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Postoperative Tachycardia: Clinically Meaningful or Benign Consequence of Orthopedic Surgery?

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Abstract

Objective: To determine the clinical significance of tachycardia in the postoperative period.

Patients and Methods: Individuals 18 years or older undergoing hip and knee arthroplasty were included in the study. Two data sets were collected from different time periods: development data set from January 1, 2011, through December 31, 2011, and validation data set from December 1, 2012, through September 1, 2014. We used the development data set to identify the optimal definition of tachycardia with the strongest association with the vascular composite outcome (pulmonary embolism and myocardial necrosis and infarction). The predictive value of this definition was assessed in the validation data set for each outcome of interest, pulmonary embolism, myocardial necrosis and infarction, and infection using multiple logistic regression to control for known risk factors.

Results: In 1755 patients in the development data set, a maximum heart rate (HR) greater than 110 beats/min was found to be the best cutoff as a correlate of the composite vascular outcome. Of the 4621 patients who underwent arthroplasty in the validation data set, 40 (0.9%) had pulmonary embolism. The maximum HR greater than 110 beats/min had an odds ratio (OR) of 9.39 (95% CI, 4.67-18.87; sensitivity, 72.5%; specificity, 78.0%; positive predictive value, 2.8%; negative predictive value, 99.7%) for pulmonary embolism. Ninety-seven patients (2.1%) had myocardial necrosis (elevated troponin). The maximum HR greater than 110 beats/min had an OR of 4.71 (95% CI, 3.06-7.24; sensitivity, 47.4%; specificity, 78.1%; positive predictive value, 4.4%; negative predictive value, 98.6%) for this outcome. Thirteen (.3%) patients had myocardial infarction according to our predetermined definition, and the maximum HR greater than 110 beats/min had an OR of 1.72 (95% CI, 0.47-6.27).

Conclusion: Postoperative tachycardia within the first 4 days of surgery should not be dismissed as a postoperative variation in HR, but may precede clinically significant adverse outcomes.

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Postoperative tachycardia is a common and largely unexamined occurrence in patients undergoing orthopedic hip and knee surgery. Postoperative sinus tachycardia is often attributed to catecholamine release in response to surgical stress or anemia, and it is theorized that most patients recover without sequelae.[1-3] In an institutional algorithm developed by orthopedists, it is recommended that patients with tachycardia not receive any further work-up for pulmonary embolism (PE) unless that patient is hypoxic.[4]

Few investigations have been performed that examine tachycardia in the postoperative period and its relationship to adverse events. An analysis of patients in the Perioperative Ischemic Evaluation trial, who underwent noncardiac surgery, provides the most data on the predictive value of tachycardia in the perioperative period. In that analysis, each 10-beats/min increase in prerandomization heart rate (HR) was associated with a 31.0% relative increase in the odds of perioperative myocardial infarction (MI). The predictive value of postoperative tachycardia, however, was not examined.[5]

There are additional studies that have looked at the relationship between tachycardia and other adverse outcomes of interest, but these investigations are limited in their generalizability. The RIETE study[6] of 2858 patients with PE, including surgical patients, found that 19.4% of the study patients had HRs greater than 110 beats/min; however, the

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timing of tachycardia and proportion of surgical patients were not specified. In addition, studies[7-10] have identified increased rates of adverse events in noncardiothoracic surgery patients with postoperative supraventricular arrhythmia.

Pulmonary embolism is an outcome of interest in the postoperative orthopedic population and has been reported to occur at a rate of 2% to 20%.[11,12] With respect to the association between tachycardia and PE, some guidance comes from the Wells[13] and Geneva[14] criteria developed for the management of PE. In the derivation of both guidelines, tachycardia was independently associated with the finding of a PE and is included in the final scoring criteria. Neither set of guidelines, however, specifically studied a surgical population, focusing instead on emergency room patients[14] or a mix of inpatients and outpatients.[13]

Given the association between preoperative tachycardia and postoperative positive troponin and MI[5] and the association of tachycardia with PE and MI in emergency and medical populations,[14,15] we proposed that postoperative tachycardia in orthopedic surgery patients would likewise have an association with these adverse events. An optimal definition of tachycardia, independently associated with the events of interest, could function as a diagnostic test that helps clinicians determine which patients are at risk and tailor resource utilization appropriately. The primary objective of this study was to determine whether there is an HR above which a postoperative orthopedic surgery patient is at increased risk of PE, myocardial necrosis, MI, and/or infection.

PATIENTS AND METHODS

We performed this study using a retrospective cohort design comparing risk factors for outcomes of interest among patients 18 years or older undergoing hip and knee arthroplasty at the New York University Hospital for Joint Diseases, an orthopedic subspecialty hospital. We collected 2 data sets from different time periods: from January 1, 2011, through December 31, 2011, and from December 1, 2012, through September 1, 2014. Patients older than 18 years admitted for hip or knee arthroplasty were included. We used the earlier time period to identify the best definition of tachycardia in terms of an association with a composite outcome of MI, PE, and positive troponin (the derivation data set). We used the second (validation) data set to explore the association between this definition of tachycardia and each component of the composite outcome using multiple logistic regression to control for known risk factors.

Patient information from 2011 and 2012 was obtained from the Integrated Clinical Information System, the electronic health record (EHR) used by our health system until December 2012, and patient information from December 2012 and beyond was derived from Epic, the EHR that replaced the Integrated Clinical Information System. Patients were identified by *International Classification of Diseases, Ninth Revision* (*ICD-9*) procedure codes for hip and knee arthroplasty. Demographic characteristics, vital signs data for the 4 immediate postoperative days, laboratory studies, imaging studies, and other diagnoses were collected.

Outcomes

The adverse outcome of interest for the development data set was a composite vascular outcome, combining patients with PE, patients with myonecrosis (positive troponin), and any additional patients coded with an MI. After assessing the derivation data set, we chose a composite outcome because of the low numbers of individual outcomes. Infection was not included in the composite because of a low number of events in this data set. Patients with MI were identified using *ICD-9* codes in this data set without manual chart review. For the validation data set, the outcomes we chose to evaluate an association with tachycardia were PE, myocardial necrosis (defined as positive troponin), MI, and infection (defined as urinary tract infection [UTI], surgical site infection [SSI], and pneumonia). Patients who had PE were identified in the data set by the presence of *ICD-9* code 415.1x. We also performed chart review of all ordered computed tomography scans of the chest with intravenous contrast to confirm that *ICD-9* coding of PEs was accurate in both study periods. We used our institution's laboratory cutoff of 0.04 ng/mL (to convert to

nmol/L, multiply by 1) to identify patients with a positive troponin I laboratory test result. For the validation data set, all patient charts with a positive troponin were manually reviewed using the third universal definition of MI[16] to identify patients with MI (see Supplemental Appendix, available online at http://www.mayoclinicproceedings.org). Patients with infections were identified by the presence of *ICD-9* billing code 599.x for UTI and by the institution's Department of Infection Prevention and Control on the basis of definitions set out by the National Healthcare Safety Network[17] for SSI and pneumonia (see Supplemental Appendix).

Predictors

We evaluated the association between maximum HR and our outcomes of interest within the first 4 days of surgery. Variables related to the risk of PE that we were able to extract from the data set include age (as a continuous variable), history of cancer (*ICD-9* codes ≥140 and <240), and history of VTE (*ICD-9* codes V12.51, 453.5x, and 453.75).

Variables we extracted from our data set for the analysis of perioperative MI include history of cerebrovascular accident (*ICD-9* codes 434.x and 438.x), history of diabetes mellitus requiring insulin (*ICD-9* code 250.x) and the presence of insulin on patients' preadmission medication lists), history of ischemic heart disease (*ICD-9* code 414.x), history of chronic kidney disease (defined as a preoperative serum creatinine level of ≥2), preoperative HR, and change in the hemoglobin level of 2 g/dL or more (to convert to mol/L, multiply by .6206) from the preoperative hemoglobin level.

Variables related to the risk of UTI that we were able to extract from the data set include sex, history of dementia (*ICD-9* code 331.x), history of hypertension (*ICD-9* code 401.x), presence of pneumonia (*ICD-9* codes 486.x and 997.32), and whether the patient had documented urinary retention during hospitalization (*ICD-9* code 788.2x).

Perioperative risk factors for SSI, such as skin and hair preparation, surgical scrub technique, operating room ventilation, temperature, and cleaning practices[18,19] are standardized within our institution and were not analyzed separately. Intravenous antibiotics with gram-negative coverage are administered to all patients preoperatively, and intravenous vancomycin is administered to all patients undergoing surgery at Hospital for Joint Diseases who have a nasal swab positive for methicillin-resistant *Staphylococcus aureus* at preadmission testing. Additional variables related to the risk of SSI that we were able to extract from the data set include serum albumin level, patient's body mass index (calculated as the weight in kilograms divided by the height in meters squared) during the admission, history of liver disease (*ICD-9* code 571.x), history of chronic obstructive pulmonary disease (*ICD-9* codes 490.x, 491.x, 492.x, and 496.x), history of smoking (*ICD-9* code V15.82 and 305.1x), and corticosteroid use during the admission as documented in the EHR.

We analyzed factors for hospital-acquired pneumonia, including intubation, history of stroke, cigarette smoking, age, blood urea nitrogen level lower than 8, between 22 and 30, or 10.7 mg/dL and above (to convert to mmol/L, multiply by 0.0259), and history of dementia.[20]

The power analysis and sample size calculation were based on the composite outcome (ie, showing at least 1 of the 3 adverse events: PE, MI, and positive troponin). There were 1755 patients in the initial time frame. We expected there would be at least 4500 patients in the second time frame. Of the 1755 patients, 24.3% had a maximum HR of greater than 110 beats/min, 12.4% of whom had at least 1 adverse event, as compared with 5.7% of the patients having a maximum HR of 110 beats/min or less. The power would be greater than 99% to detect such a difference using the second time-frame data.

Statistical Analyses

We sought an optimal definition of tachycardia for association with a composite vascular outcome of PE, positive troponin, and MI for the development data set. The relationship between HR as a continuous variable and the composite outcome was analyzed, and a receiver operating characteristic curve was generated from the development data set to determine the best HR cutoff using the Youden index.[21]

Using this best HR cutoff of 110 beats/min, we examined the validation data set. We compared the validation and the development data set to assess similarities and differences between the groups. We used the chi-square test to examine whether the presence of an HR greater than 110 beats/min documented in the vital signs was associated with each adverse outcome (PE, MI, positive troponin, or infection). For each outcome, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated from the univariate analysis using an indicator of HR greater than 110 beats/min. We then performed multiple logistic regression analysis to investigate whether the presence of an HR greater than 110 beats/min was an independent risk factor for each adverse outcome, adjusting for known risk factors.

RESULTS

We included 1755 patients who underwent total joint arthroplasty (TJA) from January 1, 2011, through December 31, 2011, in the development data set and 4621 patients who underwent TJA from December 1, 2012, through September 1, 2014, in the validation data set. Although median initial HR and HR greater than 110 beats/min did not differ significantly between groups, the validation group had more male patients than did the derivation data set (Table 1). Overall, outcomes were more common in the development data set than in the validation data set.

Using the development data set, we found that an HR cutoff of greater than 110 beats/min was the best cutoff (area under the curve, 0.585) associated with a composite vascular outcome (PE, positive troponin, and MI) using the Youden index (Figure).

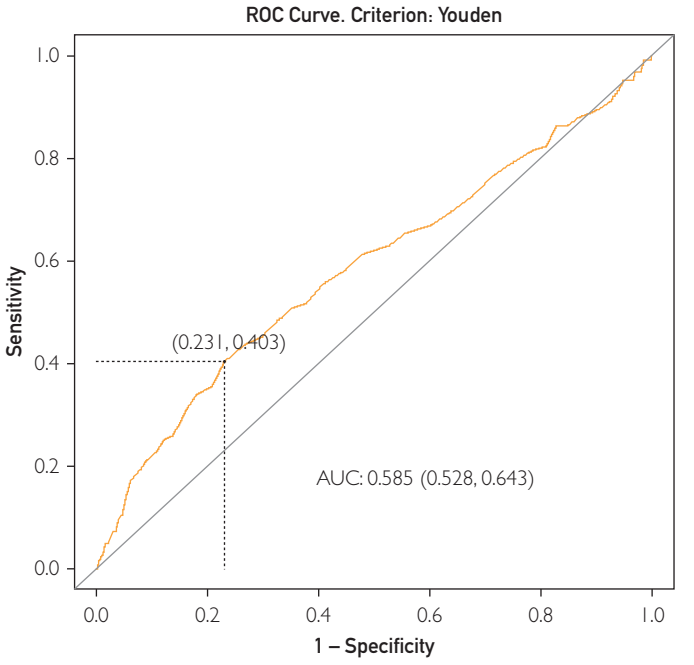
A total of 4621 patients underwent TJA from December 1, 2012, through September 1, 2014. Of those patients, 1038 (22.5%) had a maximum HR of greater than 110 beats/min (Table 1).

Univariate analysis data for each outcome are presented in Table 2. The maximum HR greater than 110 beats/min was significantly associated with PE with an odds ratio (OR) of 9.39 (95% CI, 4.67-18.87; sensitivity, 72.5%; specificity, 78.0%; PPV, 2.8%; NPV, 99.7%). For positive troponin, maximum HR had an OR of 4.71 (95% CI, 3.06-7.24; sensitivity, 47.4%; specificity, 78.1%; PPV, 4.4%; NPV, 98.6%) for this outcome. This is in contrast to MI, for which our sample had only 13 patients (Table 3) and maximum HR was not found to be significantly associated with this outcome. Thirteen MI events were identified by chart review of 97 patients in the validation data set meeting the predetermined cutoff for a positive troponin. The maximum HR greater than 110 beats/min was not significantly associated with MI (Table 3).

TABLE 1. Characteristics of the Study Cohort

Characteristic	Development data set (n=1755)	Validation data set (n=4621)	*P* value
Age (y)	62.9±10.9	63.2±13.1	.004
Maximum heart rate (beats/min)	102 (96-110)	100 (93-110)	<.001
Initial heart rate (beats/min)	73 (66-82)	73 (65-83)	.66
Heart rate >110 beats/min	427 (24.3)	1038 (22.5)	.11
Sex: female	1139 (64.9)	2812 (60.9)	.003
Pulmonary embolism	39 (2.2)	40 (0.9)	<.001
Myocardial infarction	27 (1.5)	13 (0.3)	<.001
Positive troponin	102 (5.8)	97 (2.1)	<.001
Composite vascular event (myocardial infarction, troponin, and pulmonary embolism)	124 (7.1)	123 (2.7)	<.001
Urinary tract infection	17 (1.0)	89 (1.9)	.01
Pneumonia	6 (0.3)	24 (0.5)	.36
Infection (urinary tract infection and pneumonia)	23 (1.3)	113 (2.5)	<.001
Any adverse event	128 (7.3)	225 (4.9)	<.001

Data are presented as mean ± SD, median (interquartile range), and No. (percentage). *P* values are from the Wilcoxon rank-sum test for quantitative variables and from the χ^2 test for categorical variables.



Variable	No vascular composite	Had vascular composite	Total
No HR >110 beats/min	1254	74	1328
Had HR >110 beats/min	377	50	427
Total	1631	124	1755

Data depicted from the development data set of 1755 patients.
Sensitivity, 40.3%; specificity, 76.9%; PPV, 11.7%; NPV, 94.4%

FIGURE. Sensitivity and specificity of the cutoff heart rate. AUC = area under the curve; HR = heart rate; NPV = negative predictive value; PPV = positive predictive value; ROC = receiver operating characteristic.

For the infection outcomes of interest (UTI, SSI, and pneumonia), the maximum HR greater than 110 beats/min did not have a statistically significant association. For UTI, totaling 89 (1.9%) patients, the maximum HR greater than 110 beats/min had an OR of 1.59 (95% CI, 0.98-2.58). For SSI, totaling 412 (8.9%) patients, the maximum HR greater than 110 beats/min had an OR of 1.33 (95% CI, 0.50-3.54). For pneumonia, totaling 24 (0.5%) patients, the maximum HR greater than 110 beats/min had an OR of 1.81 (95% CI, 0.72-4.56).

DISCUSSION

In this study of more than 5000 patients at a single institution, we found that tachycardia in the postoperative orthopedic population is significantly associated with adverse vascular outcomes. Tachycardia is often felt to be less clinically significant in this population, who may have substantial volume shifts, postoperative pain, and other etiologies of tachycardia. However, the present study found that tachycardia is significantly associated with PE and myocardial necrosis even in the postoperative setting and should be taken seriously.

Pulmonary embolism remains an important complication of orthopedic surgery,[22-27] with potential sequelae such as death, chronic thromboembolic disease, and pulmonary hypertension.[28] The Wells score was recently shown not to have predictive value in a postoperative orthopedic population.[29] Also, the Wells criteria consist of clinical symptoms of deep venous thrombosis (DVT), other diagnoses less likely than PE, HR greater than 100 beats/min, immobilization (≥3 days) or surgery in the previous 4 weeks, previous DVT or PE, hemoptysis, and malignant neoplasm as risk factors for PE. Most postoperative orthopedic surgical patients routinely meet 2 of the criteria (surgery and immobilization), and uncommonly meet the last 2, giving it limited utility in this population.[13] Similarly, the revised Geneva score incorporates age greater than 65 years, previous DVT or PE, surgery within 1 month of diagnosis, active malignancy, unilateral lower limb pain, lower limb pain or edema, hemoptysis, HR between 75 and 94 beats/min, and HR greater than 95 beats/min, again giving it limited applicability in this population.[14]

Our findings may guide physicians' decision making in interpreting tachycardia in the postoperative setting; if a clinician is considering working up a patient for PE or myocardial necrosis, a physical finding of an HR of greater than 110 beats/min should not be dismissed. Given the NPV of this tachycardia definition, its absence may be reassuring to the clinician, but other clinical indicators that are cause for increased suspicion for PE or myocardial necrosis are not superseded by our findings.

Finally, our investigation was unable to establish that HR greater than 110 beats/min functions as a biomarker indicating possible

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TABLE 2. Diagnostic Accuracy of a Maximum HR of >110 beats/min for Adverse Events in the Validation Cohort

Outcome	No. of patients who had outcome and HR ≤110 beats/min (percentage of the total with HR ≤110 beats/min)	No. of patients who had outcome and HR >110 beats/min (percentage of the total with HR >110 beats/min)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
PE	11 (0.3)	29 (2.8)	72.5	78.0	2.8	99.7
Positive troponin	51 (1.4)	46 (4.4)	47.4	78.1	4.4	98.6
MI	9 (0.3)	4 (0.4)	30.8	77.6	0.4	99.8
UTI	64 (1.8)	25 (2.4)	28.1	77.7	2.4	98.2
SSI	14 (0.4)	7 (0.7)	33.3	77.6	0.7	99.6
Pneumonia	14 (0.4)	10 (1.0)	41.7	77.6	1.0	99.6

HR = heart rate; MI = myocardial infarction; NPV = negative predictive value; PE = pulmonary embolism; PPV = positive predictive value; SSI = surgical site infection; UTI = urinary tract infection.

MI, and with only 13 events our study was underpowered to find this outcome. The HR greater than 110 beats/min is not a useful indicator of infection outcomes (UTI, SSI, and pneumonia) in the present study.

One limitation of this study is the variability in outcomes from the 2011 data set as compared with those from the validation data set. Rates of MI, PE, and positive troponin were higher in the initial data set than in the subsequent data set. Chart review of all ordered computed tomography scans of the chest with intravenous contrast found that the *ICD-9* coding of PEs was accurate in both study periods. We also performed chart review for cases of MI, as described above, and found that coding was accurate within the validation data set time period. No hospital-wide policies on the ordering of tests that would be important in diagnosing PE or MI, such as computed tomography scans of the chest or troponins, were changed during this time, and it seems likely that adverse outcome rates did decrease during this time period. Similar to our study, a study of 11,458 patients in the United Kingdom who underwent TJA or unicompartmental knee arthroplasty from 2002 through 2013 also found a statistically significant decrease in mortality during their study period, including a decline in VTE in the 4-year time frame studied here.[30] Finally, this study is a single-institution retrospective cohort study and is subject to the limitations that arise when using data collected for clinical documentation as research data. The large number of patient charts that we reviewed blunts this effect. As also is the case in a nonrandomized study, there are other possible confounding variables that we did not identify in the EHR.

CONCLUSION

As the age of patients seeking orthopedic care increases, so does the risk of undesirable postoperative events. These data, indicating an association between postoperative tachycardia and events such as PE and positive troponin, can help us direct testing toward patients at the highest risk of one of these adverse events. Initiating appropriate testing and therapy earlier in a patient's course has the potential to improve care by decreasing the length of stay, cost, and perhaps morbidity and mortality in this patient population. Further directions for research include external validation, analysis of other abnormal vital signs in the postoperative period that may function as biomarkers for outcomes of interest, as well as analysis of larger data sets to better understand less common outcomes of interest such as MI in this patient population.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at: http://www.mayoclinicproceedings.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

TABLE 3. Multivariate Analysis of Adverse Outcomes[a,b]

Variable	PE	Positive troponin	MI	UTI	SSI	Pneumonia
Maximum heart rate >110 beats/min	9.39 (4.67-18.87); *P*<.01	4.71 (3.06-7.24); *P*<.01	1.72 (0.47-6.27); *P*.=41	1.59 (0.98-2.58); *P*=.06	1.33 (0.50-3.54); *P*=.57	1.81 (0.72- 4.56); *P*=.21
History of venous thromboemoblism	0.47 (0.07-3.45); *P*=.46	NA	NA	NA	NA	NA
History of cancer	0.95 (0.13-7.03); *P*=.96	0.89 (0.26-3.00); *P*=.84	NA	NA	NA	NA
Age	NA	1.10 (1.07-1.13); *P*<.01	1.11 (1.04-1.18); *P*<.01	1.07 (1.05-1.09); *P*<.01	0.99 (0.96-1.03); *P*=.68	1.02 (0.99-1.05); *P*=.24
History of coronary artery disease	NA	5.12 (3.29-7.96); *P*<.01	4.23 (1.28-14.05); *P*<.01	NA	NA	NA
History of chronic kidney disease	NA	3.64 (0.61-21.5); *P*=.15	NA	NA	NA	NA
First heart rate	NA	NA	1.00 (0.95-1.04); *P*=.84	NA	NA	1.04 (1.01-1.06); *P*=.01
History of cerebrovascular accident	NA	NA	15.48 (2.91-82.42); *P*<.01	NA	NA	8.12 (1.03-64.16); *P*=.05
Sex	NA	NA	NA	1.73 (1.06-2.82); *P*=.03	NA	NA
Anemia (change in hemoglobin level >2 g/dL[c])	NA	NA	3.48 (0.73-16.62); *P*=.12	NA	NA	0.63 (0.27-1.46); *P*=.28
History of diabetes mellitus	NA	NA	NA	1.53 (0.90-2.60); *P*=.12	0.80 (0.22-2.83); *P*=.73	NA
Presence of pneumonia	NA	NA	NA	<0.01 (<0.01->99.99); *P*=1.00	NA	NA
History of urinary retention	NA	NA	NA	5.55 (3.10-9.92); *P*<.01	NA	NA
Body mass index	NA	NA	NA	NA	1.06 (1.01-1.10); *P*=.02	NA
History of tobacco use	NA	NA	NA	NA	0.97 (0.39-2.45); *P*=.96	NA
Steroid use during the admission	NA	NA	NA	NA	1.16 (0.27-5.07); *P*=.84	NA

[a]MI = myocardial infarction; NA = not analyzed; PE = pulmonary embolism; SSI = surgical site infection; UTI = urinary tract infection.
[b]Data are presented as odds ratio (95% CI).
[c]SI conversion factor: To convert to mol/L, multiply by .6026.

Abbreviations and Acronyms: **DVT** = deep venous thrombosis; **EHR** = electronic health record; **HR** = heart rate; ***ICD-9*** = *International Classification of Diseases, Ninth Revision*; **MI** = myocardial infarction; **NPV** = negative predictive value; **OR** = odds ratio; **PE** = pulmonary embolism; **PPV** = positive predictive value; **SSI** = surgical site infection; **TJA** = total joint arthroplasty; **UTI** = urinary tract infection

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