The Journal of Arthroplasty 31 (2016) S187–S191

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Complications - Other

Development and Validation of a Risk Stratification System for Pulmonary Embolism After Elective Primary Total Joint Arthroplasty

Daniel D. Bohl, MD, MPH [a], Mitchell G. Maltenfort, PhD [b], Ronald Huang, MD [b], Javad Parvizi, MD, FRCS [b], Jay R. Lieberman, MD [c], Craig J. Della Valle, MD [a, *]

[a] Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, Illinois
[b] Department of Orthopaedic Surgery, Rothman Institute, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania
[c] Department of Orthopaedic Surgery, Keck School of Medicine, University of Southern California, Los Angeles, California

ARTICLE INFO

Article history:
Received 29 August 2015
Received in revised form
9 February 2016
Accepted 23 February 2016
Available online 17 March 2016

Keywords:
venous thromboembolism
pulmonary embolism
total hip arthroplasty
total knee arthroplasty
prophylaxis

ABSTRACT

Introduction: Stratification of patients into different risk categories for pulmonary embolism (PE) after total joint arthroplasty (TJA) may allow clinicians to individualize venous thromboembolism prophylaxis based on an appropriate risk-benefit scale.
Methods: Patients undergoing primary total hip arthroplasty (THA) or total knee arthroplasty (TKA) as part of the American College of Surgeons National Surgical Quality Improvement Program were identified. Independent risk factors for PE within 30 days of surgery were identified and used to develop a point-scoring system to estimate the relative risk for PE. For validation, the system was tested on patients undergoing TJA at a single institution.
Results: A total of 118,473 patients were identified, including 72,673 (61.3%) undergoing TKA and 45,800 (38.7%) undergoing THA. The incidence of PE within 30 days of the index arthroplasty was 0.50%. The risk factors associated with PE were age ≥70, female gender, higher body mass index (25-30 kg/m^2 and ≥30 kg/m^2), and TKA (vs THA); anemia was protective. The point scores derived for each of these factors were as follows: anemia: −2; female: +1; body mass index 25-30 kg/m^2: +2; body mass index ≥30 kg/m^2: +3; age ≥70 years: +3; TKA: +5. The point-scoring system was then applied to 17,384 patients from a single institution. Single-institution patients categorized as low risk using the point-scoring system had a 0.44% 90-day risk for PE (95% CI = 0.29%-0.58%); medium risk, 1.51% (95% CI = 1.18%-1.84%); and high risk, 2.60% (95% CI = 2.09%-3.10%).
Conclusion: This point-scoring system predicts risk for PE after TJA and may help surgeons to optimize selection of chemical prophylaxis.

Pulmonary embolism (PE) is one of the most serious complications that can occur after total joint arthroplasty (TJA) [1-5]. As a result, TJA patients are commonly prescribed postoperative anticoagulation in an attempt to reduce the risk of PE. However, anticoagulation regimens are not benign, as they may increase the risk for bleeding, hematoma formation, wound healing problems, and deep infection [3,6-8]. Surgeons must weigh the benefits of anticoagulation against the risks when determining which type of PE prophylaxis to use for any given patient. To do so, surgeons might benefit from a better understanding of which patients are at greatest risk for PE.

Risk factors for PE after surgery have been characterized in both the general [9-11] and orthopedic [12-17] surgical literature. However, many of these studies have been limited by the use of administrative data, which have known imperfections [18-21], or by small sample size. Moreover, such studies typically present results of regressions identifying statistical associations. However, they do not typically provide clinicians with practical risk stratification systems based on their data and hence cannot be easily applied to practice by clinicians at this time. Finally, although Parvizi et al [12] did develop a practical system for risk stratifying patients, the system was based on administratively coded patient characteristics and the system was not evaluated for validity among a second population. Any sample of patients and set of data

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.2016.02.080.

* Reprint requests: Craig J. Della Valle, MD, Department of Orthopaedic Surgery, Rush University Medical Center, 1611 W. Harrison St, Suite 300, Chicago, IL 60612.

http://dx.doi.org/10.1016/j.arth.2016.02.080
0883-5403/

collection procedures have inherent biases; validation in a second population with differing data collection methods provides reassurance that such biases are not exclusively responsible for observed results.

As a result of the weaknesses in this literature, it is currently difficult for clinicians who would like to provide differential anticoagulation based on individual patient risk profiles to do so. Hence, many clinicians use the same prophylaxis regimen for the vast majority of their patients.

In this context, the purpose of the present study is to develop a risk stratification system for PE after elective primary TJA using a nationwide prospective surgical registry. Both total hip arthroplasty (THA) and total knee arthroplasty (TKA) cases will be included and discriminated between. The system will be based on chart-abstracted clinical data (taken from clinical charts) rather than administratively coded billing data. We posit that in order for a risk stratification system to be widely adopted, it should be validated in a second patient population with differing data collection methods. Hence, the nationwide registry-derived risk stratification system that is developed here will then be evaluated among a population of patients from a single institution for which warfarin was used for VTE prophylaxis.

Methods

Development of a Risk Stratification System for PE Using the ACS-NSQIP

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) is a surgical registry located at several hundred community and academic institutions nationwide [22-25]. As part of the program, sampled patients are prospectively registered before major surgical procedures. Sampled patients are then followed by highly trained data collection nurses during the first 30 postoperative days for the development of adverse events, including PE. PE is captured both before and after discharge, and when PE does occur, the postoperative day of occurrence is recorded. Of note, the program undergoes routine continuous auditing and has consistently demonstrated a high degree of accuracy of its demographic, comorbidity, and adverse event data [24].

For the present study, patients were identified who underwent elective primary THA or elective primary TKA as part of the ACS-NSQIP during 2006-2013. Patients undergoing primary TKA were identified using Current Procedural Terminology (CPT) code 27,130, whereas patients undergoing primary THA were identified using CPT code 27,447. The International Classification of Diseases 9th Revision diagnosis code field and additional associated CPT code fields were then used to exclude patients not clearly undergoing elective primary TJA. Specifically, patients whose cases involved additional unrelated procedures, acute trauma, major ligament reconstruction, preoperative infection, prosthesis revision, or hardware removal were excluded. Patients undergoing surgery nonelectively were excluded. Patients missing data for any demographic, comorbidity, laboratory, or procedural characteristic were excluded.

Patients were stratified by the following demographic characteristics: age (<70 or ≥70 years), sex (male or female), body mass index (<25, 25-30 [overweight], or ≥30 kg/m^2 [obese]), and functional status (independent or dependent). Similarly, patients were stratified by the following comorbidity characteristics: diabetic status (nondiabetic, non–insulin-dependent diabetes mellitus, or insulin-dependent diabetes mellitus) and presence of hypertension (defined by NSQIP as greater than 140/90 "most of the time" or requiring antihypertensive medication), chronic obstructive pulmonary disease, current smoking status, and anemia (defined as preoperative hematocrit <39 in males and <36 in females [26]). Finally, patients were stratified by the following procedural characteristics: procedure type (primary THA or primary TKA), anesthesia type (regional or general), and operative time (<90 minutes or ≥90 minutes).

Bivariate and multivariate Cox proportional hazards models were then used to test for demographic, comorbidity, and procedural associations with PE after TJA in this population. The final multivariate model was selected using a backward stepwise elimination process initially including all demographic, comorbidity, and procedural characteristics and eliminating characteristics with the highest *P*-values one by one until all characteristics had $P < .05$. A nomogram was then applied to the final multivariate model to assign point values for generation of a point-scoring risk stratification system. The maximum number of points per risk factor for the risk stratification system was set to 5. Threshold total point values were selected for low-, medium-, and high-risk total score categories such that the patients were partitioned most closely into 3 equally sized groups. Of note, the size and number of groups was arbitrary; we rationalized that 3 equally sized groups was an easy, potentially effective way for clinicians to mentally partition the population. The average risk for PE and 95% CIs were calculated for each of the 3 risk groups.

Test of Performance of the Risk Stratification System Among a Single-Institution Cohort

A second cohort of patients was then identified for testing of performance of the risk stratification system. Of note, there was partial overlap of this cohort with patients in the aforementioned study by Parvizi et al [12]. The authors maintain a prospective TJA registry at their institution into which patients are registered at the time of surgery. The registry includes demographic, comorbidity, and procedural characteristics. This registry was initially searched for all cases of primary TJA performed during 2000-2011. For the present study, an additional inclusion criterion was receipt of warfarin prophylaxis (determined by chart review of individual patient records). The standard warfarin protocol included administration of warfarin the evening after surgery and subsequent targeting of the international normalized ratio to 1.8-2.0 for 6 postoperative weeks.

The demographic, comorbidity, and procedural characteristics that had been included in the ACS-NSQIP–derived risk stratification system were extracted from the single-institution registry for each of the patients in the single-institution cohort. These included procedure type (primary TKA or primary THA), age (<70 or ≥70 years), sex (male or female), body mass index (<25, 25-30 [overweight], or ≥30 kg/m^2 [obese]), and anemia (defined as preoperative hematocrit <39 in males and <36 in females [26]). Patients missing any of these data points were excluded from the present study.

For included patients, all individual patient charts were reviewed for occurrence of PE or admission to other hospitals within 90 days of surgery. This included a review of telephone records and all follow-up notes with particular attention paid to detecting any mention of admission to hospitals other than the index. As part of routine practice, clinical suspicion for PE led to either chest CT scan or ventilation/perfusion scan. A PE was considered to have occurred if there were (1) symptoms potentially suggestive of a PE and (2) a chest CT scan read as positive for PE or a ventilation/perfusion scan read as high probability for PE.

The ACS-NSQIP-derived point-scoring system was then applied to these single-institution patients. The total points were summed for each patient. Based on the total points and the categories defined previously, patients were stratified into low-, medium-, and