Clinical research study

Benign heart murmurs as a predictor for complications following total joint arthroplasty

James M. Friedman^{a,*}, Ricardo Couso^b, Michael Kitchens^b, Venus Vakhshori^c,
Cody D. Hillin^a, Chia H. Wu^a, Joshua Steere^a, Jaimo Ahn^a, Eric Hume^a

^a Department of Orthopedics, University of Pennsylvania, Philadelphia PA, United States

^b Perelman School of Medicine, University of Pennsylvania, Philadelphia PA, United States

^c Department of Orthopedics, University of Southern California, Los Angeles CA, United States

ARTICLE INFO

Article history:

Received 24 May 2017

Accepted 30 July 2017

Available online 1 August 2017

Keywords:

Heart murmur

Total joint arthroplasty

Surgical complications

ABSTRACT

Background: There is scant literature examining the predictive role of heart murmurs in the absence of suspected structural heart disease on complications of non-cardiac surgery. We hypothesize the detection of heart murmurs in the absence of structural heart disease will help identify patients at risk for complications following total joint arthroplasty (TJA) surgery.

Method: This was a prospective cohort of patients undergoing TJA over a twenty-month period. The study was performed at a single academic institution with four subspecialty surgeons.

Patients undergoing primary TJA who were over eighteen years old, gave informed consent, and had adequate documentation were included in the study. Patients with a preoperative murmur or a newly discovered postoperative murmur were compared against patients with no murmur.

Surgery-related complications, performance with physical therapy, and discharge to a non-home facility were measured in each group.

Findings: 345 (63%) eligible patients were included. 20 (5.8%) patients had a documented preoperative murmur and 36 (10.4%) patients had a new postoperative murmur. No patient had concern for major structural heart disease. Preoperative murmurs independently predicted development of acute kidney injury (OR 7.729, $p < 0.001$; RR 1.36). Preoperative murmurs also predicted likelihood to be discharged to a non-home facility (OR 2.97, $p = 0.03$; RR 1.87). New postoperative murmurs independently correlated with decreased performance with physical therapy (OR 0.466, $p = 0.045$; RR 0.664).

Interpretation: Detection of heart murmurs both preoperatively and postoperatively is a low cost strategy to identify post-TJA surgical patients at risk for postoperative acute kidney injury, decreased physical performance, and discharge to non-home facilities. These patients may benefit from early fluid resuscitation and renally-dosed post-operative medications.

© 2017 Prof. PK Surendran Memorial Education Foundation. Published by Elsevier, a division of RELX India, Pvt. Ltd. All rights reserved.

1. Introduction

Growing demand, increasing healthcare costs, and higher financial penalties for complications of non-cardiac, elective surgery has amplified interest in low-cost strategies to identify patients at risk for post-operative complications.¹ The cardiac exam is a low-cost screening method that may be a potential tool

for identifying at-risk patients.^{2,3} Heart murmurs associated with major structural heart defects are correlated with high complication rates following non-cardiac surgery,^{3–5} and current guidelines set forth by the American Heart Association and American College of Cardiology (AHA/ACC) recommend echocardiography if there is ‘moderate probability’ for structural heart disease associated with a murmur.^{5,6} Although patients without suspected structural heart defects are usually deemed safe for elective surgery, there is no literature assessing the significance of low-grade, asymptomatic heart murmurs in patients with low-suspicion for structural disease.³ These murmurs are often considered benign and do not affect surgical planning. However, it is estimated that over 30% of

* Corresponding author at: Department of Orthopedics, University of Pennsylvania, 3737 Market St, Suite 600, Philadelphia, PA, 19104, United States.

E-mail address: James.Friedman@uphs.upenn.edu (J.M. Friedman).

elderly patients have systolic murmurs^{3,7} and an unknown number of patients have transient murmurs following surgery, both with unknown significance regarding surgical outcomes. Total joint arthroplasty (TJA) represents a subset of elective surgeries that are notable for increasing demand, high costs, and bundled payments. By 2033 the demand for total knee arthroplasty and total hip arthroplasty is predicted to increase by 174% and 673%, respectively compared to 2007 numbers^{2,8} and Medicare & Medicaid Services has made a goal of including half of all Medicare payments for TJA under a new payment model, such as bundled payments by 2018.⁹ Furthermore, TJA is a high-volume, reproducible surgery that allows for easy study comparison.

The purpose of this study was to prospectively assess the correlation between heart murmurs without suspicion of major structural heart defects and postoperative outcomes in TJA patients. Based on a pilot study, we hypothesized that heart murmurs would be associated with increased acute kidney injury (AKI) and decreased physical capacity following TJA.

2. Methods

This study was conducted with the approval of our Institutional Review Board. No outside funding was received. Written consent was given by all subjects, and no compensation was offered. This was a single-institution prospective cohort study including patients from four surgeons. Inclusion criteria were patients who underwent elective primary total hip or total knee arthroplasty between 4/1/14 and 12/15/15, were over the age of 18, spoke English, and provided informed consent. Patients were excluded if they had a planned ICU admission, were pregnant or incarcerated, or had inadequate documentation of the postoperative physical exam.

Pre-operative patient data collected included age, gender, body mass index (BMI), comorbid conditions, presence of preoperative murmur, and whether or not an echocardiogram was performed. Co-morbid conditions were stratified for analysis to diabetes, obstructive sleep disorder, pulmonary (asthma, pulmonary hypertension, chronic obstructive pulmonary disease

(COPD)), Cardiac (chronic heart failure, coronary artery disease, atrial fibrillation, pacemaker, conduction disease, transplant), history of cerebral vascular accident, endocrine (sarcoidosis, autoimmune diseases, thyroid abnormalities, adrenal abnormalities, pituitary axis abnormalities), hematologic (history of deep venous thrombosis (DVT), history of pulmonary embolism (PE), diagnosed bleeding disorders), chronic kidney disease, and liver disease (active hepatitis, cirrhosis). All patients were screened by a medical professional prior to surgery including a cardiac exam. As per our standard practice, patients with medical comorbidities that excluded them from a reasonably safe outcome did not receive a TJA and were not included in the study.

Post-operative, prospective data was collected during the inpatient hospital stay from the time of surgery until discharge. This data included surgery type, presence of postoperative murmur, postoperative complications, urine output, distance walked with physical therapy, and discharge location to home or non-home facility. Measured complications included myocardial infarction, atrial fibrillation, stroke, deep vein thrombosis, pulmonary embolism, acute kidney injury (AKI), and blood transfusion. AKI was defined as an increase in serum creatinine of 50% above baseline or increase of 0.3 mg/dL within 24 h.⁶ All study patients underwent complete physical examination by a Hospitalist attending within 24 h following surgery and included whether or not a murmur was heard on exam.

Patients with heart murmurs were categorized into two groups: those with murmurs detected during the preoperative examination and those with newly detected murmurs postoperatively.

Table 1

Patients with pre-operative murmurs demographics.

Variable	No Murmur (325)	Pre-op Murmur (20)	Pvalue
THA	130 (40%)	6 (30%)	0.374
Male	130 (40%)	4 (20%)	0.075
Age	61.01 (51.04–70.98)	68 (57.16–78.84)	0.003
BMI	32.6 (24.91–40.25)	32.7 (25.7–39.7)	0.828
Comorbidities: DM	49 (15.1%)	6 (30%)	0.077
OSA	44 (13.5%)	4 (20%)	0.418
Pulmonary	49 (15.1%)	4 (20%)	0.553
Cardiac	41 (12.6%)	7 (35%)	0.005
Stroke	12 (3.7%)	1 (5%)	0.766
Endocrine	72 (22.2%)	3 (15%)	0.452
Heme	23 (7.1%)	1 (5%)	0.723
Renal	18 (5.5%)	2 (10%)	0.407
Liver	20 (6.2%)	0 (0%)	0.253

These two groups were then compared with respect to postoperative outcomes, including total distance walked with physical therapy, likelihood to be discharged to a non-home facility, and postoperative complications. Of note, fifty feet is the distance insurance companies use to determine if a patient is eligible for discharge to a non-home facility and this cutoff was used to stratify distance walked with physical therapy.

Descriptive analyses were carried out using Student's *t*-tests and Chi-square analyses for continuous and binary variables respectively. Univariate logistic regression analysis was used to determine correlation between murmurs and measured outcomes. Univariate logistic analysis was then used to identify potential confounding variables of murmurs for identified statistically significant outcomes. Finally, multivariate regression analysis was performed to determine the independent correlation between murmurs and poor outcomes. Odds ratios were used for analysis as the unconstrained properties of odds ratios allow for more robust comparisons in a binary multivariate model. However, as relative risk is more easily clinically applicable, appropriate for prospective analysis, and makes potential future study comparison easier,¹⁰ relative risk was also reported for significant univariate outcomes.

A power analysis based on an initial pilot study of 150 patients determined that a sample size of 286 was needed to reject the null hypothesis with a 0.05 significance level and a power of 90% for AKI. All statistical analysis was performed with SPSS Statistics 23 (IBM, Armonk, NY).

Table 2

Patients with new post-operative murmurs demographics.

Variable	No Murmur (309)	PostNoPre (36)	Pvalue
THA	125 (40.5%)	11 (30.6%)	0.25
Male	124 (40.1%)	10 (27.8%)	0.15
Age	61.2 (50–87–71.53)	63.6 (71.6–55.6)	0.18
BMI	32.59 (24.95–40.24)	32.59 (25.13–40.06)	1
Comorbidities DM	48 (15.5%)	7 (19.4%)	0.544
OSA	44 (14.2%)	4 (11.1%)	0.608
Pulmonary	49 (15.9%)	4 (11.1%)	0.455
Cardiac	44 (14.2%)	4 (11.1%)	0.608
Stroke	11 (3.6%)	2 (5.6%)	0.552
Endocrine	64 (20.7%)	11 (30.6%)	0.175
Heme	22 (7.1%)	2 (5.6%)	0.727
Renal	19 (6.1%)	1 (2.8%)	0.413
Liver	18 (5.8%)	2 (5.6%)	0.948

Table 3

Univariate analysis correlating murmurs to outcomes.

Outcome	Pre-op Murmur		New Post-op Murmur	
	Odds Ratio	Pvalue	Odds Ratio	Pvalue
AKI	8.27 (0.551–2.113)	<.001	0.392 (0.138–1.107)	0.367
Blood Transfusion	1.28 (0.59–2.77)	0.751	0.298 (.106–0.839)	0.242
PT Distance Walked	0.517 (0.323–0.828)	0.161	0.416 (.289–0.6)	0.016
Non-Home Placement	2.97 (1.80–4.90)	0.03	1.39 (0.97–1.97)	0.356

3. Results

345 of 542 eligible patients (63%) were included in the study. 152 patients (28%) did not consent and 68 patients (12.5%) had inadequate documentation. The most common mode of inadequate documentation was that patients were evaluated by a hospitalist more than 24 h after surgery. The sample size exceeded the needed number calculated in the power analysis of 286 patients. 209 (60.5%) patients underwent total knee arthroplasty (TKA). 134 patients (38.8%) were male, the average age was 61.4 years, and average BMI was 32.6. 22 patients (6.3%) had postoperative AKI, and 28 patients (8.1%) received a blood transfusion. These two outcomes were included for analysis. All other complications occurred in less than 1% of patients and were not assessed.

20 patients (5.8%) had preoperative murmurs, of which all were systolic. 7 (35%) of these were evaluated by preoperative echocardiogram which did not show major heart structural defects as defined by a heart abnormality graded greater than mild-moderate. 36 patients (10.4%) had new postoperative murmurs, which were also all systolic murmurs. Seventeen (47%) patients with new murmurs had a documented preoperative echocardiogram that did not show major structural defects. There were no postoperative echocardiograms. Patients with a preoperative murmur were significantly older (68 vs 61, $p=0.003$) and were more likely to have a cardiac comorbidity (35% vs 12.6%, $p=0.005$) compared to patients without a preoperative murmur (Table 1). Patients with a new postoperative murmur were statistically comparable to those who did not have a postoperative murmur (Table 2).

Univariate logistic regression analysis of heart murmurs with respect to study outcomes is shown in Table 3. Preoperative murmurs were correlated with postoperative AKI (OR 8.27, $p<0.001$; RR 1.36) and with discharge to a non-home facility

(OR 2.97, $p=0.03$; RR 1.87). All patients with preoperative murmurs who developed AKI with recorded urine output (UOP) met criteria for prerenal AKI (UOP <0.5 mL/Kg/h), all of which resolved within 48 h with administration of IV fluids. New postoperative murmurs were correlated with walking less than 50 feet with physical therapy (OR 0.416, $p=0.016$; RR 0.664). Having a murmur at any time did not correlate with receiving a blood transfusion.

Univariate logistic regression analysis of potential confounding variables for preoperative and new postoperative murmurs is shown in Table 4. In patients with preoperative murmurs, age over 65 (OR 2.6, $p=.032$, RR 1.069) was the only other variable found to correlate with developing AKI. Female gender (OR 3.19, $p<.001$, RR 1.739), BMI greater than 35 (OR 3.196, $p<0.001$, RR 1.225), diabetes (OR 2.411, $p<0.004$, RR 1.593), OSA (OR 2.474, $p=.005$, RR 1.626), and receiving a TKA (OR 1.551, $p=.05$, RR 1.215) correlated with discharge to a non-home facility. For patients with new postoperative murmurs, female sex (OR .382, $p<.001$, RR 0.669), age greater than 65 (OR 0.618, $p=0.036$, RR 0.773), BMI greater than 35 (OR 0.413, $p<0.001$, RR 0.632), diabetes (OR 0.277, $p=0.014$, RR 0.695), and undergoing TKA (OR 0.587, $p=0.018$, RR 0.739) were correlated with walking less than 50 feet with physical therapy.

Multivariate logistic regression analysis for preoperative and new postoperative murmurs is shown in Table 5a and b respectively. Preoperative murmurs independently correlated with developing AKI (OR 7.729, $p<0.001$), but did not independently correlate with discharge to a non-home facility. New postoperative murmurs independently correlated with a walking less than 50 feet with physical therapy.

Table 4

Univariate analysis identifying confounders to significant outcomes.

Outcomes	Pre-operative Murmur Confounders				Post-op murmur confounders	
	AKI		SNF Placement		Ptdist > 50	
Confounders	Odds Ratio	Pvalue	Odds Ratio	Pvalue	Odds Ratio	Pvalue
Female	1.388 (.866–2.226)	0.487	3.19 (2.519–4.055)	<.001	.382 (.303–.483)	<.001
Age	2.6 (1.667–4.059)	0.032	1.534 (1.219–1.931)	0.063	.618 (.491–.777)	0.036
BMI	2.106 (1.352–3.281)	0.093	3.196 (2.519–4.055)	<.001	.413 (.522–.327)	<.001
DM	1.606 (.945–2.732)	0.373	2.411 (1.777–3.271)	0.004	.477 (.353–.644)	0.014
OSA	1.409 (.792–2.507)	0.552	2.474 (1.79–3.421)	0.005	.581 (.424–.795)	0.084
Pulmonary	1.242 (.7–2.206)	0.705	1.414 (1.049–1.908)	0.246	.742 (.55–1)	0.317
Cardiac	2.509 (1.513–4.162)	0.069	1.359 (.995–1.857)	0.325	.706 (.964–.517)	0.265
Stroke	2.838 (1.271–6.334)	0.194	1.966 (1.1–3.515)	0.245	.491 (.274–.877)	0.22
Endocrine	1.063 (.628–1.8)	0.908	.458 (.352–.596)	0.767	1.188 (.912–1.547)	0.515
Heme	.621 (.218–1.768)	0.649	1.742 (1.134–2.675)	0.195	.458 (.296–.709)	0.074
Renal	<.0001	0.998	0.978 (.616–1.554)	0.963	1.224 (.765–1.96)	0.668
Liver	<.0001	0.998	1.210 (.763–1.919)	0.678	.643 (.405–1.021)	0.34
TKA	1.149 (.727–1.817)	0.762	1.551 (1.24–1.941)	0.05	.587 (.469–.735)	0.018

Table 5

a Multivariate analysis for pre-operative murmurs.

a			Non-Home Discharge		
Variables	Odds Ratio	Pvalue	Variables	Odds Ratio	Pvalue
AKI			Preop Murmur	2.326 (1.373–3.939)	0.109
Preop Murmur	7.729 (4.410–13.545)	<.001	Female	2.11(1.645–2.707)	0.003
Age > 65	2.42 (1.531–3.827)	0.053	BMI > 35	2.106 (1.603–2.768)	0.006
			DM	1.706 (1.23–2.366)	0.102
			OSA	1.768 (1.229–2.545)	0.118
			Total Hip	1.116 (.876–1.422)	0.651

b		
Variables	Odds Ratio	Pvalue
PT dist > 50		
PostMurmur	.466 (.318–.685)	0.047
Female	.498 (.389–.637)	0.005
Age > 65	.591 (.463–.757)	0.033
BMI > 35	.505 (.390–.654)	0.008
DM	.658 (.477–.908)	0.194
Total Hip	.770 (.605–.981)	0.282

4. Conclusion

Our study investigated the correlation between low-grade cardiac murmurs and postoperative outcomes following non-cardiac surgery, specifically TJA. We stratified murmurs as existing pre-operatively or newly-developed post operatively. We observed that preoperative murmurs independently predict postoperative AKI and correlate with discharge to a non-home facility. New postoperative murmurs are surprisingly common and independently correlate with decreased performance with physical therapy but are not associated with any major postoperative complications or discharge to a non-home facility.

While a murmur may not indicate severe structural defects in the heart, a murmur may have important physiologic implications for patients undergoing surgery. A murmur may indicate decreased cardiac efficiency and physiologic reserve even in the context of mild structural abnormality.^{3,11,12} In our study, patients with pre-operative murmurs had a much higher likelihood of developing AKI which may reflect the description of decreased physiologic reserve represented as the body's difficulty in compensating for fluid shifts following surgery. All patients who developed AKI responded to IV fluid indicating that patients with preoperative murmurs may benefit from increased IV fluid immediately following surgery. This is opposed to waiting for metabolic labs usually collected on post-operative day one or two. Giving lower doses of medications that are known to damage the kidney may also help prevent AKI in these patients. Pre-operative murmurs also correlated with discharge to a non-home facility, a major cost-driver for TJA,^{13–15} however, this finding was confounded by female gender and high BMI, and it is not clear in this study if the reduction in AKI would translate to increased discharges to home.

Post-operative murmurs did not appear to affect patient outcomes other than immediate performance with physical therapy. Based on this data, post-operative murmurs with low suspicion for acute cardiac disease can likely be safely ignored. However more study is required to determine if intervention in these patients could help improve performance.

These findings are significant as there is scant literature measuring the significance of benign heart murmurs following elective non-cardiac surgery.³ Systolic murmurs not associated with severe structural defects have, in a single study, not been associated with increased perioperative cardiac complications in elective non-cardiac surgery,¹⁶ however this study only examined cardiovascular complications. Because of increasingly stringent

screening protocols and improving medical management, major complications following TJA are low,¹⁷ which agreed with the findings of this study. However, the reduction of even minor complications can significantly decrease the costs of post-operative hospital stays.^{2,9,10}

Secondary findings of this study showed that advanced age, female sex, and elevated BMI independently predicted increased risk of AKI and decreased performance with physical therapy. This is consistent with previous studies identifying BMI, older age, female sex, diabetes, renal disease, pulmonary disease, and bleeding disorders^{2,14,15,18,19} as predictors of poor outcomes following TJA. Our analysis also found that diabetes may play a role in decreased performance with physical therapy. However, our study did not find that renal disease, pulmonary disease, or bleeding disorders independently correlate with measured post-operative outcomes.

There are a few limitations to this study. Firstly, systolic murmurs are not always accurately recorded if suspicion for heart disease is low.²⁰ Therefore, preoperative detection of heart murmurs may have been underreported. Secondly, although the study was adequately powered to measure the primary outcomes of interest, the sample size was not large enough to accurately measure less common outcomes such as DVT or PE. A much larger sample size would be needed to measure correlations between heart murmurs and these less common complications. Lastly, 40% of eligible patients chose not to participate in the study or had inadequate documentation. We have no indication that there was a pattern to which patients chose not to participate that would significantly alter the study groups, thus it is less likely to have significantly affected our analysis. Future studies are needed to determine longer term outcomes in patients with heart murmurs.

In summary we have found evidence that the simple detection of heart murmurs represents a low-cost strategy to help predict risk of AKI and decreased performance with physical therapy in patients undergoing TJA. Although often considered benign, detection of pre-operative murmurs may predict complications following surgery, and these patients may benefit from more aggressive fluid resuscitation following surgery. These findings may also help surgeons to better stratify and care for other non-cardiac surgical patients.

Conflict of interest

None.

Acknowledgements

The authors of this manuscript have no conflicts of interest to report. Author JF had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. JF and JA conducted all data analysis within this manuscript.

References

1. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240:205–213.
2. Ng VY, Lustenberger D, Hoang K, et al. Preoperative risk stratification and risk reduction for total joint reconstruction: AAOS exhibit selection. *J Bone Joint Surg Am*. 2013;95:e191–1510.2106/JBJS.L.00603.
3. Cowie B. The preoperative patient with a systolic murmur. *Anesthesiol Pain Med*. 2015;5:e3210510.5812/aapm.32105.
4. Bajaj NS, Agarwal S, Rajamanickam A, et al. Impact of severe mitral regurgitation on postoperative outcomes after noncardiac surgery. *Am J Med*. 2013;126:529–53510.1016/j.amjmed.2012.12.005.
5. Cheitlin M, Armstrong W, Aurigemma G, Beller G, Bierman F. ACC/AHA/ASE guideline update for the clinical application of echocardiography. *J Am Soc Echocardiogr*. 2003;200316:1091–1110.
6. Shub C. Echocardiography or auscultation?: How to evaluate systolic murmurs. *Can Fam Physician*. 2003;49:163–167.
7. Roelandt JRTC. The decline of our physical examination skills: is echocardiography to blame? *Eur Heart J Cardiovasc Imaging*. 2014;15:249–25210.1093/ehjci/jet195.
8. 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 Jt Surg*. 2007;89:78010.2106/JBJS.F.00222.
9. Huddleston JI, Maloney WJ, Wang Y, Verzier N, Hunt DR, Herndon JH. Adverse events after total knee arthroplasty. *J Arthroplasty*. 2009;24:95–10010.1016/j.arth.2009.05.001.
10. Zou GY. One relative risk versus two odds ratios: implications for meta-analyses involving paired and unpaired binary data. *Clin Trials*. 2007;4:25–3110.1177/1740774506075667.
11. Heidenreich PA, Schnitger I, Hancock SL, Atwood JE. A systolic murmur is a common presentation of aortic regurgitation detected by echocardiography. *Clin Cardiol*. 2004;27:502–506.
12. Guntheroth WG. Innocent murmurs: a suspect diagnosis in non-pregnant adults. *Am J Cardiol*. 2009;104:735–73710.1016/j.amjcard.2009.04.031.
13. 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;31:1155–116210.1016/j.arth.2015.11.044.
14. Snow R, Granata J, Ruhil AV, Vogel K, McShane M, Wasielewski R. Associations between preoperative physical therapy and post-Acute care utilization patterns and cost in total joint replacement. *J Bone Jt Surg-Am*. 2014;96:e165–1–810.2106/JBJS.M.01285.
15. Bozic KJ, Wagie A, Naessens JM, Berry DJ, Rubash HE. Predictors of discharge to an inpatient extended care facility after total hip or knee arthroplasty. *J Arthroplasty*. 2006;21:151–15610.1016/j.arth.2006.04.015.
16. Lee D, Chen CH, Hsu TL, Chiang CE, Wang SP, Chang MS. Reappraisal of cardiac murmurs related to aortic regurgitation. *Zhonghua Yi Xue Za Zhi (Taipei)*. 1995;56:152–158.
17. Pulido L, Parvizi J, Macgibeny M, et al. In hospital complications after total joint arthroplasty. *J Arthroplasty*. 2008;23:139–14510.1016/j.arth.2008.05.011.
18. Courtney PM, Whitaker CM, Gutsche JT, Hume EL, Lee G-C. Predictors of the need for critical care after total joint arthroplasty: an update of our institutional risk stratification model. *J Arthroplasty*. 2014;29:1350–135410.1016/j.arth.2014.02.028.
19. de Pablo P, Losina E, Phillips CB, et al. Determinants of discharge destination following elective total hip replacement. *Arthritis Rheum*. 2004;51:1009–101710.1002/art.20818.
20. Alfonso DT, Toussaint RJ, Alfonso BD, Strauss EJ, Steiger DT, Di Cesare PE. Nonsurgical complications after total hip and knee arthroplasty. *Am J Orthop (Belle Mead NJ)*. 2006;35:503–510.