

General

Preoperative Factors Associated With Pulmonary Embolism Following Primary Total Hip Arthroplasty: An ACS-NSQIP Analysis of 2017–2021 Data

Niki R Patel¹✉, Pranay Gadikota²✉, Thor S. Stead, MD³✉, Omar Viswanath, MD⁴✉, Latha Ganti, MD⁵✉

¹ Canterbury Collegiate Preparatory HS, ² Harvard University, ³ Weill Cornell Medicine, ⁴ Creighton University School of Medicine, ⁵ The Warren Alpert Medical School of Brown University

Keywords: total hip arthroplasty, pulmonary embolism, ACS-NSQIP, logistic regression, body mass index

<https://doi.org/10.52965/001c.172452>

Orthopedic Reviews

Vol. 18, 2026

Background

This study examined preoperative factors associated with 30-day pulmonary embolism (PE) after primary total hip arthroplasty.

Methods

ACS-NSQIP records from 2017–2021 with CPT code 27130 were analyzed. Complete cases were included using cleaned body mass index (BMI), age, sex, steroid use, and disseminated cancer. These five variables were entered jointly into logistic regression.

Results

Among 196,495 complete cases, 484 (0.246%) had PE. Adjusted odds ratios were 6.44 for disseminated cancer, 1.69 for steroid use, 1.23 for female sex, 1.041 per year of age, and 1.031 per kg/m² of BMI (all $P < .05$). Apparent AUC was 0.647 (95% CI, 0.622–0.672). The Hosmer–Lemeshow test indicated lack of fit ($P = .012$).

Conclusions

Five preoperative characteristics were associated with PE. Discrimination was modest, calibration limitations were present, and validation is required before clinical use.

INTRODUCTION

Total hip arthroplasty (THA) is a commonly performed orthopedic procedure, with continued growth projected in the United States.¹ Venous thromboembolism, including pulmonary embolism (PE), remains an important perioperative concern, and prevention after hip and knee arthroplasty has been extensively discussed.² Identifying characteristics associated with postoperative PE may support further investigation of risk assessment, but association estimates alone do not establish the effectiveness of a preventive strategy.

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) provides standardized perioperative data and 30-day outcomes across participating institutions.³ Previous research has examined predictors of PE following THA using NSQIP.^{4–6} The present study evaluated associations of age, sex, body mass index (BMI), chronic steroid use, and disseminated cancer with 30-day PE following primary THA in the 2017–2021 dataset, based on standard NSQIP analysis methods.⁷ It also assessed the apparent discrimination and calibration of the five-variable logistic regression model.

METHODS

DATA SOURCE AND COHORT

This retrospective cohort analysis used the ACS-NSQIP data extract covering 2017–2021. All 199,967 records in the extract had primary Current Procedural Terminology (CPT) code 27130. Records were included in the analytic cohort when age, sex, cleaned BMI, steroid-use status, disseminated-cancer status, and the PE outcome were available. No restriction to elective procedures was applied. Records were analyzed as supplied, without imputing missing values.

VARIABLES AND DATA CLEANING

The outcome was postoperative PE within 30 days, identified by NPULMBOL = 1; this indicator agreed with the PULMBOL category “Pulmonary Embolism.” The predictors were age in years, female versus male sex, BMI in kg/m², steroid use (Yes versus No), and disseminated cancer (Yes versus No).

BMI was taken from the cleaned “BMI 2” field. Its non-missing values were verified against 703 × weight in pounds

/ height in inches squared using the supplied “WEIGHT 2” and “HEIGHT 2” fields. The original BMI field included calculations based on –99 missing-value codes in height or weight and was not used. Missing values in the cleaned fields were left missing. No additional trimming or winsorization of nonmissing BMI values was performed. Missing age values were not assigned an age category or replacement value.

STATISTICAL ANALYSIS

Continuous variables were summarized as means and standard deviations, and categorical variables as counts and percentages. The five specified predictors were entered jointly into a multivariable logistic regression model fitted by maximum likelihood.⁸ No univariable screening, stepwise selection, or additional covariate adjustment was performed in this analysis. Age and BMI were modeled as linear terms in the log odds. Binary predictors were coded 1 for female sex, steroid use, or disseminated cancer, and 0 for their respective reference categories. No interaction terms were included. Adjusted odds ratios (ORs), Wald 95% confidence intervals (CIs), and two-sided Wald P values were calculated. ORs describe changes in odds rather than absolute risk differences.⁹

Overall model fit was compared with an intercept-only model using a likelihood-ratio test. Discrimination was assessed by the area under the receiver operating characteristic curve (AUC), with a 95% CI calculated using the non-parametric DeLong variance. Calibration was assessed with the Hosmer–Lemeshow statistic using ten groups formed from quantiles of predicted probabilities and eight degrees of freedom. All performance measures were calculated in the same records used to fit the model and represent apparent performance. No bootstrap validation, cross-validation, held-out validation, or external validation was performed. Statistical significance was defined as $P < .05$.

RESULTS

COHORT AND EVENT FREQUENCY

The initial dataset contained 199,967 records, including 507 PE events. Age was missing in 1,735 records, cleaned BMI in 1,811, and sex in 7; steroid use, disseminated cancer, and PE status had no missing values. Because missingness overlapped across variables, 3,472 unique records were excluded, including 23 PE events. The final complete-case cohort comprised 196,495 records, with 484 PE events (0.246%) and 196,011 records without PE (99.754%) (Figure 1).

The analytic cohort had a mean age of 65.5 ± 11.1 years (range, 18–89 years) and mean BMI of 30.3 ± 6.2 kg/m² (range, 10.49–103.22 kg/m²). Female sex was recorded in 107,336 cases (54.6%), steroid use in 7,410 (3.8%), and disseminated cancer in 895 (0.5%). Cohort characteristics are presented in Table 1.

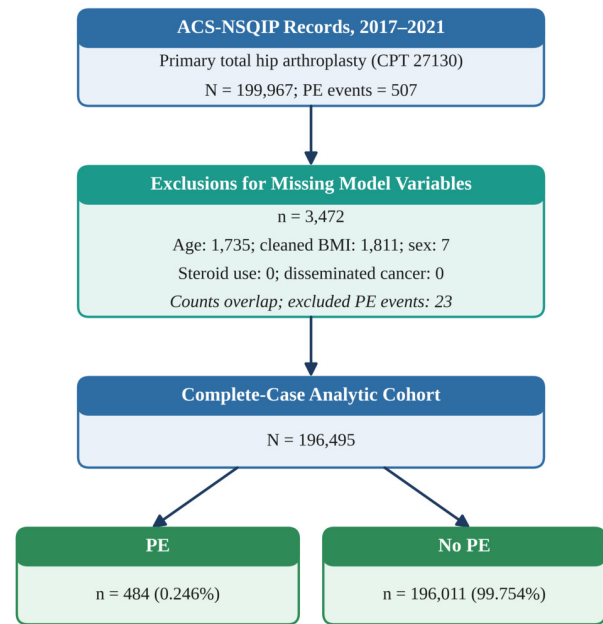


Figure 1. Cohort selection.

Exclusion counts by variable are not mutually exclusive. The analysis uses cleaned BMI and complete data for all five predictors. THA, total hip arthroplasty; PE, pulmonary embolism; BMI, body mass index.

Table 1. Characteristics of the complete-case cohort (N = 196,495).

Characteristic	Value
Age, years, mean $\pm$ SD	65.5 $\pm$ 11.1
BMI, kg/m ² , mean $\pm$ SD	30.3 $\pm$ 6.2
Female	107,336 (54.6%)
Male	89,159 (45.4%)
Steroid use	7,410 (3.8%)
Disseminated cancer	895 (0.5%)
PUF year 2017	36,700 (18.7%)
PUF year 2018	39,634 (20.2%)
PUF year 2019	44,972 (22.9%)
PUF year 2020	34,959 (17.8%)
PUF year 2021	40,230 (20.5%)
30-day pulmonary embolism	484 (0.246%)

Categorical values are n (%); continuous values are mean $\pm$ standard deviation (SD). PUF, Participant Use File; BMI, body mass index.

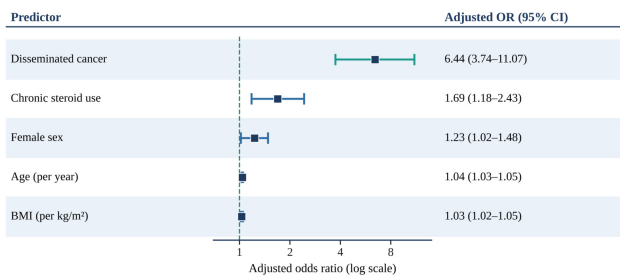
ADJUSTED ASSOCIATIONS

Disseminated cancer was associated with higher odds of PE (adjusted OR, 6.44; 95% CI, 3.74–11.07; $P < .001$), as were steroid use (OR, 1.69; 95% CI, 1.18–2.43; $P = .005$) and female sex (OR, 1.23; 95% CI, 1.02–1.48; $P = .029$). Each additional year of age was associated with an OR of 1.041 (95% CI, 1.031–1.050; $P < .001$), and each additional kg/m² of BMI with an OR of 1.031 (95% CI, 1.017–1.046; $P < .001$).

Table 2. Five-variable logistic regression for 30-day pulmonary embolism.

Term	Coefficient	Adjusted OR (95% CI)	P value
Intercept	-9.809642	—	—
Age, per year	0.039841	1.041 (1.031–1.050)	<.001
BMI, per kg/m ²	0.030680	1.031 (1.017–1.046)	<.001
Female versus male	0.206209	1.23 (1.02–1.48)	.029
Steroid use versus no use	0.524983	1.69 (1.18–2.43)	.005
Disseminated cancer versus none	1.861822	6.44 (3.74–11.07)	<.001

N = 196,495; PE events = 484. Binary predictors are coded 1 for the listed exposure and 0 for the reference. The linear predictor is the intercept plus the sum of coefficient × predictor; the fitted probability is $1 / [1 + \exp(-\text{linear predictor})]$. Coefficients are provided for reproducibility, not as a validated clinical calculator.

**Figure 2. Adjusted associations with 30-day PE.**

Squares indicate odds ratios and horizontal bars indicate 95% confidence intervals. The horizontal axis is logarithmic. Age and BMI effects are per one-unit increase. All estimates come from the same five-variable model.

These estimates are adjusted for the other four predictors in the model (Table 2; Figure 2).

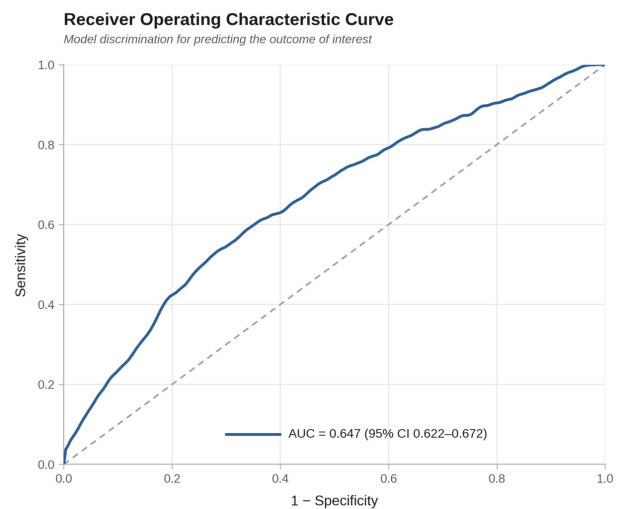
APPARENT MODEL PERFORMANCE

The likelihood-ratio statistic was 128.67 with five degrees of freedom ($P < .001$). Apparent AUC was 0.647 (95% CI, 0.622–0.672), indicating modest discrimination (Figure 3). The Hosmer–Lemeshow statistic was 19.56 with eight degrees of freedom ($P = .012$), indicating evidence of lack of fit across the ten predicted-risk groups. These findings do not establish good calibration or clinical utility.

DISCUSSION

In this analysis of 196,495 primary THA records, 484 PE events were recorded within 30 days. Disseminated cancer, steroid use, female sex, older age, and higher BMI were associated with greater odds of PE after adjustment for the other included variables. The model showed modest apparent discrimination and evidence of calibration limitations. The findings describe associations within the available complete-case cohort and do not demonstrate that these variables form a validated clinical prediction tool.

Disseminated cancer had the largest adjusted OR among the categorical predictors. Cancer-associated thrombosis has been examined extensively, and metastatic disease has also been studied in relation to complications after primary hip and knee arthroplasty.^{10,11} The present extract does not establish which cancer characteristics, treatments, or sur-

**Figure 3. Empirical receiver operating characteristic curve calculated from the fitted probabilities in the complete-case cohort.**

AUC = 0.647 (95% CI, 0.622–0.672; DeLong method). The dashed line represents chance discrimination. Performance is apparent and was not corrected for optimism.

gical indications account for the association. The reference group was absence of disseminated cancer, not necessarily absence of all cancer. The analysis cannot determine an appropriate prophylaxis agent or duration for this subgroup.

Steroid use was associated with higher PE odds, but the analysis did not separate a medication effect from the conditions for which steroids were prescribed. Steroid dose, duration, indication, and perioperative supplementation were not included in the model. Consequently, the result should not be used to recommend changes to steroid treatment or to infer a specific mechanism.

Age and BMI were associated with PE when modeled as continuous variables. Prior literature has examined associations between obesity and venous thromboembolism, as well as age-related changes in thrombosis biology.^{12,13} These sources provide context, but the present analysis did not measure biological mechanisms or test whether risk changed nonlinearly with age or BMI. Similarly, the association with female sex cannot establish an explanation involving hormone exposure, anatomy, or operative positioning. Those explanations were not tested.

The AUC of 0.647 indicates limited separation between records with and without PE. A low event rate does not, by itself, justify describing this discrimination as strong. The significant likelihood-ratio test establishes improvement in fit over an intercept-only model, but does not demonstrate useful clinical thresholds, favorable clinical consequences, or suitability for individualized treatment decisions. The significant Hosmer–Lemeshow result also argues against describing calibration as good. No conclusions about benefit from intensified prophylaxis or enhanced surveillance can be drawn from this analysis.

LIMITATIONS

The analysis was retrospective and limited to the supplied NSQIP extract. It was not a probability sample of all US THA procedures. Complete-case exclusion removed 3,472 records and 23 PE events, and no imputation was performed. Results therefore apply to the analyzed records and may differ from those in excluded records. The original BMI field contained values derived from missing-value codes; use of the supplied cleaned BMI field avoided those calculations, but remaining measurement error cannot be excluded.

Adjustment was limited to five predictors. Anesthesia type, functional status, and transfusion information were present in the extract but were not included in this model. The analysis did not evaluate prophylaxis regimens, prior VTE, cancer subtype, steroid indication, or postoperative mobility. Residual confounding is possible. The dataset included elective and nonelective procedures, and this analysis did not estimate separate effects by operative indication. Outcomes were limited to 30 days, so the study does not describe later PE events.

The model assumed linear log-odds relationships for age and BMI and did not include interactions. It treated records as independent without a hospital-level adjustment. Performance was assessed in the development data, without

internal or external validation or optimism correction. No clinical-utility analysis was performed. The reported associations and apparent performance should therefore not be interpreted as evidence supporting clinical deployment.

CONCLUSION

Among 196,495 complete records of primary THA from 2017–2021, 484 (0.246%) had PE within 30 days. Disseminated cancer, steroid use, female sex, age, and BMI were associated with PE in a five-variable logistic regression model. Apparent discrimination was modest, and the calibration test indicated lack of fit. These results support further evaluation of the observed associations, but do not establish a validated risk calculator or a basis for changing thromboprophylaxis.

ETHICS STATEMENT

The Brown University Regulatory Advisory Unit, Office of Research Integrity, reviewed this study and determined that it does not constitute human subjects research under applicable U.S. Department of Health and Human Services (DHHS) and Food and Drug Administration (FDA) regulations. The study involved secondary analysis of de-identified data from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database. Because investigators had no direct interaction with participants and no access to identifiable private information, institutional review board (IRB) review and approval were not required. Informed consent was not required for this secondary analysis of de-identified data.

Submitted: October 06, 2026 EDT. Accepted: October 11, 2026 EDT. Published: October 18, 2026 EDT.

REFERENCES

1. Singh JA, Yu S, Chen L, Cleveland JD. Rates of Total Joint Replacement in the United States: Future Projections to 2020-2040 Using the National Inpatient Sample. *J Rheumatol*. 2019;46(9):1134-1140. doi:[10.3899/jrheum.170990](https://doi.org/10.3899/jrheum.170990)
2. Hilliard I, Stead TS, Banerjee A, Hua Y, Ganti L. Mind the clot: Predictors of pulmonary embolism after total knee arthroplasty- An analysis of 150,119 cases. *Orthop Rev (Pavia)*. 2025;17:143769. doi:[10.52965/001c.143769](https://doi.org/10.52965/001c.143769). PMID:41069860
3. Raval MV, Pawlik TM. Practical Guide to Surgical Data Sets: National Surgical Quality Improvement Program (NSQIP) and Pediatric NSQIP. *JAMA Surg*. 2018;153(8):764-765. doi:[10.1001/jamasurg.2018.0486](https://doi.org/10.1001/jamasurg.2018.0486)
4. Bulut H, Maestre MJ, Tomey D. Predictors and risk factors of pulmonary embolism after total hip arthroplasty: an NSQIP study. *Hip Int*. 2025;35(1):70-75. doi:[10.1177/11207000241270205](https://doi.org/10.1177/11207000241270205)
5. Fowler C, Tlimat A, Kaelber DC, et al. Obstructive sleep apnea is associated with a higher 28-day incidence of venous thromboembolism and stroke after total hip arthroplasty. *Sleep Breath*. 2026;30(3):181. doi:[10.1007/s11325-026-03657-4](https://doi.org/10.1007/s11325-026-03657-4). PMID:42262663
6. Ervando H, Ridwan LS, Dilogio IH. Factors related to deep vein thrombosis as a complication of post-total hip arthroplasty patients: a systematic review. *Eur J Orthop Surg Traumatol*. 2025;35(1):82. doi:[10.1007/s00590-025-04209-4](https://doi.org/10.1007/s00590-025-04209-4). PMID:40021493
7. Stead TS, Ganti L, Hua Y. Using the American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) Database to Teach Data Exploration, Statistical Analysis, and Clinical Inference to Residents and Medical Students. *Academic Medicine & Surgery*. Published online May 10, 2025. doi:[10.62186/001c.137943](https://doi.org/10.62186/001c.137943)
8. Hua Y, Stead TS, George A, Ganti L. Clinical Risk Prediction with Logistic Regression: Best Practices, Validation Techniques, and Applications in Medical Research. *Academic Medicine & Surgery*. Published online March 7, 2025. doi:[10.62186/001c.131964](https://doi.org/10.62186/001c.131964)
9. George A, Stead TS, Ganti L. What's the Risk: Differentiating Risk Ratios, Odds Ratios, and Hazard Ratios? *Cureus*. 2020;12(8):e10047. doi:[10.7759/cureus.10047](https://doi.org/10.7759/cureus.10047)
10. Khorana AA, Francis CW. Risk prediction of cancer-associated thrombosis: Appraising the first decade and developing the future. *Thromb Res*. 2018;164 Suppl 1:S70-S76. doi:[10.1016/j.thromres.2018.01.036](https://doi.org/10.1016/j.thromres.2018.01.036)
11. Sloan M, Lee GC. Mortality and Complications in Patients with Metastatic Disease after Primary Total Hip and Total Knee Arthroplasty. *J Arthroplasty*. 2020;35(12):3512-3516. doi:[10.1016/j.arth.2020.06.080](https://doi.org/10.1016/j.arth.2020.06.080)
12. Hotoleanu C. Association between obesity and venous thromboembolism. *Med Pharm Rep*. 2020;93(2):162-168. doi:[10.15386/mpr-1372](https://doi.org/10.15386/mpr-1372)
13. Koniecznyńska M, Natowska J, Undas A. Thrombosis and Aging: Fibrin Clot Properties and Oxidative Stress. *Antioxid Redox Signal*. 2024;41(4-6):233-254. doi:[10.1089/ars.2023.0365](https://doi.org/10.1089/ars.2023.0365)