Does discharge disposition after primary total joint arthroplasty affect readmission rates? J Arthroplasty 2010;25:114–7.
[23] Ponnusamy KE, Naseer Z, El Dafrawy MH, Okafor L, Alexander C, Sterling RS, et al. Post-discharge care duration, charges, and outcomes among medicare patients after primary total Hip and knee arthroplasty. J Bone Joint Surg Am 2017;99:e55.

Neuromuscular Electrostimulation Device Reduces Preoperative Edema and Accelerates Readiness for Theater in Patients Requiring Open Reduction Internal Fixation for Acute Ankle Fracture

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Abstract: Significant edema manifests as soft tissue swelling that can delay surgery in patients with ankle fractures. Interventions that expedite swelling reduction may yield clinical and economic benefits. This case-control pilot study aimed to assess the ability to recruit ankle fracture patients to a prospective study using a neuromuscular electrostimulation (NMES) device. Device effectiveness, safety, and patient acceptability were also assessed. Prospective evaluation of 20 patients admitted for ankle fracture fixation with the application of NMES device to the skin just below the knee (intervention arm). Participants were matched for baseline demographics and injury descriptors to a historical operative cohort (control arm). The time until the swelling had settled to a level permitting surgery ("readiness for surgery") was recorded alongside patient tolerability and device acceptance. The mean time until swelling reduced to a level permitting surgery was 1.66 days (NMES) versus 3.66 days (control) ($P=0.001$). Overall 60% of participants were ready for theater after 2 days of treatment with the NMES device compared with 27% in the control group ($P<0.01$). Independent health economic modeling of this scenario suggests that the savings associated with this accelerated readiness for theater is £569 per patient. The NMES device is safe and well tolerated by patients with ankle fractures. It is easy to apply, can be worn continuously, and does not restrict patients to their bed space. This study suggests that it is effective in reducing ankle edema and accelerating readiness for theater and may therefore allow earlier surgery and reduced length of stay in this patient group.

Level of Evidence: Diagnostic Level 3. See Instructions for Authors for a complete description of levels of evidence.

Key Words: ankle, surgery, swelling, transcutaneous electric nerve stimulation, trauma

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Ankle fractures comprise 9% of all orthopedic fracture referrals and ~15,000 cases are surgically treated every year in the United Kingdom.[1,2] Indications for fixation include actual or potential fracture displacement with associated talar shift and loss of joint congruency.[3] Soft tissue swelling secondary to edema resultant from tissue disruption at injury can delay surgery because of concerns about potential wound breakdown.[4] Delay in fixation may increase hospital stay, result in a higher risk of generic complications of recumbency, and lower levels of patient satisfaction.[5,6]

Various strategies are in use to decrease swelling in patients with ankle fractures with no "gold standard" treatment. "Passive" methods such as leg elevation and ice therapy and "active" interventions such as arteriovenous foot pumps (AVFP) and intermittent pneumatic compression (IPC) devices have all been described.[7–11] A recent systematic review on the use of AVFP and IPC devices suggested that although there was some evidence that these devices reduce time to surgery and degree of swelling before the operative intervention, the overall strength of evidence to support their use is poor.[12]

The NMES device (Fig. 1) used in this study offers an alternative to traditionally used AVFP and IPC devices. It is applied to the skin just proximal to the patient's plaster cast overlying the common peroneal nerve (Fig. 2). Neuromuscular electrostimulation (NMES) of the nerve activates the calf and foot muscle pumps of the lower leg that return blood towards the heart mimicking the process observed when walking.[13] By activating the muscle pump, intermittent pressure is created within the veins, interstitial, and lymph system. This augments venous and lymphatic return. It has been shown to reduce edema in a range of traumatic and nontraumatic settings,[14,15] including ankle sprain[16] and has been found to be safe and effective in a systematic review,[17] with no reported adverse incidents.

The primary aim of this study was to evaluate the ability to recruit ankle fracture patients to a prospective study utilizing the NMES device within a major trauma center. Secondary aims were to: (a) assess time until swelling reduced permitting surgery for patients requiring ankle fixation when treated with NMES compared with data from matched retrospective controls and (b) assess the safety and tolerability of the NMES device in this population.

METHODS

This study was a single-center, feasibility, open-label comparison of a prospective cohort of patients treated with the NMES device against a retrospective matched control group. The prospective cohort allowed assessment of the feasibility to recruit ankle fracture patients to a study utilizing the NMES

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The study was ethically approved by the UK Research Ethics Service ref: 16/LO/0380 and before the first participant being recruited the study registered on clinicaltrials.gov ref: NCT02841007.
All patients provided informed consent for inclusion in the study.
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The authors declare no conflict of interest.
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FIGURE 1. The geko device.

device (primary aim) in addition to assessing the safety and tolerability of the NMES device in this patient population (secondary aim). Matching to a retrospective control group allowed for preliminary assessment of the effectiveness of the NMES for the treatment of preoperative ankle edema in patients awaiting surgery for an ankle fracture (secondary aim).

Prospective Cohort

The prospective cohort included 20 consecutive consenting patients with ankle fractures requiring surgical fixation presenting to the trauma service of a major trauma center. Eligible participants were recruited between July 2016 and January 2017. Inclusion and exclusion criteria are described in Table 1. All participants consented into the study before the application of the NMES device.

Patients were approached at the point of admission to the trauma ward. Initial care in the emergency department followed standard practice (initial x-ray, fracture reduction if needed, application of plaster backslab, repeat x-ray in the cast to confirm satisfactory reduction and fracture position).

Every patient presenting with an ankle fracture that, in the opinion of the treating surgeon, required surgical fixation was assessed for inclusion in the study. Once consented the participants had their swelling assessed for suitability for theater by an experienced orthopedic surgeon (senior registrar or consultant) by splitting their backslab and the NMES device was then applied. The NMES device was worn continuously from application until theater. Standard care included inpatient admission for bed rest and elevation in the plaster backslab. No other adjunctive measures to reduce swelling (eg, cryotherapy and pneumatic foot pumps) were used for the duration of the study.

Further assessments of ankle swelling were made each morning by the treating orthopedic consultant. This was on the basis of subjective assessment of "readiness for theater" on the basis of their standard practice. This mirrors standard care across the United Kingdom as presently there are no guidelines for the assessment of a patient's suitability for theater after ankle fracture and no standardized method for assessing edema in this patient population. This continued until the patient

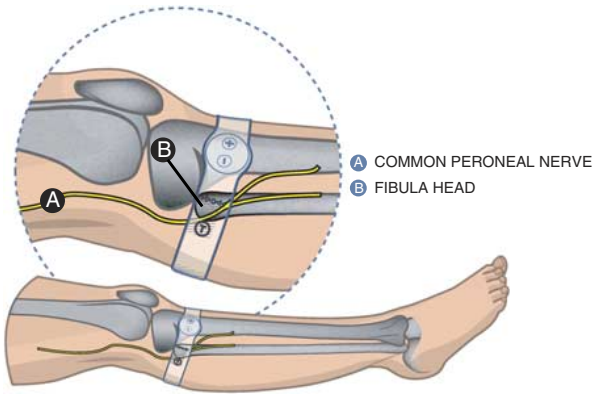

FIGURE 2. The geko device placement.

TABLE 1. Study Inclusion and Exclusion Criteria

Inclusion criteria	Aged 18-60 y old
	Clinically and radiologically diagnosed acute ankle fracture that, in the opinion of the treating surgeon, requires operative fixation
	Able to understand the patient information sheet and willing to sign the written informed consent form
	Able and willing to follow the protocol requirements
Exclusion criteria	Has a pacemaker
	Morbid obesity (BMI $>40\ kg/m^2$)
	Patients who on presentation to the hospital are known to be pregnant
	Clinically significant comorbidities that need to be treated before surgical intervention and could therefore impact upon time to theater
	History or signs of previous deep or superficial vein thrombosis/pulmonary embolism
	Varicosities, ulceration, or erosion around the area of the leg where the study device would be fitted
	Diabetic
	Already taking part in a clinical study, or has so within the last 8 wk
	Nonresponder to NMES device

BMI, body mass index; NMES, neuromuscular electrostimulation.

underwent surgical fixation. For each participant, the time from admission until their swelling was deemed to be "ready for theater" was noted. This does not always coincide with time to theater and this was separately recorded. Length of hospital stay both preoperation and after surgery was noted. Tolerability of the device was evaluated each morning using a Likert scale (1: no sensation to 5: severe discomfort). Adverse events and device removal for each patient were monitored and recorded. For each patient, the time to surgery from admission and length of hospital stay were noted.

The NMES Device

The geko is a (Conformite Europeene) CE-marked small disposable, internally powered, neuromuscular stimulation (NMES) device that is applied to the skin (Fig. 1). The device is self-adhesive and is applied to the lateral/posterior aspect of the knee. This positioning enables integral electrodes to apply a stimulus to the common peroneal nerve eliciting a twitch of the muscles activating the venous pumps of the leg (Fig. 2).

In the study cohort, the effectiveness of the NMES device was assessed by looking for discernible dorsiflexion of the foot when the impulse was generated.[18] If the T2 (27 mA) device did not generate a satisfactory contraction, then the protocol allowed an R-2 (54 mA) device to be applied. In this cohort, no R-2 devices were used as there were no nonresponders with the T-2 geko device.

Retrospective Matching

To allow comparative analysis each patient from the prospective cohort was retrospectively matched to historical control. Matching was undertaken on the basis of 5 defined criteria: age (±5 y), sex, ethnicity, fracture type (unimalleolar vs. bimalleolar/trimalleolar), dislocated at presentation to hospital (yes vs. no) and the match had to agree for all 5 criteria for it to be valid. Matches were achieved by working back from December 31, 2015 through surgically treated ankle fracture cases treated within the trust. The first valid match was chosen for each case (Fig. 3).

The case notes of all matches were reviewed to confirm they fulfilled both the matching criteria and the inclusion

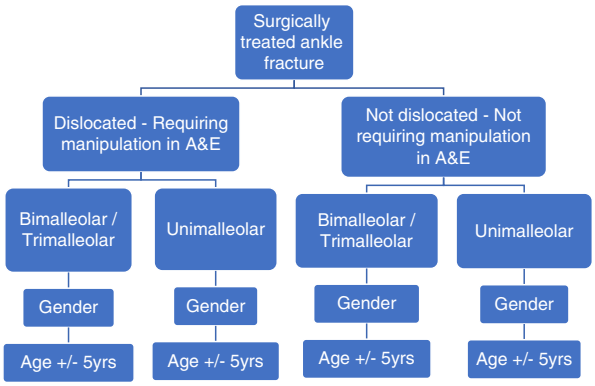

FIGURE 3. Outline of the algorithm used to match historical patients to our prospective cohort.

criteria used within the prospective element of the trial. If they did not fulfill the inclusion criteria, then the next most recent match was identified and similarly assessed. This continued until an appropriate match on the basis of the matching algorithm and fulfillment of the study inclusion criteria was identified. Having identified an appropriate match, the case notes were reviewed for information relating to "readiness for theater," time to theater, and length of stay.

Data Analysis and Statistics

A comparison of readiness for surgery and time to surgery for the study group and the matched retrospective cohort was assessed using the Wilcoxon signed-rank test. Tolerability data for each intervention were collected on discharge, measured using a Likert 1 to 5 scale. Interventions were compared with the Mann-Whitney U test. A P-value of <0.05 was considered to be significant. A formal power calculation was not used as this was a pilot feasibility study with the primary aim of assessing the ability to recruit ankle fracture patients to a prospective study utilizing the NMES device.

Health Economic Analysis

Independent health economic analysis was conducted by Mtech Access Ltd (Bicester) alongside the study to assess the potential savings associated with earlier "readiness for theater." Costs were sourced locally and the only differences between the 2 pathways where the inclusion or exclusion of the NMES device and the respective time from admission to "readiness for theater."

Ethics

The study was ethically approved by the UK Research Ethics Service ref: 16/LO/0380 and before the first participant being recruited the study registered on clinicaltrials.gov ref: NCT02841007.

Funding

This study was sponsored by Firstkind Ltd (High Wycombe, UK). The participants were not reimbursed for participation in the study.

RESULTS

Twenty eligible participants (9 female individuals) of mean age 45.4 years (range, 19 to 64) were recruited over a 6-month period, comprising 14 bimalleolar/trimalleolar and 6 single malleolus fractures. Eleven were dislocated or subluxated at presentation, undergoing manipulation in the emergency department.

TABLE 2. Demographic Details of the Matched Comparison Groups

Variable	All Participants (N = 30)	Retrospective Matched Controls (N = 15)	NMES Group (N = 15)
Mean age	48.4 (±13.0)	49.6 (±13.5)	47.3 (±12.9)
Sex			
Male	16 (53%)	8	8
Female	14 (47%)	7	7
Ethnicity			
White	30 (100%)	15	15
Dislocation			
Yes	14 (47%)	7	7
No	16 (53%)	8	8
Unimalleolar	12 (40%)	6	6
Of which dislocated	4 (33%)	2	2
Bimalleolar/ Trimalleolar	18 (60%)	9	9
Of which dislocated	10 (56%)	5	5
Readiness for theater days, mean (SEM)	2.66 (0.40)	3.66 (0.59)	1.66 (0.37)

NMES, neuromuscular electrostimulation.

Five patients were withdrawn from the study. One participant was treated without an operation after discussion among the surgical team; 4 participants were treated with external fixation by their treating surgeon before the index open reduction internal fixation procedure and details on "readiness for theater" were therefore not available. However, all 4 of the participants who underwent external fixation wore the device for a minimum of 2 days allowing safety and device tolerability data to be collected for these participants. Data matching and subsequent analysis were performed on the remaining 15 participants. The details of the comparison groups are given in Table 2.

Edema, "Readiness for Theater" and Time to Theater

The mean time until the edema had been reduced facilitating a "readiness for theater" was 1.66, with a standard error of mean (SEM) 0.37 days in the NMES group versus 3.66 (SEM 0.59) days in the control group ($P = 0.001$). Overall 60% of participants were ready for theater after 2 days of treatment by the NMES device compared with 27% in the control arm ($P < 0.01$).

Despite earlier "readiness for theater" the time to theater for both groups was similar: NMES group 3.87 days (SD, 0.6) versus control group 4.00 days (SD, 0.7), ($P = 0.89$). In the NMES group, participants waited for a combined total of 2.2 days for theater after swelling had subsided because of the lack of theater capacity which may explain this finding.

Safety and Tolerability

A 1 to 5 scale for the tolerability of the device was used, with 1 = no sensation and 5 = severe discomfort. On the first-day postadmission, 15 of 19 (79%) participants rated the device tolerability as a 2 = minimal sensations, 1 of 19 (5%) as 3 = mild discomfort, 2 of 19 (10%) as moderate discomfort, and 1 of 19 (5%) as severe discomfort. Of the 19 participants fitted with the device, only 1 participant was noncompliant with its use and stopped using it on day 3 postadmission, the remaining 95% of participants wore the device until withdrawal or of the open reduction internal fixation procedure. In the NMES group, there was 1 device deficiency (battery failure). This was replaced with a new device.

Health Economics

Independent health economic modeling of the study outcome ("readiness for theater") demonstrated that the value of reducing the readiness for theater by 2 days compared with the historical control group would save £569 per patient.

DISCUSSION

This study demonstrates that the NMES device is both safe and well tolerated in a group of patients with ankle fractures awaiting fixation. We found that it is possible to recruit ankle fracture patients into a prospective study and rates of patient-related withdrawals because of device issues was extremely low. In addition, within the limitations of the study design, the device demonstrated greater preoperative edema reduction when compared with a retrospective "standard care" control group. On average, patients were ready for theater 2 days earlier.

Ankle fractures are common injuries with a substantial number requiring fixation. Operating in the presence of edema can result in suboptimal soft tissue conditions leading to wound problems. Surgeons often delay surgery to allow edema to resolve with a resultant increase in the length of hospital stay and cost to the health care system.[19,20] In settings where ankle fractures are managed as outpatients after a 7 to 10 day delay, the device can potentially reduce that delay, with the additional benefit of reducing the risk of deep vein thrombosis,[21] and earlier return to work. The NMES device is an adjunct to allow early resolution of soft tissue edema that may consequently help to minimize delays to surgery. In this study, patients treated with NMES were ready for surgery 2 days earlier when compared with a matched historical cohort. However, the *overall* time to fixation in both groups was similar. There are a number of reasons that may explain this finding. First, the time periods in which data on the 2 groups were collected were different. The control group coincided with the early development of the local trauma network, whereas the NMES group occurred once this had been established and came during a period when referrals into the trauma service had increased without an associated expansion in a service capacity. This meant that routine trauma such as ankle fracture fixations were on average waiting longer for surgery because of the clinical prioritization of other fracture types. Delays to surgery were observed even when patients were deemed "ready" because of the competing interests of major trauma cases, hip fractures, and long bone fractures that are all associated with best practice guidelines relating to timing of surgery.[22]

NMES is not the only modality that can influence postinjury swelling. A recent systematic review of established treatment strategies included only 5 comparative studies of which only 1 showed a reduction in time to surgery with the use of either AVFP or IPC devices.[7] Overall compliance with treatment and the patient's tolerability were globally poor. Application of AVFP and IPCs can be time consuming and can require specialist equipment such as compressor pumps that are noisy and restrict patients to their bed space. Their application is frequently delayed because of availability of trained staff, equipment, and requirement for patients to be admitted into a hospital bed. In contrast, NMES can be easily applied as soon as the patients' fracture is stabilized in a backslab. It can be worn 24 hours a day, it does not restrict the patient and could therefore be used out of the hospital. In this situation, patients could be managed at home using NMES to reduce edema before readmission for "day case" surgery. This has the dual advantage of reducing inpatient bed demands and allowing the time of surgery to be planned. In the current study, the NMES device was well tolerated by almost all participants and only 1 patient developed a reaction to the device in the form of a heat rash.

This work was designed as a pilot feasibility study. It was restricted to a small group of patients to ensure compliance, tolerability, and clinical benefit before a larger study is undertaken. We were able to recruit 20 participants within the 6 months and >90% of patients approached to participate consented to their involvement. Despite the nature of the study and the number of participants recruited, the size effect observed for the "readiness to theater" outcome was so large that we were able to demonstrate a significant difference between the groups.

We accept that there are a number of limitations to this work. Inferences made from the study are limited by its design with data collected during 2 different periods of time during which service demand and capacity significantly differed. This is reflected in the difference between the patient being "ready for surgery" earlier, but frustratingly, not progressing to the operating theater at that point. The study design was primarily chosen to assess the feasibility of recruitment alongside device safety and tolerability. A prospective randomized controlled trial would have allowed a more robust comparison between the intervention and control groups while limiting the effects of confounders and bias in this pilot. Furthermore, the use of "readiness" for theater as an outcome measure is limited by its subjective nature. There is a risk of selection bias if the treating surgeon is aware that the patient is wearing an NMES device as was the case in this study.

Measurement of swelling and its perceived impact is a challenge in the acute management of ankle fractures. There is currently no "gold-standard" method to quantify edema in patients with a lower limb fracture stabilized in a plaster. Surgeons rely on subjective assessments such as skin wrinkling, decreased tension of the edematous skin, and resolution of blisters. More objective markers of edema are difficult to implement in this patient population. Circumferential ankle/calf measurement figure of 8 measurements and water displacement are difficult when the leg is supported by a plaster cast unless tape measures are placed within the cast before the application or the cast is removed.[23,24] This is difficult to achieve either because the orthopedic team only becomes aware of the patient once initial reduction and stabilization have been achieved within the emergency department or removal of the cast risks loss of fracture reduction.

This pilot study has established the safe use of the NMES device in perioperative ankle fracture management. There was an improvement in the time to be "ready for theater" because of edema resolution. Patient compliance with the device was good and it was well tolerated. Within the limitations discussed above, the NMES device can be safely used in ankle fracture patients in which soft tissue swelling does not allow immediate surgery or if this is not possible because of other factors such as theater availability. In the United States, the device costs (in the region of US$21 per pair) are covered within a Diagnostic-Related Group (DRG) payment for an ankle fracture. Should the finding of reduced time for "readiness for theater" be confirmed in a further prospective randomized controlled trial, NMES could potentially deliver significant clinical and economic benefits to the patient and their health care team.

REFERENCES

1. Lash N, Horne G, Fielden J, et al. Ankle fractures: functional and lifestyle outcomes at 2 years. *ANZ J Surg*. 2002;72:724–730.
2. Singh R, Kamal T, Roulohamin N, et al. Ankle fractures: a literature review of current treatment methods. *Open J Orthop*. 2014;4:292–303.
3. Ramsey P, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift. *J Bone Joint Surg*. 1976;58:356–357.

4. Hoiness P, Stromsoe K. The influence of the timing of surgery on soft tissue complications and hospital stay. A review of 84 closed ankle fractures. *Ann Chir Gynaecol*. 2000;89:6–9.
5. Sukeik M, Qaffaf M, Ferrier G. Ankle fractures: impact of swelling on timing of surgery, length of hospital stay and the economic burden. *Injury Extra*. 2010;41:133–134.
6. Ashton F, Hamid K, Sulieman S, et al. Factors influencing patient experience and satisfaction following surgical management of ankle fractures. *Injury*. 2017;48:960–965.
7. Keehan R, Guo S, Ahmad R, et al. Impact of intermittent pneumatic foot pumps on delay to surgery following ankle fracture. *Foot Ankle Surg*. 2013;19:173–176.
8. Caschman J, Blagg S, Bishay M. The efficacy of the A-V impulse system in the treatment of posttraumatic swelling following ankle fracture. *J Orthop Trauma*. 2004;18:596–601.
9. Rohner-Spengler M, Frotzler A, Honigmann P, et al. Effective treatment of posttraumatic and postoperative edema in patients with ankle and hindfoot fractures. *J Bone Joint Surg Am*. 2014;96:1263–1271.
10. Stöckle U, Hoffmann R, Schütz M, et al. Fastest reduction of posttraumatic edema: continuous cryotherapy or intermittent impulse compression? *Foot Ankle Int*. 1997;18:432–438.
11. Thordarson DB, Ghalambor N, Perlman M. Intermittent pneumatic pedal compression and edema resolution after acute ankle fracture: a prospective, randomized study. *Foot Ankle Int*. 1997;18:347–350.
12. Clarkson R, Mahmoud SS, Rangan A, et al. The use of foot pumps compression devices in the perioperative management of ankle fractures: systematic review of the current literature. *Foot (Edinb)*. 2017;31:61–66.
13. Tucker A, Maass A, Bain D, et al. Augmentation of venous, arterial and microvascular blood supply in the leg by isometric neuromuscular stimulation via the peroneal nerve. *Int J Angiol*. 2010;19:31–37.
14. Ravikumar R, Williams K, Babber A, et al. Pilot randomised control trial: neuromuscular electrical stimulation in treating venous disease. *Eur J Vasc Endovasc Surg*. 2015;50:398.
15. Ingves MV, Power AH. Two cases of transcutaneous electrical nerve stimulation of the common peroneal nerve successfully treating refractory, multifactorial leg edema. *J Investig Med High Impact Case Rep*. 2014;2:232470961455983.
16. Wainwright TW, Burgess LC, Middleton RG. Does neuromuscular electrical stimulation improve recovery following acute ankle sprain? A pilot randomised controlled trial. *Clin Med Insights Arthritis Musculoskelet Disord*. 2019;12:1–6.
17. Burgess LC, Immins T, Swain I, et al. Effectiveness of neuromuscular electrical stimulation for reducing oedema: a systematic review. *J Rehabil Med*. 2019;51:237–243.
18. Lattimer CR, Zymvragoudakis V, Geroulakos G, et al. Venous thromboprophylaxis with neuromuscular stimulation: is it calf muscle pumping or just twitches and jerks? *Clin Appl Thromb Hemost*. 2017;24:446–451.
19. Stull JD, Bhat SB, Kane JM, et al. Economic burden of inpatient admission of ankle fractures. *Foot Ankle Int*. 2017;38:997–1004.
20. Pietzik P, Qureshi I, Langdon J, et al. Cost benefit with early operative fixation of unstable ankle fractures. *Ann R Coll Surg Engl*. 2006;88:405–407.
21. Summers JA, Clinch J, Radhakrishnan M, et al. The geko™ electro-stimulation device for venous thromboembolism prophylaxis: a NICE medical technology guidance. *Appl Health Econ Health Policy*. 2015;13:135–147.
22. NHS England. Additional information on Best Practice Tariff proposals. 2017. Available at: www.england.nhs.uk/publication/additional-information-on-best-practice-tariff-proposals/. Accessed April 26, 2018.
23. Watson C, Boland R, Refshauge K. Measurement reliability of swelling in the acute ankle sprain. *Foot Ankle J*. 2008;1:112.
24. Petersen EJ, Irish SM, Lyons CL, et al. Reliability of water volumetry and the figure of eight method on subjects with ankle joint swelling. *J Orthop Sports Phys Ther*. 1999;29:609–615.