The Journal of Arthroplasty 31 (2016) 1170–1174

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Health Policy & Economics

The Total Joint Arthroplasty Cardiac Risk Index for Predicting Perioperative Myocardial Infarction and Cardiac Arrest After Primary Total Knee and Hip Arthroplasty

Brian R. Waterman, MD [a], Philip J. Belmont Jr., MD [b], Julia O. Bader, PhD [a, c], Andrew J. Schoenfeld, MD, MSc [d, *]

[a] Department of Orthopaedic Surgery and Rehabilitation, William Beaumont Army Medical Center, El Paso, Texas
[b] Anderson Orthopaedic Clinic, Alexandria, Virginia
[c] Department of Clinical Investigations, William Beaumont Army Medical Center, El Paso, Texas
[d] Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts

ARTICLE INFO

Article history:
Received 30 September 2015
Received in revised form
4 December 2015
Accepted 8 December 2015
Available online 17 December 2015

Keywords:
risk index
total hip arthroplasty
total knee arthroplasty
myocardial infarction
cardiac complications

ABSTRACT

Background: Current indices fail to consistently predict risk for major adverse cardiac events after major total joint arthroplasty.
Methods: All primary total knee arthroplasty (TKA) and total hip arthroplasty (THA) were identified from the National Surgical Quality Improvement Program data set. Based on prior analyses, age ≥80 years, history of hypertension, and history of cardiac disease were evaluated as predictors of myocardial infarction and cardiac arrest using stepwise multivariate logistic regression. A series of predictive scores were constructed and weighted to identify the influence of each variable on 30-day postoperative cardiac events, while comparing with the Revised Cardiac Risk Index (RCRI).
Results: Among 85,129 patients, age ≥80 years, hypertension, and a history of cardiac disease were all statistically significant predictors of postoperative cardiac events (0.32%; n = 275) after TKA and THA ($P \leq .02$). Equal weighting of all variables maintained the highest discriminative capacity in both THA and TKA cohorts. Adjusted models explained 75% and 71% of the variation in postoperative cardiac events for those with THA and TKA, respectively, without statistically significant lack of fit ($P = .52$; $P = .23$, respectively). Conversely, the RCRI was not a significant predictor of postoperative cardiac events after TKA (odds ratio, 3.36; 95% CI, 0.19, 58.04; $P = .40$), although it maintained a similar discriminative capacity after THA (76%).
Conclusion: The current total joint arthroplasty Cardiac Risk Index score was the most economical in predicting postoperative cardiac complication after primary unilateral TKA and THA. The RCRI was not a significant predictor of perioperative cardiac events for TKA patients but performed similarly to the current model for THA.

With reproducible clinical outcomes, measurable improvements in patient-reported quality of life, and reliable long-term implant survivorship, the demand for total knee arthroplasty (TKA) and total hip arthroplasty (THA) has escalated dramatically over the past 50 years [1,2]. Some authors project that over 4 million primary TKA and THA procedures will be performed annually in the United States by 2030, a reported increase of up to 673% from 2005 [3]. Yet, despite the prevalence of lower extremity total joint arthroplasty (TJA), particularly in patients with comorbid disease, current algorithms for risk stratification and the prediction of perioperative complications are underdeveloped [4,5]. Among adverse clinical outcomes, cardiac complications represent the principal cause of death for individuals undergoing noncardiac

Investigation performed at Department of Orthopaedic Surgery and Rehabilitation, William Beaumont Army Medical Center, El Paso, Texas; Anderson Orthopaedic Clinic, Mount Vernon, Virginia; Brigham and Women's Hospital, Boston, Massachusetts.
One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2015.12.013.
The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Department of Defense or the US government. Some authors are employees of the US government. No funding was received in support of the performance of this study or the composition of the article.
* Reprint requests: Andrew J. Schoenfeld, MD, MSc, Department of Orthopedics, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115.

http://dx.doi.org/10.1016/j.arth.2015.12.013
0883-5403/

surgery [6,7], with 30-day cardiac-related mortality reported in 0.35% of THA and 0.18% of TKA patients [8]. Furthermore, major cardiac events may contribute significant short-term morbidity in as many as 2% of patients undergoing THA and TKA [4,8]. Such events may extend the length of hospital stay by an average of 11 days [9].

In an attempt to improve on the predictive capacity of existing risk indices and better inform preoperative patient counseling, the purpose of this study was to establish a new TJA cardiac risk index and validate its clinical utility within a broad, contemporary arthroplasty cohort in the United States. Based on prior work at our institution [8], we hypothesized that this new adjusted index would significantly predict postoperative cardiac events after lower extremity TJA and demonstrate superior discriminative capacity than the Revised Cardiac Risk Index (RCRI) currently espoused under the American College of Cardiology (ACC) and American Heart Association (AHA) 2007 guidelines [10].

Materials and Methods

This study received approval from our institution's investigational review board before its commencement. After authorization from the American College of Surgeons, the data used in this analysis were obtained from the National Surgical Quality Improvement Program (NSQIP) public use files for the years 2012 and 2013. The methodology behind data collection and quality control within the NSQIP has been extensively described in the recent literature [8,11-13]. Patients eligible for inclusion in this analysis were those who underwent a unilateral primary TKA or THA (determined by current procedural terminology code) between January 1, 2012, and December 31, 2013, and had their clinical information registered with the NSQIP. The data used in this study was limited to that of NSQIP 2012 and 2013 because 2006-2011 data had been used in the preliminary work [8] on which the new TJA cardiac risk index was based. Patients who underwent bilateral TJA during a single hospital encounter, revision arthroplasty procedures, and/or had a surgical indication due to fracture were excluded from this investigation. The coding algorithms used to identify eligible patients are available from the authors by request.

All patients identified for inclusion had their NSQIP records abstracted, and demographic information (age, gender, and race), medical history, perioperative characteristics, and the occurrence of postoperative cardiac events (eg, cardiac arrest or acute myocardial infarction) recorded. Medical history consisted of an itemized list of medical comorbidities, including hypertension and cardiac disease, and the American Society of Anesthesiologists (ASA) score assigned at the time of surgery. Perioperative characteristics consisted of operative time in minutes, and the type of anesthesia, classified as general, spinal and/or epidural, or other.

The dependent variable for this analysis was the occurrence of an acute postoperative cardiac event, defined as myocardial infarction or cardiac arrest requiring cardio-pulmonary resuscitation, within 30 days of TJA. Based on the results of our prior analysis [8], we sought to evaluate age ≥80 y, history of hypertension, and history of cardiac disease as the primary predictor variables. Those aged ≥80 years were compared with patients aged 79 years or younger. Individuals with a history of hypertension were compared with those without this condition, and patients with a history of cardiac disease were, likewise, compared with those without that comorbidity. The predictors were initially evaluated using logistic regression to ensure that they were statistically associated with postoperative cardiac events individually and in combination. A multivariable logistic regression analysis was then performed, controlling for gender, race, ASA score, operative time, and the type of anesthesia to ensure that the predictors retained significance after adjusting for these confounders. The results of all logistic regression tests were conferred using odds ratios (ORs) and 95% CIs, and *P* values. Statistically significant predictor variables were considered to be those that displayed ORs and 95% CIs exclusive of 1.0, with *P* values <.05, following adjusted multivariable analysis. The discriminative capacity and calibration of the final model was assessed using the c-statistic and Hosmer–Lemeshow goodness-of-fit test, respectively. All testing was performed separately in the TKA and THA cohorts.

Development and Evaluation of the Predictive Score

Based on the performance of the predictor variables in the adjusted logistic regression model, a series of predictive scores were constructed that weighted the influence of each predictor on the odds of a postoperative cardiac event. The initial model weighted each variable equally, while subsequent renditions emphasized a history of cardiac disease and assessed for the presence of a ceiling effect in terms of scoring. The discriminative capability of each model was evaluated using the c-statistic, and the calibration was determined by Hosmer–Lemeshow testing. The optimal score was considered, a priori, to be the one which demonstrated a gradient dose–response effect, maintained the greatest discriminative capacity, was well calibrated to the data, and performed equally well in both the TKA and THA cohorts.

The sensitivity and specificity of the final models were assessed as was the performance of the new TJA cardiac risk score against that of the RCRI using adjusted multivariable logistic regression that accounted for patient age, gender, race, ASA score, operative time, and the type of anesthesia. The correlation between the new TJA cardiac risk score and the RCRI was evaluated using the Pearson correlation coefficient.

Results

Cohort Composition

This study consisted of 51,063 patients who received TKA and 34,066 who underwent THA. In both cohorts, most patients were women (TKA, 63%; THA, 56%; Table 1) and of white race (TKA, 90%; THA, 91%). Forty-six percent of those undergoing TKA and 40% of patients receiving THA had ASA scores ≥3. General anesthesia was the most common type of anesthesia in both groups (TKA, 54%; THA, 56%). The average age of patients in the TKA group was 67.1 (standard deviation, 9.8), whereas it was 65.4 (standard deviation, 11.8) among those receiving THA. Eleven percent and 12% of patients receiving TKA and THA, respectively, were aged 80 years or older. A plurality of patients had the diagnosis of hypertension (TKA, 66%; THA, 57%), and cardiac disease was present in approximately 1.2% of the cohorts (TKA, 1.2%; THA, 1.2%). Postoperative cardiac events occurred in 158 patients (0.3%) after TKA and in 117 individuals (0.3%) after THA.

Logistic Regression Testing

Logistic regression analysis revealed that age ≥80 years, hypertension, and a history of cardiac disease were all statistically significant predictors of postoperative cardiac events in both the TKA and THA cohorts (Table 2). These factors retained significance, even after multivariable analysis that adjusted for confounders. After adjusted analysis, among patients receiving TKA, the odds of postoperative cardiac events were increased by 85% (OR, 1.85; 95% CI, 1.23-2.79; $P = .003$) for those aged 80 years and older. Patients with hypertension experienced a more than 2-fold elevation in the

Table 1
Demographic Characteristics of the Total Knee Arthroplasty (TKA) and Total Hip Arthroplasty (THA) Cohorts.

Characteristics	No. of TKA Patients (% of Study Cohort)	No. of THA Patients (% of Study Cohort)
Age, y (mean ± standard deviation)	67.1 ± 9.8	65.4 ± 11.8
Age ≥80 y	5778 (11)	4174 (12)
Age ≤79 y	45,285 (89)	29,892 (88)
Gender		
Male	18,942 (37)	15,063 (44)
Female	32,121 (63)	19,003 (56)
Race		
White	40,662 (90)	27,110 (91)
Black	3340 (7)	2173 (7)
Other	1486 (3)	689 (2)
ASA classification		
ASA ≥3	23,615 (46)	13,721 (40)
ASA ≤2	27,407 (54)	20,305 (60)
Anesthesia type		
General	27,795 (54)	19,072 (56)
Spinal/epidural	19,170 (38)	12,336 (36)
Other	4097 (8)	2657 (8)
Operative time, min (mean ± standard deviation)	92.5 ± 37.1	93.5 ± 41.8

ASA, American Society of Anesthesiologists Score.

odds of postoperative cardiac events (OR, 2.14; 95% CI, 1.30-3.52; $P = .003$), whereas the odds increased by a factor of 4 for those with a history of cardiac disease (OR, 4.03; 95% CI, 2.08-7.80; $P < .001$).

For patients treated with THA, age 80 years and older increased the odds of postoperative cardiac event by more than a factor of 4 (OR, 4.39; 95% CI, 2.92-6.61; $P < .001$), with a similar effect encountered for those with a history of cardiac disease (OR, 3.74; 95% CI, 1.77-7.88; $P < .001$; Table 2). A history of hypertension increased the odds of postoperative cardiac event by close to a factor of 2 (OR, 1.82; 95% CI, 1.09-3.03; $P = .02$). The final adjusted model for TKA explained 71% of the variation in postoperative cardiac events, whereas that for THA explained 76% of the variation. There was no statistically significant evidence of poor fit for either model (TKA, $P = .24$; THA, $P = .62$).

Development and Evaluation of the Predictive Score

The optimal predictive score that demonstrated a gradient dose−response effect in terms of influencing the odds of postoperative cardiac events, maintained the highest discriminative capacity and performed as well in both THA and TKA cohorts was the score that weighted all predictor variables equally. Thus, the resultant predictive score ranges from 0 to 3, with one point each attributed for the presence of hypertension, a diagnosis of cardiac disease, and age of 80 years or older. For example, patients with a score of zero have none of these risk factors, whereas those with a score of 3 have all 3.

In unadjusted analysis, the predictive score was found to be significantly associated ($P < .001$) with the odds of postoperative cardiac events, and these associations persisted in adjusted analysis ($P < .001$, Table 3). The predictive score was associated with race, gender, ASA score, and operative time for TKA patients and gender, ASA score, and type of anesthesia for THA patients, supporting the inclusion of these factors in the adjusted analysis.

In the adjusted model, compared with TKA patients with a score of zero, individuals with scores of 1 (OR, 2.23; 95% CI, 1.27-3.89), 2 (OR, 4.84; 95% CI, 2.58-9.08), and 3 (OR, 11.19; 95% CI, 2.49-50.40) were all found to be at increased odds of postoperative cardiac events. In the THA cohort, compared with individuals with a score of 0, patients with scores of 1 (OR, 2.43; 95% CI, 1.27-4.63), 2 (OR, 9.97; 95% CI, 5.06-19.63), and 3 (OR, 16.27; 95% CI, 3.49-75.85) were also at increased odds of postsurgical cardiac events. The c-statistic was 0.75 for the model considering THA and 0.71 for TKA. There was no evidence of statistically significant lack of fit for either of these models (TKA: $P = .23$; THA: $P = .52$). At the 0.3% cardiac event level, the identical incidence of cardiac events as encountered in this study, the sensitivity and specificity of the predictive score was 89% and 31%, respectively, for TKA patients and 88% and 40%, respectively, for THA patients. Identical values were encountered at a 0.2% rate of cardiac events.

In comparison, the RCRI was not found to be a significant predictor of postoperative cardiac events after TKA (OR, 3.36; 95% CI, 0.19-58.04; $P = .40$). Among patients receiving THA, the cardiac risk index alone explained only 51% of the variation in postoperative cardiac events and showed poor precision, despite having a statistically significant effect, overall (OR, 29.04; 95% CI, 8.4-100.23; $P < .001$). In THA patients, the final adjusted model including the RCRI had a c-statistic comparable with that of our predictive score (0.76). The new TJA predictive score for cardiac events was correlated with the RCRI for both TKA ($r = 0.16$, $P < .001$) and THA ($r = 0.20$, $P < .001$) patients.

Discussion

Among an at-risk demographic of 85,129 patients undergoing TKA and THA from the NSQIP data sample, the current investigation reports that 0.32% of all TJA patients experience a postoperative cardiac event within the 30 days of surgery. The TJA Cardiac Risk Index was a significant predictor of cardiac complications in this

Table 2
The Effect of Age ≥80 y, Hypertension, and History of Cardiac Disease on 30-d Postoperative Cardiac Events as Determined by Logistic Regression in Unadjusted and Adjusted Analyses for the Total Knee Arthroplasty (TKA) and Total Hip Arthroplasty (THA) Cohorts.

Variables	Unadjusted			Adjusted[a]		
	Odds Ratio	95% CI	P Value	Odds Ratio	95% CI	P Value
TKA						
Age ≥80 y	2.0	1.37-2.91	<.001	1.85	1.23-2.79	.003
Hypertension	2.73	1.75-4.26	<.001	2.14	1.30-3.52	.003
History of Cardiac Disease	6.60	3.77-11.54	<.001	4.03	2.08-7.80	<.001
THA						
Age ≥80 y	5.23	3.60-7.59	<.001	4.39	2.92-6.61	<.001
Hypertension	2.05	1.31-3.23	.002	1.82	1.09-3.03	.02
History of cardiac disease	3.69	1.77-7.70	<.001	3.74	1.77-7.88	<.001

[a] Adjusted for gender, race, American Society of Anesthesiologists Score, operative time, and anesthesia type.

Table 3
The Association Between the Predictive Score and 30-d Postoperative Cardiac Events as Determined by Logistic Regression in Unadjusted and Adjusted Analyses for the Total Knee Arthroplasty (TKA) and Total Hip Arthroplasty (THA) Cohorts.

Predictive Score	Unadjusted			Adjusted[a]		
	Odds Ratio	95% CI	P Value	Odds Ratio	95% CI	P Value
TKA						
0	Reference			Reference		
1	2.88	1.74-4.76	<.001	2.23	1.27-3.89	.005
2	7.32	4.18-12.81	<.001	4.84	2.58-9.08	<.001
3	24.59	7.14-84.71	<.001	11.19	2.49-50.40	.002
THA						
0	Reference			Reference		
1	3.08	1.71-5.54	<.001	2.43	1.27-4.63	.007
2	13.90	7.64-25.27	<.001	9.97	5.06-19.63	<.001
3	19.78	4.44-88.17	<.001	16.27	3.49-75.85	<.001

[a] Adjusted for gender, race, American Society of Anesthesiologists Score, operative time, and anesthesia type.

cohort after multivariable regression analysis, with equal weighting assigned to the selected, high-risk variables (ie, age ≥80 years, hypertension, and a history of cardiac disease). This adjusted model maintained a high discriminative capacity and an appropriate risk gradient for postoperative cardiac events after either TKA or THA. Conversely, the RCRI inconsistently anticipated short-term cardiac morbidity, with no significant capacity for prediction among patients undergoing TKA.

Given the rising prevalence of medical comorbidities within the general US population [11-15] and increasing scrutiny of perioperative complications by the Centers for Medicare and Medicaid Services, the detection and quantification of clinically meaningful risk factors that predict adverse outcomes are of paramount importance. This has, in part, contributed to an overutilization of diagnostic cardiac testing and unwarranted interventions in asymptomatic or low-risk patients with false positive results. Sheffield et al [5] estimated that over 56,000 Medicare patients underwent unnecessary stress testing before noncardiac surgery, and up to 2.9% of asymptomatic patients undergo angiography or cardiac revascularization.[16] In low-risk or asymptomatic patients, overzealous cardiac work-ups can lead to significant surgical delays and excessive health care expenditures without measurable benefits in clinical outcomes [16-20].

The initial description of the RCRI was validated as a 6-point scale for assessments of cardiac risk [21], and encompassed 6 independent predictors: high-risk surgery, history of ischemic heart disease, history of congestive heart failure, history of stroke, preoperative treatment with insulin, and preoperative serum creatinine >2.0 mg/dL. Subsequently incorporated by the ACC/AHA Task Force in 2007, the updated practice guidelines were promulgated to guide preoperative evaluation and risk stratification of patients' risk for cardiovascular complications [10]. However, the RCRI and other current risk indices have inconsistently performed for selected cohorts, with suboptimal discriminative capacity identified for those undergoing vascular interventions [22] and other noncardiac surgeries [23,24]. Devereaux et al [25] also reported that the actual rate of major cardiovascular complications was approximately 6-fold greater than that predicted by the RCRI among an international prospective cohort of 432 patients.

In the wake of these findings, many authors have encouraged the development of new propensity scales to improve the prediction of major adverse cardiac events [25-27]. The 2014 ACC/AHA practice guidelines have acknowledged the limitations of RCRI as the previous "gold standard" and have integrated additional risk models adapted from the NSQIP [24,28,29]. Gupta et al [24] described an interactive cardiac risk calculator comprising type of surgery, dependant functional status, abnormal creatinine, American Society of Anesthiologists' class, and advancing age. When applied to 211,410 patients undergoing noncardiac surgery in the NSQIP, this risk model exhibited significantly better performance than the RCRI for prediction of myocardial infarction and/or cardiac arrest after multivariate logistical regression analysis. In an orthopedic cohort undergoing THA and TKA at a single institution, NSQIP risk estimates for cardiac complications significantly correlated with actual occurrences [4]. However, the c-statistic for this analysis demonstrated poor discriminative capacity (0.693) and could not accurately discern individual cardiac risk [4]. By comparison, the adjusted models used in the present study accounted for 75% and 71% of all cardiac complications in THA and TKA patients, respectively.

As with any database-driven research, this investigation does have certain inherent limitations. Although the NSQIP patient sampling is diversified across nearly 500 participating centers, this demographic cohort may still be susceptible to selection and indication bias that could confound results. In addition, although this study establishes a predictive model within the NSQIP data set, future studies should seek to apply the TJA Cardiac Risk Index to outside populations to confer external validity. The authors also acknowledge unavailability of other relevant parameters from the database, such as glomerular filtration rate cutoffs (vis-à-vis predetermined creatine thresholds) [27] or other variables that may significantly contribute to enhanced discrimination. Finally, the NSQIP does not afford extended cardiac surveillance for the full "episode of care" (eg, 90 days postoperatively) as defined by Centers for Medicare and Medicaid Services. This could underestimate the role of other key variables predicting delayed cardiac complications after the initial 30-day window. However, Belmont et al [8] demonstrated that nearly 80% of all major cardiac complications and 44% of all perioperative deaths occurred within the first week after TKA or THA. Nonetheless, these remain important lines of further inquiry.

Conclusion

A TJA Cardiac Risk Index score that considered age ≥80 years, history of cardiac disease, and hypertension requiring medication successfully predicted postoperative cardiac complications after primary unilateral TKA and THA. In comparison, the RCRI was not a significant predictor of perioperative cardiac events for TKA patients but performed similarly to the current model for THA. The validated TJA Cardiac Risk Index can help identify patients for both primary unilateral TKA and THA who are at greatest risk for 30-day cardiac events. Preoperative cardiology evaluation for identified individuals and medical comanagement in the perioperative period may ultimately decrease the likelihood for adverse events in this population.

References

1. Hawker GA, Badley EM, Croxford R, et al. A population-based nested case-control study of the costs of hip and knee replacement surgery. Med Care 2009;47(7):732.
2. Kim S. Changes in surgical loads and economic burden of hip and knee replacements in the US: 1997-2004. Arthritis Rheum 2008;59(4):481.
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(4):780.
4. Edelstein AI, Kwasny MJ, Suleiman LI, et al. Can the American College of Surgeons risk calculator predict 30-day complications after knee and hip arthroplasty? J Arthroplasty 2015;30(9 Suppl):5.
5. Sheffield KM, McAdams PS, Benarroch-Gampel J, et al. Overuse of preoperative cardiac stress testing in medicare patients undergoing elective noncardiac surgery. Ann Surg 2013;257(1):73.
6. Mangano DT, Browner WS, Hollenberg M, et al. Association of perioperative myocardial ischemia with cardiac morbidity and mortality in men undergoing noncardiac surgery. The Study of Perioperative Ischemia Research Group. N Engl J Med 1990;323(26):1781.
7. Mangano DT. Preoperative risk assessment: many studies, few solutions. Is cardiac risk assessment paradigm possible? Anesthesiology 1995;83(5):897.
8. Belmont Jr PJ, Goodman GP, Kusnezov NA, et al. Postoperative myocardial infarction and cardiac arrest following primary total knee and hip arthroplasty: rates, risk factors, and time of occurrence. J Bone Joint Surg Am 2014;96(24):2025.
9. Fleischmann KE, Goldman L, Young B, et al. Association between cardiac and noncardiac complications in patients undergoing noncardiac surgery: outcomes and effects on length of stay. Am J Med 2003;115(7):515.
10. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: executive summary. J Am Coll Cardiol 2007;50(17):1707.
11. 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;28:1499.
12. Belmont Jr PJ, Goodman GP, Hamilton WG, et al. Morbidity and mortality in the thirty-day period following total hip arthroplasty: risk factors and incidence. J Arthroplasty 2014;29(10):2025.
13. Belmont Jr PJ, Goodman GP, Waterman BR, et al. Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. J Bone Joint Surg Am 2014;96(1):20.

14. Gonzalez Della Valle A, Chiu YL, Ma Y, et al. The metabolic syndrome in patients undergoing knee and hip arthroplasty: trends and in-hospital outcomes in the United States. J Arthroplasty 2012;27:1743.
15. Hedley AA, Ogden CL, Johnson CL, et al. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002. JAMA 2004;291(23):2847.
16. Chou R, Arora B, Dana T, et al. Screening asymptomatic adults with resting or exercise electrocardiography: a review of the evidence for the U.S. Preventive Services Task Force. Ann Intern Med 2011;155(6):375.
17. Grayburn PA, Hillis LD. Cardiac events in patients undergoing noncardiac surgery: shifting the paradigm from noninvasive risk stratification to therapy. Ann Intern Med 2003;138(6):506.
18. Wijeysundera DN, Beattie WS, Austin PC, et al. Non-invasive cardiac stress testing before elective major non-cardiac surgery: population based cohort study. BMJ 2010;340:b5526.
19. Aktas MK, Ozduran V, Pothier CE, et al. Global risk scores and exercise testing for predicting all-cause mortality in a preventive medicine program. JAMA 2004;292(12):1462.
20. Cournot M, Taraszkiewicz D, Galinier M, et al. Is exercise testing useful to improve the prediction of coronary events in asymptomatic subjects? Eur J Cardiovasc Prev Rehabil 2006;13(1):37.
21. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999;100(10):1043.
22. Ford MK, Beattie WS, Wijeysundera DN. Systematic review: prediction of perioperative cardiac complications and mortality by the revised cardiac risk index. Ann Intern Med 2010;152(1):26.
23. Wotton R, Marshall A, Kerr A, et al. Does the revised cardiac risk index predict cardiac complications following elective lung resection? J Cardiothorac Surg 2013;8:220. Erratum in: J Cardiothorac Surg. 2013;8:220.
24. Gupta PK, Gupta H, Sundaram A, et al. Development and validation of a risk calculator for prediction of cardiac risk after surgery. Circulation 2011;124(4):381.
25. VISION Pilot Study Investigators, Devereaux PJ, Bradley D, Chan MT, et al. An international prospective cohort study evaluating major vascular complications among patients undergoing noncardiac surgery: the VISION Pilot Study. Open Med 2011;5(4):e193.
26. Protopapa KL, Simpson JC, Smith NC, et al. Development and validation of the Surgical Outcome Risk Tool (SORT). Br J Surg 2014;101(13):1774.
27. Biccard B. Proposed research plan for the derivation of a new Cardiac Risk Index. Anesth Analg 2015;120(3):543.
28. Cohen ME, Ko CY, Bilimoria KY, et al. Optimizing ACS NSQIP modeling for evaluation of surgical quality and risk: patient risk adjustment, procedure mix adjustment, shrinkage adjustment, and surgical focus. J Am Coll Surg 2013;217(2):336.
29. Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. Developed in collaboration with the American College of Surgeons, American Society of Anesthesiologists, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Vascular Medicine Endorsed by the Society of Hospital Medicine. J Nucl Cardiol 2015;22(1):162.