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Original Research

Usefulness of Perioperative Laboratory Tests in Total Hip and Knee Arthroplasty: Are They Necessary for All Patients?

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ABSTRACT

Background: Laboratory studies are routinely obtained preoperatively and postoperatively for total hip arthroplasty (THA) and total knee arthroplasty (TKA). This study evaluates the necessity of routine, perioperative laboratory tests and identifies risk factors for laboratory-associated interventions.
Methods: This retrospective review evaluated 967 consecutive patients scheduled for primary, unilateral TKAs (n = 593) or THAs (n = 374) over an 18-month period at a single institution. Preoperative prothrombin time (PT) and International Normalized Ratio (INR), complete blood count (CBC), complete metabolic panel (CMP), and postoperative CBC and basic metabolic panel (BMP) were recorded along with any laboratory-associated intervention. Patient demographics and comorbidities identified risk factors for abnormal or actionable laboratory studies.
Results: Preoperatively, the actionable rates for PT/INR, CMP, and CBC were 0.3%, 1.4%, and 0.5%, respectively. Vascular, renal, and immunologic diseases were risk factors for an actionable CBC. Risk factors for an actionable CMP include cardiac arrhythmia and diabetes. There were no risk factors for an actionable PT/INR. Postoperatively, only 1.5% of BMPs and 1.5% of CBCs were actionable. Congestive heart failure, renal disease vascular disease, or history of cancer ($P = .030$) were risk factors for an actionable CBC. There were no risk factors for an actionable BMP. Patients with an abnormal preoperative lab were 2.4 times more likely to have an actionable postoperative lab. Patients with an actionable preoperative lab were 11.3 times more likely to have an actionable postoperative lab.
Conclusion: Routine preoperative and postoperative labs may not be necessary on all patients undergoing a TKA or THA. Comorbid risk factors and abnormal or actionable preoperative CMPs and CBCs can help determine the usefulness of postoperative laboratory assessments.

Introduction

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) have been heralded as two of the most successful surgical procedures [1,2]. The prevalence of hip and knee replacement continues to rise [3]. As the length of stay has decreased over the decades since the inception of these procedures [4,5], the hospital readmission rates [6] and revision rates have increased [7]. Providers and payers are concerned over the projection of economic burden to the health system given the stark rise in prevalence of primary and revision total joint replacement [8]. Of late, the old paradigm of spending independent of concern for quality has shifted to a more cost-conscious, value-driven episode of care [9]. Orthopedic surgeons are turning their attention to cost-containing alternatives that do not sacrifice quality.

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The preoperative assessment has been established as instrumental in improving outcomes after total joint replacement [10,11]. Preoperative assessments taking place closer to the date of planned surgery improves postoperative outcomes [12]. Patient risk factors for infection [13-21], transfusion [15,22,23], and electrolyte abnormalities [24-30] have been borne out in reports over the years. Reports over the past several decades have called into question the usefulness of perioperative labs in other facets of surgery [31-50]. With very little literature to source, there is not a consensus in the orthopedic community regarding perioperative lab assessment for routine THA and TKA.

Recent studies evaluating the utility of routine postoperative complete blood count (CBC) and basic metabolic panel (BMP) tests have been called into question given a low-percentage of actionable lab values [51-55]. These studies did not attempt to answer the question if preoperative studies are necessary for all patients. The purpose of this study is to evaluates the necessity of routine, perioperative laboratory tests and identifies risk factors for laboratory-associated interventions. We hypothesized that routine preoperative and postoperative laboratory assessments are not necessary for every patient. We set out to examine independent variables that would identify the profile of a patient for whom certain perioperative labs are not required for primary THA and TKA.

Materials and methods

This IRB-approved retrospective review, for which no funding was used, was performed on all patients who underwent primary, unilateral THA or TKA at a single institution from June 2016 through December 2017. Exclusion criteria included patients who underwent revision surgery, bilateral surgery, partial knee arthroplasty, and those with missing data. At our institution, all patients who are scheduled to undergo THA or TKA are evaluated by a specific, arthroplasty internal medicine team comprised of 4 physicians. These physicians evaluate and follow up the patients postoperatively as well. It is customary that all patients are preoperatively evaluated with a PT/INR, CMP, and CBC. Postoperatively, patients are assessed with a CBC and BMP. Further testing over ensuing hospital days is at the discretion of the rounding internal medicine physician.

All patient charts meeting inclusion and exclusion criteria were manually reviewed to analyze the following: age, gender, procedure type, diagnosis, body mass index, American Society of Anesthesiologists score, operative time, length of stay, preoperative PT/INR, CMP, CBC, and postoperative CBC and BMP.

Medical comorbidities were evaluated and categorized into the following 17 categories: hepatobiliary, hypertension, arrhythmia, coronary artery disease (CAD), congestive heart failure (CHF), vascular or hematologic conditions (such as peripheral vascular disease or blood dyscrasia), renal-chronic kidney disease (CKD), respiratory (such as asthma, chronic obstructive pulmonary disorder, or pulmonary hypertension), insulin-dependent diabetes mellitus (IDDM), non–insulin-dependent diabetes mellitus, diet-controlled diabetes mellitus, hyperlipidemia, endocrine (pituitary axis disorder), neoplastic (history of cancer), immunologic (rheumatologic disorders), neurologic disorders, or gastrointestinal disorders.

An abnormal preoperative PT/INR, CMP, or CBC and an abnormal postoperative CBC or BMP were identified and recorded if outside of our institution's normal ranges. Abnormal preoperative labs leading to further workup or resulting delay or cancellation of surgery were recorded. Abnormal postoperative labs that necessitated medical, in-hospital intervention (actionable) were recorded: fluid bolus, fluid restriction, electrolyte supplementation, addition or discontinuation of medication, addition of insulin, packed red blood cell (PRBC) or platelet transfusion, and additional testing. Specifically, regarding postoperative hemoglobin, our institution does not have an automatic hemoglobin trigger. In general, we transfuse PRBCs only if the patient is symptomatic.

Patient comorbidities were assessed as risk factors for abnormal or actionable labs in the preoperative and postoperative settings using logistic regression analyses. Data are presented using mean and standard deviations for continuous variables. Categorical data are presented as percentages with corresponding counts. Results are presented using odds ratios and 95% confidence intervals. A P value $< .05$ was considered statistically significant. All analyses were completed using a statistical analyses software program (Minitab, version 17.0; Minitab, LLC, State College, PA).

Results

A total of 985 patients undergoing primary TKA or THA were identified including 534 (54.2%) females and 451 males (45.8%). After the 18 bilateral cases were excluded and accounting for 9 cases that were delayed or canceled because of laboratory abnormalities, 958 patients undergoing unilateral THA or TKA remained in the study for analysis. A complete demographic profile of the patients is provided in Table 1.

The overall rate of abnormal preoperative PT/INR was 7.5% (n = 71). However, 52 of the 71 (73.2%) patients with abnormal preoperative PT/INR were on chronic anticoagulation. Of the patients not on chronic anticoagulation, the rate of abnormal preoperative PT/INR requiring medical intervention (actionable) including further diagnostic testing was 0.3% (3/852). One surgery was delayed, and one surgery was canceled because of an abnormal, actionable preoperative PT/INR. Table 2 details a complete list of preoperative labs, the associated rates of abnormal or actionable labs, and the associated rates of surgery delay or cancellation. Arrhythmia, CHF, vascular or hematologic conditions, CKD, and IDDM were found to be associated with a higher rate of abnormal preoperative PT. Table 3 details the 17 medical comorbidities evaluated and the respective odds ratios and confidence intervals for an abnormal or actionable preoperative lab. Arrhythmia, vascular or hematologic conditions, and IDDM were found to be associated with a higher rate of abnormal preoperative INR. None of the evaluated comorbidities had a higher risk of an actionable PT/INR.

Table 1
Patient demographics, diagnosis, operative time, length of stay.

Gender (N = 958)[a,b]	Female (%)	520 (54.3)
	Male (%)	438 (45.7)
Age (N = 958)[a,b]	Mean ± SD	64.2 ± 9.8
BMI (N = 958)[a,b]	Mean ± SD	29.6 ± 6.0
Surgery type (N = 958)[a,b]	Primary THA (%)	372 (38.8)
	Primary TKA (%)	586 (61.2)
ASA (N = 958)[a,b]	I (%)	15 (1.6)
	II (%)	554 (57.8)
	III (%)	379 (39.6)
	IV (%)	10 (1.0)
Diagnosis (N = 958)[a,b]	AVN	1 (0.1)
	FN FX	3 (0.3)
	OA	942 (98.3)
	Posttraumatic OA	9 (0.9)
	RA	3 (0.3)
Operative time (min) (N = 958)[a,b]	Mean ± SD	77.8 ± 19.1
Length of stay (h) (N = 958)[a,b]	Mean ± SD	34.8 ± 14.0
Length of stay (d) (N = 958)[a,b]	Mean ± SD	1.4 ± 0.6

BMI, body mass index; ASA, American Society of Anesthesiologists score; RA, rheumatoid arthritis; OA, osteoarthritis; FN FX, femoral neck fracture; AVN, avascular necrosis.
[a] Nine surgeries canceled.
[b] Eighteen bilateral surgeries excluded.

Table 2
Preoperative laboratory assessments.

Preoperative lab	Abnormal (%)	Abnormal & actionable (%)	Surgery delayed (%)	Lab implicated in delay (n)	Surgery cancellation (%)	Lab implicated in cancellation (n)
PT/INR N = 944	71 (7.5)	3 (0.3)	1 (0.1)	PT/INR (1)	1 (0.1)	PT/INR (1)
CMP N = 936	550 (58.8)	13 (1.4)	9 (1.0)	Sodium (2) BUN (3) Glucose (8) Hbg (8) AST (2) ALT (3) Alkaline phosphatase (1) Albumin (6)	5 (0.5)	Sodium (2) BUN (1) Glucose (4) Hbg (5) AST (2) ALT (2) Alkaline phosphatase (1) Albumin (3)
CBC N = 933	251 (26.9)	5 (0.5)	6 (0.6)	WBC (2) RBC (3) HCT (5) Hgb (4) Platelet (2)	3 (0.3)	WBC (2) RBC (2) HCT (2) Hgb (2) Platelet (1)

BUN, blood urea nitrogen.

The overall rate of abnormal preoperative CMP was 58.8%; however, only 1.4% were actionable. Of the 1.4% (13/936) patients with actionable CMPs, 9 of 13 patients (1.0%, 9/936) had their surgeries delayed, and 5 of the 9 delayed surgeries (0.5%, 5/936) were eventually canceled (Table 2). Data pertaining to the individual lab assessments are listed in Table 3. The medical comorbidities found to be associated with a higher rate of abnormal preoperative CMP were hepatobiliary conditions, hypertension, CHF, CKD, and diabetes. The comorbidities found to be associated with a higher rate of actionable CMPs include arrhythmia and IDDM (Table 3).

The overall rate of abnormal preoperative CBC was 26.9% (251/933); however, only 0.5% (5/933) were actionable (Table 1). Six (0.6%, 6/933) patients had their surgeries delayed because of an abnormal CBC. Of the 5 patients that had abnormal and actionable CBCs, 3 patients (0.3%, 3/933) eventually had their surgeries canceled because of the CBC abnormality. Data pertaining to the individual lab assessments are listed in Table 1. Hepatobiliary conditions, CAD, CH, vascular or hematologic conditions, CKD, and IDDM were associated with higher rates of abnormal preoperative CBC tests. However, only vascular or hematologic conditions, CKD,

Table 3
Seventeen medical comorbidities evaluated and the respective odds ratios and confidence intervals for an actionable preoperative laboratory assessment.

Preoperative comorbidities vs labs	Actionable PT N = 944 (%)	Actionable INR N = 944 (%)	Actionable CMP N = 936 (%)	Actionable CBC N = 933 (%)
Hepatobiliary	1 (0.1), $P = .155$ OR: 7.7 [0.69-86.8]	1 (0.1), $P = .155$ OR: 7.7 [0.69-86.8]	2 (0.2), $P = .245$ OR: 2.8 [0.59-12.76]	1 (0.1), $P = .306$ OR: 3.8 [0.41-34.09]
Cardiac-HTN	2 (0.2), $P = .723$ OR: 1.5 [0.14-16.9]	2 (0.2), $P = .723$ OR: 1.5 [0.14-16.94]	10 (1.1), $P = .131$ OR: 2.5 [0.69-9.28]	3 (0.3), $P = .888$ OR: 1.1 [0.19-6.83]
Cardiac-Arrhythmia	1 (0.1), $P = .671$ OR: 0.6 [0.05-6.7]	1 (0.1), $P = .669$ OR: 0.6 [0.05-6.63]	2 (0.2), $\mathbf{P = .020}$ OR: 0.2 [0.05-0.97]	4 (0.4), $P = .111$ OR: 4.9 [0.54-43.64]
Cardiac-CAD	0 (0)	0 (0)	2 (0.2), $P = .455$ OR: 1.9 [0.41-8.56]	0 (0)
Cardiac-CHF	0 (0)	0 (0)	0 (0)	1 (0.1), $P = .079$ OR: 13.4 [1.42-126.25]
Vascular or Hematologic	3 (0.3)	3 (0.3)	3 (0.3), $P = .429$ OR: 0.6 [0.17-2.21]	5 (0.5), $\mathbf{P = .001}$
Renal	2 (0.2), $P = .172$ OR: 5.0 [0.45-55.5]	2 (0.2), $P = .173$ OR: 5.0 [0.45-55.33]	4 (0.4), $P = .871$ OR: 1.1 [0.34-3.61]	4 (0.4), $\mathbf{P = .017}$ OR: 10.1 [1.12-90.43]
Respiratory	2 (0.2), $P = .088$ OR: 7.6 [0.69-84.15]	2 (0.2), $P = .089$ OR: 7.6 [0.68-83.73]	3 (0.3), $P = .873$ OR: 1.1 [0.30-4.08]	1 (0.1), $P = .951$ OR: 0.9 [0.10-8.40]
Metabolic-IDDM	1 (0.1), $P = .089$ OR: 12.9 [1.15-145.98]	1 (0.1), $P = .089$ OR: 12.9 [1.15-146.15]	7 (0.7), $\mathbf{P = .000}$ OR: 37.3 [11.8-118.2]	0 (0)
Metabolic-NIDDM	0 (0)	0 (0)	2 (0.2), $P = .237$ OR: 2.8 [0.61-13.01]	0 (0)
Metabolic-DC Diabetes	0 (0)	0 (0)	1 (0.1), $P = .579$ OR: 1.9 [0.24-14.90]	0 (0)
Metabolic-Hyperlipidemia	1 (0.1), $P = .718$ OR: 0.7 [0.06-7.18]	1 (0.1), $P = .718$ OR: 0.7 [0.06-7.18]	6 (0.6), $P = .851$ OR: 1.1 [0.37-3.33]	0 (0.0)
Endocrine	1 (0.1), $P = .797$ OR: 1.4 [0.12-15.28]	1 (0.1), $P = .797$ OR: 1.4 [0.12-15.28]	4 (0.4), $P = .756$ OR: 1.2 [0.37-3.96]	2 (0.2), $P = .529$ OR: 1.8 [0.30-10.88]
Neoplastic	1 (0.1), $P = .356$ OR: 3.5 [0.31-38.34]	1 (0.1), $P = .356$ OR: 3.5 [0.31-38.34]	1 (0.1), $P = .559$ OR: 0.6 [0.07-4.41]	0 (0)
Immunologic	0 (0)	0 (0)	0 (0)	2 (0.2), $\mathbf{P = .042}$ OR: 8.4 [1.39-51.32]
Nervous	0 (0)	0 (0)	0 (0)	0 (0)
Gastrointestinal	0 (0), $P = .102$	0 (0), $P = .103$	8 (0.9), $P = .058$ OR: 2.9 [0.95-8.99]	1 (0.1), $P = .439$ OR: 0.4 [0.05-4.01]

IDDM, non–insulin-dependent diabetes mellitus.
Bold values are statistically signficant.

Table 4
Postoperative day 1 laboratory assessments.

Postoperative day 1 labs	Abnormal (%)	Abnormal lab	Abnormal & actionable (%)	Abnormal & actionable lab
BMP N = 955	846 (88.6)	Sodium (76) Potassium (56) CO2 (44) BUN (157) Creatine (120) Glucose (798)	14 (1.5)	Sodium (6) Potassium (2) CO2 (1) BUN (4) Creatine (4) Glucose (11)
CBC N = 957	851 (88.9)	HCT (851) Hgb (819) WBC (6) RBC (10) Platelet (3)	14 (1.5)	HCT (14) Hgb (14) WBC (1) RBC (2) Platelet (0)

BUN, blood urea nitrogen.

and immunologic conditions were associated with actionable preoperative CBCs (Table 3).

On postoperative day number one (POD1), the overall rate of patients with an abnormal BMP was 88.6% (846/955). Only 1.5% (14/955) of patients had an actionable postoperative BMP. Specifics with regard to the content of the abnormal BMP can be found in Table 4. Medical comorbidities that were associated with an abnormal postoperative BMP included CHF, vascular or hematologic conditions, non–insulin-dependent diabetes mellitus, and gastrointestinal conditions (Table 5). None the medical comorbidities were associated with an increased risk for actionable BMPs.

The overall rate of patients with abnormal postoperative CBCs on postoperative day number one was 88.9% (851/957). However, only 14 (1.5%, 14/957) were actionable because of low hemoglobin levels that led to either transfusion of PRBCs or repeat testing (Table 4). CHF, vascular or hematologic conditions, CKD, and neoplastic conditions were found to have higher rates of actionable, postoperative CBCs (Table 5).

Patients with any abnormal preoperative lab were 2.4 times (odds ratio: 2.4, confidence interval: 1.0-5.9) more likely to have an actionable postoperative lab. Patients with any abnormal and actionable preoperative lab were 11.3 times more likely (odds ratio: 11.3, confidence interval: 3.8-33.5) to have an actionable postoperative lab (Table 6).

Discussion

Cost containment has been the focus of much discussion within the realm of total joint arthroplasty in recent years. Assuming a steady incidence in TKA and THA by 2030, the prevalence of TKA and THA is expected to rise by 4 million joint replacements in the United States [3]. Without efforts of cost containment per unit, this could will be crippling to the heavily burdened U.S. health-care system. To date, there are no specific guidelines for preoperative or postoperative laboratory assessments. To our knowledge, this is the first study to attempt qualify which patients should have preoperative PT/INR, CMP, and CBC as well as postoperative CBC and CMP by stratifying patients based on comorbidities. Moreover, we report on the postoperative actionable labs in the setting of abnormal or actionable preoperative labs. We have found that

Table 5
Medical comorbidities evaluated for increased risk of actionable postoperative d 1 laboratory assessments.

Postoperative d 1 comorbidities vs labs	Actionable BMP N = 955 (%)	Actionable CBC N = 957 (%)
Hepatobiliary	0 (0)	2 (0.2), $P = .254$ OR: 2.7 [0.59-12.32]
Cardiac-HTN	8 (0.8), $P = .964$ OR: 1.0 [0.35-2.98]	8 (0.8), $P = .963$ OR: 1.1 [0.38-2.98]
Cardiac-Arrhythmia	7 (0.7), $P = .725$ OR: 1.2 [0.42-3.47]	7 (0.7), $P = .719$ OR: 1.2 [0.42-3.49]
Cardiac-CAD	1 (0.1), $P = .842$ OR: 0.8 [0.11-6.32]	3 (0.3), $P = .137$ OR: 3.1 [0.82-10.91]
Cardiac-CHF	1 (0.1), $P = .261$ OR: 4.2 [0.52-33.80]	2 (0.2), $\mathbf{P = .025}$ OR: 9.7 [2.00-46.71]
Vascular or Hematologic	4 (0.4), $P = .726$ OR: 0.8 [0.25-2.62]	12 (1.3), $\mathbf{P = .000}$ OR: 12.6 [2.81-56.70]
Renal	4 (0.4), $P = .992$ OR: 1.0 [0.31-3.20]	8 (0.8), $\mathbf{P = .025}$ OR: 3.4 [1.17-9.87]
Respiratory	3 (0.3), $P = .987$ OR: 1.0 [0.28-3.66]	3 (0.3), $P = .984$ OR: 1.0 [0.28-3.67]
Metabolic-IDDM	2 (0.2), $P = .094$ OR: 4.7 [1.02-22.04]	2 (0.2), $P = .094$ OR: 4.8 [1.02-22.09]
Metabolic-NIDDM	1 (0.1), $P = .842$ OR: 1.2 [0.16-9.65]	0 (0)
Metabolic-DC Diabetes	1 (0.1), $P = .627$ OR: 1.7 [0.22-13.57]	0 (0)
Metabolic-Hyperlipidemia	6 (0.6), $P = .957$ OR: 1.0 [0.33-2.82]	3 (0.3), $P = .081$ OR: 0.4 [0.10-1.26]
Endocrine	4 (0.4), $P = .832$ OR: 1.1 [0.35-3.66]	7 (0.7), $P = .055$ OR: 2.9 [1.00-8.30]
Neoplastic	1 (0.1), $P = .473$ OR: 0.5 [0.07-3.91]	5 (0.5), $P = .030$ OR: 3.8 [1.26-11.56]
Immunologic	1 (0.1), $P = .978$ OR: 1.0 [0.13-7.54]	2 (0.2), $P = .366$ OR: 2.2 [0.47-9.78]
Nervous	0 (0), $P = .084$	2 (0.2), $P = .623$ OR: 1.5 [0.33-6.75]
Gastrointestinal	5 (0.5), $P = .994$ OR: 1.0 [0.33-3.00]	5 (0.5), $P = .999$ OR: 1.0 [0.33-3.01]

IDDM, non–insulin-dependent diabetes mellitus.
Bold values are statistically signficant.

Table 6
Likelihood of having an abnormal or actionable postoperative lab if an abnormal or actionable preoperative lab is present.

Preop vs. Postop d 1	Abnormal	*P*-Value (Chi Squared)	Abnormal (pre- Op) & Actionable (postop)	*P*-Value (Chi Squared)	Actionable (pre- Op) & Actionable (postop)	*P*-Value (Chi squared)
Preop	641 (66.4)		641 (66.3)		19 (2.0)	
POD1	956 (98.3)	N = 636 *P* = .285 OR: 1.9 [0.6-6.9]	34 (3.5)	N = 28 **P = .034** OR: 2.4 [1.0-5.9]	34 (3.5)	N = 5 **P = .000** OR: 11.3 [3.8-33.5]

POD1, postoperative day number one.
Bold values are statistically signficant.

routine postoperative lab assessments are not necessary in patients undergoing unilateral TKA or THA.

There is a paucity of literature guiding physicians on which patients would benefit from a preoperative PT/INR. This study reports an abnormal PT/INR incidence of 7.5% across nearly 1000 patients who underwent preoperative testing for THA or TKA. The vast majority of abnormal results were from patients on anticoagulation. Thus, it is not surprising that cardiac arrhythmia was a comorbid risk factor. Another reasonable finding was that patients with vascular or hematologic conditions also are at increased risk for an abnormal PT/INR. Many patients with vascular disease or a history of blood dyscrasia are on chronic anticoagulation in the form of warfarin which would prolong the PT leading to an increased INR. One interesting finding was that patients with renal disease and IDDM were at risk for an increased PT/INR. Despite these findings of abnormal PT/INR, only 3 (0.3%, 3/852) patients with abnormal PT/INRs necessitated further diagnostic workup or experienced surgical delay or cancellation. This calls into the question routine preoperative testing for PT/INR. Our institution's current Medicare reimbursement rate for a PT/INR is $5.36. Extrapolating this number across 4 million additional THAs and TKAs by 2030 would yield an additional cost to the health-care system of $21.44 million dollars. One study published by Rohrer et al. evaluated the utility of preoperative PT/INR to identify occult coagulopathies in all patients before elective general and vascular procedures [45]. The authors found that indiscriminate testing without considering historical or clinical indicators of coagulopathy resulted in 46% of screen coagulations tests to be of no value. Bushick et al. came to the same conclusion after a similar study published in 1989 [32]. Peterson et al. published a 1998 position article recommending preoperative surgical testing with a PT/INR only in patients who have a history suggesting a possible bleeding disorder [44]. Our data combined with these previously published studies suggest that indiscriminate, routine, preoperative PT/INR testing lacks utility.

The idea of discriminately ordering preoperative laboratory testing is not new. Vetter et al. published a 2017 column detailing a new pilot program with an aim at improving value in joint replacement surgery [11]. The authors report that the goal of the program is to increase value by showing that quality can increase while cost decreases by targeting specific patients for preoperative laboratory testing. At our institution, the current Medicare reimbursement rate for a CMP is $14.39 and $6.79 for a CBC without differential. These 2 tests per total joint replacement cost $21.18. Extrapolating this cost across 4 million additional THAs and TKAs expected by year 2030 would yield a cost of $84.72 million to the health-care system. We are not advocating for the elimination of all preoperative testing. Rather, the current literature and our data suggest that selective, discriminate testing is prudent. Our data suggest that routine testing for all patients is of little utility. Furthermore, we have found specific comorbidities (Table 3) that may help guide physicians based on patients' histories alone. Our data suggest that patients with a past medical history of arrhythmia, CHF, vascular or hematologic conditions, CKD, and IDDM would benefit from a preoperative PT/INR. Patients with a history of hepatobiliary disease, hypertension, arrhythmia, CHF, kidney disease, and diabetes mellitus would benefit from a preoperative CMP. Finally, patients with a history of hepatobiliary disease, arrhythmia, CAD, CHF, vascular or hematologic disease, CKD, and IDDM would benefit from a preoperative CBC. Although our study reports a low actionable incidence for these labs, especially the PT/INR, these preoperative labs may help predict abnormal and actionable labs (Table 6).

Recent literature has tended to focus on the utility of postoperative laboratory assessment of joint replacement patients. Shaner et al. recently published a report of 322 patients undergoing partial knee replacement [53]. The authors report an actionable rate of 1.6%. The total hospital charges associated with postoperative lab tests in this study totaled over $84,000. The authors conclude that routine CBC and BMP testing was not necessary nor cost-effective. Kildow et al. recently published a study reporting on the utility of a BMP after total joint replacement in 767 patients [51]. After a multivariate logistic regression analysis, the authors state that patients with diabetes, CKD, or with an abnormal preoperative BMP should obtain a BMP after total joint arthroplasty. Similarly, Kildow et al. published a study reporting on the utility of CBC after THA [54]. After a review of 352 patients, the authors concluded that postoperative CBCs in most patients yielded no actionable information that would otherwise necessitate medical intervention. These studies' findings are congruent with the results of our study. We implore a selective, discriminate ordering of postoperative BMPs and CBCs. Patients with a history significant for CHF, vascular or hematologic conditions, gastrointestinal conditions, or diabetes mellitus would benefit from a postoperative BMP (Table 5). Although we did not find a higher incidence of abnormal or actionable postoperative BMP in insulin-dependent diabetics, we believe that this may be due to vigilant, strict blood glucose monitoring and treatment by our anesthesia and medicine colleagues. Because insulin and well-functioning kidneys play vital roles in cellular potassium homeostasis, we still advocate for a postoperative BMP for all patients with diabetes and CKD. The rapid decline in patients with abnormal potassium levels is far more ominous that other electrolyte imbalances that present with a more insidious clinical decline. Patients with a past medical history suggestive of CHF, vascular or hematologic disease, CKD, or history of cancer, especially those with suppressed bone marrow, would benefit from a postoperative CBC (Table 5).

One of the limitations of this retrospective review was our inability to assess the clinical symptoms of patients with abnormal preoperative or postoperative laboratory values. We did not discern between abnormal lab values just outside of the normal range and those far outside the normal range. While it may be safe to assume that the actionable labs in this study were likely farther outside the normal range, we cannot say that with certainty. In some cases, lab values are treated based on their value as opposed to the clinical

symptoms the patient exhibits. Another limitation of the study is that we did not account for chronic medications, such as antihypertensive or antipsychotic medications, that may skew these lab assessments. While we attempted to be as comprehensive as possible with the medical comorbidities evaluated in this study, other medical problems might not have been included because of the constraints inherent to a retrospective review. In addition, we did not evaluate intraoperative factors such as fluid administration, urine output, or medications. Finally, while our medical team physicians have attempted to standardize their practice, this may not account for one's judgment to have action upon a particular lab value in conjunction with the patients' symptoms.

Conclusions

Routine preoperative and postoperative laboratory assessments for all patients undergoing unilateral TKA or THA does not appear to be necessary based on the low rates of medical intervention. To our knowledge, this is the first study that attempts to provide practitioners guidelines for which patients' preoperative and postoperative laboratory assessments should be ordered based on a comprehensive list of comorbidities. Selective ordering of specific lab tests based on comorbidities may help eliminate fiscal waste in THA and TKA and, thus, increase the value of such procedures.

Conflict of interests

D. A. Dennis received royalties from DePuy and Johnson & Johnson Company; is in the speakers bureau of/gave paid presentations for Corin U.S.A, DePuy, and Johnson & Johnson Company; is a paid consultant for Corin U.S.A, DePuy, and Johnson & Johnson Company; has stock or stock options in Corin U.S.A and Joint Vue; received research support from DePuy, Johnson & Johnson Company, and Porter Adventist Hospital; received royalties, financial, or material support from Wolters Kluwer Health—Lippincott Williams & Wilkins; is in the medical/orthopaedic publications editorial/governing board of CORR, JOA, JBJS, and Orthopedics Today. J. M. Jennings received royalties from Total Joint Orthopedics; is a paid consultant for Total Joint Orthopedics and Xenex; has stock or stock options in Xenex; and received reserahc support from DePuy.

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