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Frequency and Outcomes of Preoperative Stress Testing in Total Hip and Knee Arthroplasty from 2004 to 2017

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Supplemental content

IMPORTANCE Cardiac stress testing is often performed prior to noncardiac surgery, although trends in use of preoperative stress testing and the effect of testing on cardiovascular outcomes are currently unknown.

OBJECTIVE To describe temporal trends and outcomes of preoperative cardiac stress testing from 2004 to 2017.

DESIGN, SETTING, AND PARTICIPANTS Cross-sectional study of patients undergoing elective total hip or total knee arthroplasty from 2004 to 2017. Trend analysis was conducted using Joinpoint and generalized estimating equation regression. The study searched IBM MarketScan Research Databases inpatient and outpatient health care claims for private insurers including supplemental Medicare coverage and included patients with a claim indicating an elective total hip or total knee arthroplasty from January 1, 2004, to December 31, 2017.

EXPOSURES Elective total hip or knee arthroplasty.

MAIN OUTCOMES AND MEASURES Trend in yearly frequency of preoperative cardiac stress testing.

RESULTS The study cohort consisted of 801 396 elective total hip (27.9%; n = 246 168 of 801 396) and total knee (72.1%; 555 228 of 801 396) arthroplasty procedures, with a median age of 62 years (interquartile range, 57-70 years) and 58.1% women (n = 465 545 of 801 396). The overall rate of stress testing during the study period was 10.4% (n = 83 307 of 801 396). The rate of stress tests increased 0.65% (95% CI, 0.09-1.21; *P* = .03) annually from quarter (Q) 1 of 2004 until Q2 of 2006. A joinpoint was identified at Q3 of 2006 (95% CI, 2005 Q4 to 2007 Q4) when preoperative stress test use decreased by −0.71% (95% CI, −0.79% to 0.63%; *P* < .001) annually. A second joinpoint was identified at the Q4 of 2013 (95% CI, 2011 Q3 to 2015 Q3), when the decline in stress testing rates slowed to −0.40% (95% CI, −0.57% to −0.24%; *P* < .001) annually. The overall rate of myocardial infarction and cardiac arrest was 0.24% (n = 1677 of 686 067). Rates of myocardial infraction and cardiac arrest were not different in patients with at least 1 Revised Cardiac Risk Index condition who received a preoperative stress test and those who did not (0.60%; n = 221 of 36 554 vs 0.57%; n = 694 of 122 466; *P* = .51).

CONCLUSIONS AND RELEVANCE The frequency of preoperative stress testing declined annually from 2006 through 2017. Among patients with at least 1 Revised Cardiac Risk Index condition, no difference was observed in cardiovascular outcomes between patients who did and did not undergo preoperative testing.

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Preoperative cardiac stress testing is used to assess cardiac risk in patients scheduled for noncardiac surgery.[1-4] The American College of Cardiology and American Heart Association (ACC/AHA) practice guidelines for perioperative cardiovascular evaluation for noncardiac surgery aim to improve the effectiveness of perioperative care, optimize patient outcomes, and improve resource use.[5] The guidelines have consistently deemphasized preoperative cardiac testing prompted solely by the upcoming surgery in the absence of signs or symptoms that would warrant testing outside of the preoperative setting.[6-8] Additionally, over the last 2 decades, there has been an increased national focus on potential overuse of cardiac testing.[9] Appropriate use criteria, prior authorization requirements from third-party payers, and medical society initiatives, such as the Choosing Wisely campaign, have attempted to optimize use and decrease unnecessary cardiovascular stress testing.[10-12] As a result, there has been a decline in the overall use of cardiac stress tests in the last decade.[13,14] However, the trend in the frequency of preoperative cardiac stress testing and the effect of testing on perioperative cardiac outcomes are currently unknown.

Our study had 2 main aims. The first aim was to identify the trends in the frequency of preoperative cardiac stress testing during the study period. The second aim was to identify whether the presence of identified cardiac risk factors, through the Revised Cardiac Risk Index (RCRI), were associated with the decision to pursue preoperative cardiac stress testing and whether stress testing was associated with a decrease in myocardial infarction and cardiac arrest. We hypothesized that the frequency of preoperative cardiac stress tests would decrease over the study period.

Key Points

Question How has the frequency of preoperative cardiac stress testing changed over time, and what are the outcomes of patients who received a test?

Findings In this cross-sectional study of patients receiving total knee and hip arthroplasty, after increasing from 2004 to 2006, the frequency of stress testing started to decline in the fourth quarter of 2006 through 2017. Rates of myocardial infraction and cardiac arrest were not different between patients with at least 1 Revised Cardiac Risk Index condition who received a preoperative stress test and those who did not.

Meaning Preoperative stress testing has steadily decreased since 2006, and rates of subsequent myocardial infarction or cardiac arrest were not different.

Methods

Data Source and Study Population

The University of Chicago institutional review board approved this study and did not require informed consent because the data lacked patient identifiers. Data used for the analysis were derived from the IBM MarketScan 2003 to 2017 Commercial and Medicare Supplemental Databases. These databases represent the health services of approximately 185 million employees, dependents, and retirees in the United States. The Commercial and Medicare Supplemental Databases are generally representative of the population of the United States in terms of sex (48% men), and the mean ages of the commercial and Medicare supplemental populations were 33 years and 74 years, respectively. These databases provide unique identifiers that allow enrollees to be followed up across institutions and clinicians, and over time. All enrollment records and inpatient, outpatient, ancillary, and drug claims were collected in accordance with the Health Insurance Portability and Accountability Act, and all patient data were deidentified. Certain populations without employer-sponsored insurance, including uninsured and Medicaid patients, are not represented in these databases.

Cohort Selection

Using MarketScan inpatient claims data from 2003 to 2017, we selected patients according to *International Classification of Diseases, Ninth Revision, Clinical Modification* and *International Statistical Classification of Diseases, Tenth Revision, Clinical Modification* (*ICD-9-CM* and *ICD-10-CM*, respectively) who underwent total knee arthroplasty and total hip arthroplasty surgeries (eTable 1 in the Supplement). After the initial cohort selection (n = 1 369 098), we applied the following exclusion criteria to patients: (1) undergoing elective surgery only, based on the principal diagnosis of osteoarthrosis, (2) 18 years and older, (3) first surgery observed only, and (4) active enrollment in the insurance plan 12 months prior to surgery (eFigure 1 in the Supplement). This selection process yielded 801 396 elective total hip and knee replacement surgeries performed between 2004 and 2017.

Outcomes

The primary outcome measure was the presence of any cardiac stress test within the 60 days prior to elective lower extremity joint replacement surgery. A 60-day period was chosen owing to previous analyses of the frequency of preoperative stress testing.[2] Cardiac stress tests were identified in outpatient claims data using the *Current Procedural Terminology (CPT)* codes for exercise-induced or pharmacologically induced stress electrocardiogram, myocardial perfusion imaging (MPI), stress echocardiography, and stress magnetic resonance imaging (eTable 2 in the Supplement). Additionally, we identified patients who underwent a cardiac stress test in the year prior to surgery prior to the 60-day threshold. This was included as an explanatory variable in our analysis and as a sensitivity analysis as mentioned subsequently. Secondary outcomes included a diagnosis of myocardial infarction or cardiac arrest during the inpatient claim associated with the total joint arthroplasty (eTable 3 in the Supplement).

Patient Characteristics

Patient characteristics included age at the time of surgery and sex. Race/ethnicity were not available in our data. The RCRI conditions were assessed using *ICD-9-CM* and *ICD-10-CM* diagnosis codes, which can be found in eTable 4 in the Supplement. These diagnoses were assigned to cohort patients if observed at least once in the inpatient or outpatient claims data in the year prior to, but not including, the date of the elective surgery. Secondary analyses that used RCRI conditions were limited to patients belonging to an insurance plan whose drug benefit data are captured in the database, which are used to determine the presence of insulin-dependent type 2 diabetes in our cohort (n = 686 067). Patients were considered insulin dependent if at least 1 outpatient prescription for insulin was observed in the year prior to elective surgery.

The RCRI was calculated on a scale from 0 to 5 points, with 1 point assigned for each of the following patient characteristics: ischemic heart disease, heart failure, insulin therapy for diabetes, cerebrovascular disease, and chronic kidney disease.[15] The database did not contain sufficient laboratory data in our cohort to rely on obtaining a preoperative serum creatinine value of greater than 2.0 mg/dL (to convert to micromoles per liter, multiply by 88.4); thus, we used the diagnosis of chronic kidney disease stage III or higher as indicative of a creatinine level of greater than 2.0 mg/dL as used in previous studies.[16]

In addition to the RCRI, we calculated the Elixhauser comorbidity score to estimate comorbidities not captured by the RCRI.[17,18] The Elixhauser comorbidity score is a composite score of the 30 Elixhauser comorbidities (eTable 5 in the Supplement) that can be used as a single numeric score that summarizes disease burden and is adequately discriminative for death in hospital.[17] The Elixhauser score was used to evaluate whether physicians were more likely to perform a preoperative cardiac stress test on patients with a higher burden of disease that is not represented by the RCRI.

Previous analyses have evaluated stress test use based on capitated vs noncapitated plans; thus, we divided insurance plans into 3 categories: capitated, noncapitated, and unknown (eTable 6 in the Supplement).[19,20]

Statistical Analysis

The data analysis was generated using SAS software, version 9.4 (SAS Institute Inc) and Joinpoint Regression Program, version 4.7.0.0 (National Cancer Institute).[21] We performed joinpoint regression analysis to identify any change in the yearly trends of the unadjusted frequency of preoperative stress test over the study period. We tested 9 models with 0 to 8 joinpoints, with final model selection based on the permutation test. To evaluate the association among patient factors and preoperative stress tests, we performed a generalized estimating equation with a logit link function. The model was clustered on metropolitan statistical area to account for local variation in practice and used a compound symmetry covariance pattern. Clinical risk factors were represented using the composite risk measures of RCRI and Elixhauser score. We modeled 2-time segments based on the results of the Joinpoint trend analysis. The Cochran-Armitage test was used to test the trend in number of RCRI conditions among patients with preoperative stress tests. Percentages of complications are reported for those with none and 1 or more RCRI condition, overall, and by occurrence of preoperative stress test, by year. Trends in complications over time for each RCRI condition are tested using the Cochran-Armitage test, and 3-way interactions are tested using the Cochran-Mantel-Haenzel test. All statistical tests were 2-sided and had a significance level of .05.

We conducted 3 sensitivity analyses. First, we estimated the frequency of stress testing in patients in the year prior to surgery up until 2 months before the surgical procedure to evaluate the effect of overall stress testing rates on our cohort. Second, we expanded the definition of diabetes for an RCRI condition to include patients with a diagnosis of diabetes not receiving insulin. Third, we evaluated patient outcomes in patients who had a stress test in the year before surgery but not within 2 months of surgery.

Results

Patient Characteristics

The study cohort consisted of 801 396 elective total hip arthroplasty procedures (27.9%) and total knee arthroplasty procedures (72.1%) in the MarketScan database from 2004 to 2017. Overall, 10.4% of patients (n = 83 307 of 801 396) underwent a preoperative cardiac stress test in the 60 days prior to surgery. Characteristics of the study cohort are described in **Table 1**. Among patients who underwent a stress test during the entire study period, 49% (n = 35 351 of 71 905) had no RCRI conditions. The percentage of patients who had 0 RCRI conditions and underwent a stress test increased from 44.7% (n = 1636 of 3659) in 2004 to 52.6% (n = 1594 of 3032) in 2017 ($P < .001$) (**Table 2**; eFigure 2 in the Supplement). Patients who received a preoperative stress test were more likely to be older, with a median age of 66 years (interquartile range [IQR], 60-75 years) vs 62 years (IQR, 56-70 years), and male (n = 38 191 [45.8%] vs n = 297 660 [41.5%]).

Changes in Stress Test Frequency

Joinpoint analysis identified 2 joinpoints in the yearly percentage of preoperative cardiac stress tests in the third quarter (Q) of 2006 (95% CI, 2005 Q4 to 2007 Q4) and Q4 of 2013 (95% CI, 2011 Q3 to 2015 Q3) (**Figure**, A). Prior to the 2006 inflection point, preoperative stress testing increased 0.65% (95% CI, 0.09-1.21; $P = .03$) per year. From 2006 Q4 to 2013 Q4, preoperative stress testing decreased −0.71% (95% CI, −0.79 to −0.63; $P < .001$) per year. For the remainder of the study period, 2013 Q4 to 2017 Q4, the percentage change was slower (−0.40%; 95% CI, −0.57% to −0.24%; $P < .001$ per year).

Types of Stress Test Used and Change Through the Study Period

The frequency for each stress test modality can be seen in the Figure, B (eTable 7 in the Supplement**)**. The MPI was the most common test performed 84.1% (n = 70 092 of 83 307), followed by stress echocardiography 11.3% (n = 9432 of 83 307) and then magnetic resonance imaging and electrocardiogram 4.6% (n = 3783 of 83 307). Each modality decreased throughout the study period, with the largest decrease noted from MPI tests.

Characteristics Associated With Stress Testing

The results from the logistic regression analysis can be seen in **Table 3**. Patient characteristics that were associated with increased odds of a cardiac stress test include age, male sex, and

Table 1. Characteristics for All Elective Total Hip Replacement and Total Knee Replacement Patients in MarketScan Databases 2004 to 2017

Characteristic	No. (%) Preoperative cardiac stress test (n = 83 307)	No. (%) No preoperative cardiac stress test (n = 718 089)	*P* value
Procedure			
Total hip arthroplasty	24 842 (29.8)	221 326 (30.8)	<.001
Total knee arthroplasty	58 465 (70.2)	496 763 (69.2)	
Sex			
Male	38 191 (45.8)	297 660 (41.5)	<.001
Female	45 116 (54.2)	420 429 (58.5)	
Age, median (IQR)	66 (60-75)	62 (56-70)	<.001
Age group, y			
18-44	35 351 (49.2)	491 696 (80.1)	<.001
45-54	7415 (8.9)	117 693 (16.4)	
55-64	31 127 (37.4)	319 506 (44.5)	
65-74	22 713 (27.3)	155 532 (21.7)	
75-84	18 436 (22.1)	94 519 (13.2)	
85 and older	3139 (3.8)	13 209 (1.8)	
RCRI component conditions			
Chronic kidney disease stage III or higher	3018 (3.6)	17 108 (2.4)	<.001
History of cerebrovascular disease	7974 (9.6)	33 157 (4.6)	<.001
History of heart failure	6987 (8.4)	27 100 (3.8)	<.001
History of insulin dependent diabetes[a]	3859 (5.4)	18 556 (3.0)	<.001
History of ischemic heart disease	33 781 (40.6)	86 632 (12.1)	<.001
RCRI[a]			
0	35 351 (49.2)	491 696 (80.1)	<.001
1	26 772 (37.2)	93 313 (15.2)	
2	8009 (11.1)	23 358 (3.8)	
3	1522 (2.1)	4857 (0.8)	
4	231 (0.3)	839 (0.1)	
5	20 (0.0)	99 (0.0)	
Elixhauser score			
<1	39 830 (47.8)	447 597 (62.3)	<.001
1-5	23 525 (28.2)	162 134 (22.6)	
6-10	11 123 (13.4)	60 087 (8.4)	
11-15	5632 (6.8)	30 711 (4.3)	
>15	3197 (3.8)	17 560 (2.4)	
Year			
2004	3837 (4.6)	26 258 (3.7)	<.001
2005	5584 (6.7)	37 644 (5.2)	
2006	5151 (6.2)	31 859 (4.4)	
2007	6240 (7.5)	40 939 (5.7)	
2008	6367 (7.6)	44 323 (6.2)	
2009	6694 (8.0)	49 241 (6.9)	
2010	6664 (8.0)	52 693 (7.3)	
2011	8854 (10.6)	75 175 (10.5)	
2012	8671 (10.4)	80 984 (11.3)	
2013	6815 (8.2)	68 752 (9.6)	
2014	7136 (8.6)	77 398 (10.8)	
2015	4349 (5.2)	47 907 (6.7)	
2016	3758 (4.5)	44 528 (6.2)	
2017	3187 (3.8)	40 388 (5.6)	

(continued)

Table 1. Characteristics for All Elective Total Hip Replacement and Total Knee Replacement Patients in MarketScan Databases 2004 to 2017 (continued)

Characteristic	No. (%) Preoperative cardiac stress test (n = 83 307)	No preoperative cardiac stress test (n = 718 089)	*P* value
Insurance plan type			
Capitated payment plan	8156 (9.8)	88 281 (12.3)	<.0001
Noncapitated payment plan	72 620 (87.2)	606 293 (84.4)	<.0001
Unknown	2531 (3.0)	23 515 (3.3)	.0003

Abbreviations: IQR, interquartile range; RCRI, Revised Cardiac Risk Index.

[a] Insulin-dependent diabetes and RCRI require prescription drug data to determine. Values shown exclude 115 329 patients for whom prescription data are not available.

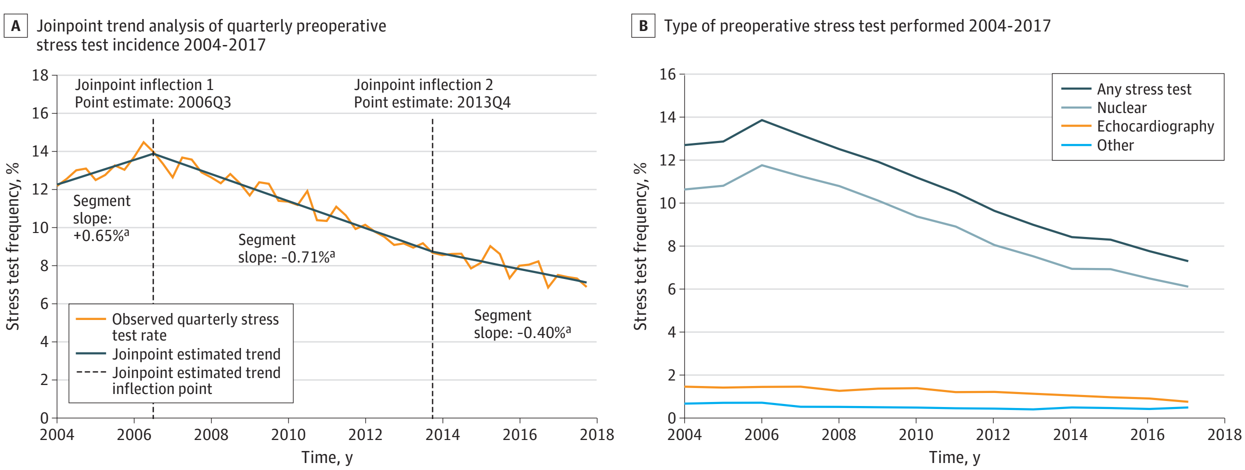
Table 2. RCRI Among Patients Who Underwent Preoperative Stress Tests[a]

Year	RCRI, No./total No. (%) 0	1	≥2
2004	1636/3659 (44.7)	1547/3659 (42.3)	476/3659 (13.0)
2005	2393/5268 (45.4)	2169/5268 (41.2)	706/5268 (13.4)
2006	2323/4966 (46.8)	1985/4966 (40.0)	658/4966 (13.3)
2007	2644/5414 (48.8)	2079/5414 (38.4)	691/5414 (12.8)
2008	2763/5670 (48.7)	2188/5670 (38.6)	719/5670 (12.7)
2009	2992/6003 (49.8)	2218/6003 (36.9)	793/6003 (13.2)
2010	2865/5710 (50.2)	2104/5710 (36.8)	741/5710 (13.0)
2011	3506/6980 (50.2)	2550/6980 (36.5)	924/6980 (13.2)
2012	3315/6514 (50.9)	2323/6514 (35.7)	876/6514 (13.4)
2013	2674/5414 (49.4)	1933/5414 (35.7)	807/5414 (14.9)
2014	2843/5606 (50.7)	1939/5606 (34.6)	824/5606 (14.7)
2015	2013/4117 (48.9)	1455/4117 (35.3)	649/4117 (15.8)
2016	1790/3552 (50.4)	1228/3552 (34.6)	534/3552 (15.0)
2017	1594/3032 (52.6)	1054/3032 (34.8)	384/3032 (12.7)
Total	35 351/71 905 (49.2)	26 772/71 905 (37.2)	9782/71 905 (13.6)

Abbreviation: RCRI, Revised Cardiac Risk Index.

[a] Excludes patients for whom insulin-dependent diabetes status could not be determined owing to missing prescription drug data (n = 11 402 of 83 307).

Figure. Trends in Frequency of Preoperative Cardiac Stress Testing



Q indicates quartile.

[a] Indication of statistical significance of slopes between joinpoint inflection points, tested against the null hypothesis of slope = 0 at the *P* less than .05 significance level.

RCRI greater than zero. As expected, recent cardiac stress test was associated with decreased odds of another stress test within the 60 days prior to the surgical procedure. Patients enrolled in a capitated insurance plan had decreased odds of a stress test. Each increase in the Elixhauser score increased the odds of a preoperative cardiac stress test because the Elixhauser score represents comorbidities not accounted for by the RCRI (eTable 8 in the Supplement).

Table 3. Regression Results[a]

Variable	Odds ratio (95% CI)	*P* value
Age group, y		
18-44	1 [Reference]	NA
45-54	2.27 (1.90-2.71)	<.001
55-64	3.22 (2.71-3.81)	<.001
65-74	4.01 (3.38-4.75)	<.001
75-84	4.61 (3.89-5.45)	<.001
85 and older	5.31 (4.37-6.45)	<.001
Sex (female = 0; male = 1)	1.11 (1.09-1.12)	<.001
Trends		
Segment 1 (per quarter 2004 Q1 to 2006 Q2)	1.02 (1.01-1.03)	<.001
Segment 2 (per quarter 2006 Q3 to 2017 Q4)	0.98 (0.98-0.98)	<.001
RCRI (5-point scale)		
0	1 [Reference]	NA
1	4.35 (4.18-4.53)	<.001
2	5.65 (5.39-5.93)	<.001
≥3	5.33 (4.95-5.73)	<.001
Recent cardiac stress test	0.15 (0.13-0.17)	<.001
Insurance plan type		
Noncapitated	1 [Reference]	NA
Capitated	0.80 (0.73-0.87)	<.001
Unknown	0.95 (0.90-1.00)	.07

Abbreviations: Q, quartile; RCRI, Revised Cardiac Risk Index.

[a] Generalized estimating equation regression predicting use of preoperative cardiac stress test based on patient characteristics. *P* less than .05 was considered statistically significant. To control for stress tests that may have been performed prior to the operation, we included stress tests performed between 61 days and 1 year prior to the surgery as "recent cardiac stress test."

Perioperative Complications: Myocardial Infarction and Cardiac Arrest

The overall unadjusted complication rate for all patients for myocardial infarction and cardiac arrest was 0.24% (n = 1677 of 686 067; **Table 4**). Rates of complications for patients with 0 RCRI conditions were 0.14% (n = 762 of 527 047) overall and decreased throughout the study period (*P* < .001). The rate of myocardial infarction and cardiac arrest was 0.58% (n = 915 of 159 020) for patients with 1 or more RCRI conditions, and also decreased over time (*P* = .005). Among patients with 1 or more RCRI conditions, stress testing was not associated with lower rates of complications. Patients with 0 RCRI conditions who received a stress test had a mean complication rate of 0.27% (n = 95 of 35 351) that decreased from 2004 to 2017 (*P* < .001) but was double the complication rate of patients without RCRI conditions who did not receive a stress test (0.14%; n = 667 of 491 696; *P* < .001).

Sensitivity Analyses

Among patients in the study cohort who did not undergo a preoperative stress test, the overall frequency of stress testing in the year before surgery was 10.2% and decreased over the study period (*P* < .001) (eFigure 3 in the Supplement). The proportion of stress tests performed in the 2 months before surgery was 51.0% compared with 49.0% over the 10 months before surgery (eTable 9 in the Supplement). Additionally, the overall frequency of yearly stress testing in the entire MarketScan population decreased over the study period from 5.8% (n = 809 000 of 13 958 000) to 4.8% (n = 974 000 of 20 498 000) (eTable 10 in the Supplement). We did not observe any difference in outcomes of patients who underwent a stress test compared with patients who did not have a stress test (0.60%; n = 221 of 36 554 vs 0.53%; n = 447 of 85 085; *P* = .09) with 1 or more RCRI conditions after excluding patients who had a stress test before the preoperative period (eTable 11 in the Supplement). The frequency of a preoperative stress test in patients with zero RCRI conditions was 37.8% (n = 27 195 of 71 905) with a definition of diabetes that did not require insulin, compared with 49.2% (n = 35 351 of 71 905) with a definition of diabetes that required insulin. There was no clinically meaningful change in the proportion of patients with zero RCRI conditions who underwent stress testing with a definition of diabetes that did not require insulin throughout the study period (eTable 12 in the Supplement).

Discussion

Our study identified a clear inflection point in the use of preoperative cardiac stress testing, with a peak frequency in 2006 followed by a decline in each subsequent year throughout the study period. The reason for this decline is likely multifactorial because it occurred with a national focus on use and costs, with a shift to the value-based health care era. In our sensitivity analysis, we observed a decrease in overall use of stress testing outside of the preoperative period. The effect of the ACC/AHA preoperative guidelines may have been one contributor. However, we did not find a meaningful change in the number of stress tests performed in patients with zero RCRI risk factors, those patients for whom preoperative stress testing was specifically discouraged by the new guidelines. This finding suggests limited adherence to the guidelines and an opportunity for further reductions in preoperative stress testing.

Our findings of a decrease in preoperative stress tests are consistent with previous studies that demonstrated a decrease in overall stress tests in the general population.[14,19,20] In the early 2000s, there was significant growth in cardiac imaging that led to increased health care costs and concerns from clinicians and payers about overuse.[9,22] In response to these concerns, a number of interventions occurred in an effort to limit overuse and optimize care, including the development of appropriate use criteria, new clinical practice guidelines, and third-party prior authorizations programs. Studies have demonstrated an overall decreased use of MPI stress tests that began around the same time as the decrease noted in our study.[14,19,23] It is notable that this decrease was observed in both capitated insurance plans and a Medicare population, despite different barriers to testing. Our sensitivity analysis also identified an overall decrease in stress testing outside of the preoperative period. Patients in our cohort with a capitated insurance plan had a decreased odds of receiving

Table 4. Surgical Admission Morbidity (Myocardial Infarction and Cardiac Arrest)[a]

	RCRI = 0		RCRI ≥1		All RCRI	
Variable	Rate, %	No./total No.	Rate, %	No./total No.	Rate, %	No./total No.
Without preoperative stress test	0.14	667/491 696	0.57	694/122 466	0.22	1361/614 162
With preoperative stress test	0.27	95/35 351	0.60	221/36 554	0.44	316/71 905
Total	0.14	762/527 047	0.58	915/159 020	0.24	1677/686 067

Abbreviation: RCRI, Revised Cardiac Risk Index.

[a] Morbidity rates include cardiac arrest and myocardial infarction. Within each RCRI and preoperative stress test category, numerators represent the number of patients with adverse outcomes and denominators represent the total number of patients in the cohort belonging to each category.

a preoperative stress test. This is not surprising given that capitated models have financial incentives to reduce all testing. However, this is unlikely to be the primary driver of the sustained decrease in testing as capitated insurance plans decreased throughout the study period. Our finding of a decline in preoperative stress testing is more likely the result of the same factors that led to the decrease in frequency of stress testing overall.

Despite a simplified approach in the ACC/AHA guidelines, we identified a high frequency of preoperative stress tests in patients with zero RCRI conditions. The 2007 and 2014 ACC/AHA guidelines specify that no patient with zero RCRI conditions warrants preoperative stress testing prior to an intermediate-risk surgery, such as total hip or knee arthroplasty, even those with poor functional status. However, we observed nearly half of the patients who underwent a preoperative stress test had zero documented RCRI conditions. In a study[24] of anesthesia residents that evaluated simulated patients according to the 2007 guidelines, only 45% of recommended treatment options were consistent with the guidelines. A follow-up study[25] of attending physicians did not demonstrate improved compliance with guideline recommendations for simulated preoperative patients. Our study does not support the conclusion that the simplified stepwise approach instituted in the 2007 guidelines led to a decrease in preoperative stress testing or more appropriate testing. In fact, it identifies substantial ongoing unnecessary preoperative stress testing and suggests an opportunity for educational initiatives or clinical pathways to improve resource use and reduce costs.

Preoperative stress testing did not demonstrate any difference in the rate of myocardial infarction or cardiac arrest in patients with 1 or more RCRI conditions. Our analysis of outcomes was performed as the guidelines should be applied, and thus we did not account for other patient characteristics other than the guidelines recommendations or apply additional statistical methods, such as propensity scores. Surprisingly, the complication rate of patients with zero RCRI conditions who received a stress test was twice the rate of patients with zero RCRI conditions who did not receive a stress test. This difference suggests that the RCRI may not fully account for the risk of myocardial infarction or cardiac arrest in our cohort. Our overall rates of myocardial infarction and cardiac arrest are consistent with previously published rates in similar patient populations.[26,27]

Limitations

While the MarketScan database is a well-established and validated source of claims data, it is possible that some RCRI conditions were not coded, which would lead to an underestimation of patient comorbidities and the appearance of overutilization of stress tests. MarketScan includes patients with employer-sponsored insurance and Medicare supplemental insurance, which underrepresents the Medicare population. Because testing rates increase with age, the overall national rates of preoperative testing would be higher if the entire Medicare population was included. Thus, our results underestimate a nationally representative population of all adults. Patients who had a positive preoperative stress test result that changed the operative plan were not captured by our methods. This is an inherent limitation in these methods; however, given the low likelihood of a positive stress test result, this would only make up a very small fraction of the overall patient population where the results of the test would result in deferring the surgical procedure.[28] We may have identified stress tests that were regularly scheduled and not as part of the preoperative workup; however, the increase in testing frequency in the 2 months before surgery suggests these tests were associated with the upcoming surgical procedure.[2] We could not identify functional capacity in this patient population and so cannot account for it. However, patients presenting for total joint arthroplasty of the lower extremity likely have limited functional capacity owing to their primary diagnosis of osteoarthritis; thus, baseline functional capacity is likely comparable between patients.

Conclusions

Our study identified a sustained decline in the frequency of preoperative cardiac stress tests in patients who underwent a total hip or knee arthroplasty beginning in Q4 of 2006. We did not observe any difference in myocardial infarction or cardiac arrest in patients with at least 1 RCRI condition who underwent stress testing, which suggests stress testing may not contribute to risk stratification in this patient population. Further, the proportion of stress tests conducted for patients with zero RCRI conditions remains high, which suggests an opportunity for interventions to further reduce preoperative cardiac stress testing. Additional investigation is needed to evaluate the optimal patient conditions that would warrant stress testing and whether our results are generalizable to other surgical procedures.

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