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Implementation and Validation of the 2013 Caprini Score for Risk Stratification of Arthroplasty Patients in the Prevention of Venous Thrombosis

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Abstract

Appropriate chemoprophylaxis choice following arthroplasty requires accurate patient risk assessment. We compared the results of our prospective department protocol to the Caprini risk assessment model (RAM) retrospectively in this study group. Our goal was to determine whether the department protocol or the Caprini score would identify venous thromboembolism (VTE) events after total joint replacement. A secondary purpose was to validate the 2013 Caprini RAM in joint arthroplasty and determine whether patients with VTE would be accurately identified using the Caprini score. A total of 1078 patients met inclusion criteria. A Caprini score of 10 or greater is considered high risk and a score of 9 or less is considered low risk. The 2013 version of the Caprini RAM retrospectively stratified 7 of the 8 VTE events correctly, while only 1 VTE was identified with the prospective department protocol. This tool provided a consistent, accurate, and efficacious method for risk stratification and selection of chemoprophylaxis.

Keywords

arthroplasty, Caprini risk assessment model, risk stratification, chemoprophylaxis, aspirin, apixaban, rivaroxaban

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Introduction

The increased risk for venous thromboembolism (VTE), which includes deep vein thrombosis (DVT) and pulmonary embolism (PE), is well documented following joint arthroplasty. Current thromboprophylaxis strategies in orthopaedic surgery consist of a multimodal approach that includes both chemical and mechanical options. There is agreement that early mobilization and mechanical compression devices play an integral role in reducing the risk of VTE. However, consensus on a chemoprophylaxis regimen remains elusive and controversial. The optimal regimen should be safe, effective, and inexpensive. Chemoprophylaxis places the orthopaedic patient at increased risk of postoperative bleeding and its sequelae. These risks include wound bleeding, hematoma, delayed wound healing, risk of dehiscence or infection, joint stiffness, compromised functional outcome, and increased need for an allogeneic blood transfusion.[1] Thus, safety and efficacy are of equal importance in the eyes of the orthopaedic surgeon.

Prior to 2012, there was disharmony among guidelines and national quality measures with respect to appropriate chemoprophylaxis for the arthroplasty patient. The 2007 American Academy of Orthopaedic Surgeons (AAOS) guidelines on VTE prevention advised the use of aspirin with a grade C recommendation, acknowledging the lack of sufficient studies to identify an optimal dose.[1] In 2012, the American Academy of Chest Physicians released their ninth edition Antithrombotic Therapy

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and Prevention of Thrombosis, with a chapter dedicated specifically to prevention of VTE following orthopaedic surgery.[2] This document recognized, for the first time, the validity of aspirin for postoperative chemoprophylaxis. In January 2014, the Centers for Medicare and Medicaid Services added aspirin as an "allowable value" to prevent hospital-acquired VTE following total joint arthroplasty (TJA).[3,4] The AAOS reached a consensus recommendation on using prophylaxis for patients with additional VTE risk factors undergoing major orthopaedic surgery but did not define these risk factors, stratify patients, or identify specific prophylaxis agents. It did, however, acknowledge the "appeal" of individualized risk factor assessment in choosing a pharmacologic agent for VTE prophylaxis.[1] Venous thromboembolism prophylaxis presents the clinical dilemma of balancing postoperative thrombotic risk along with anticoagulation-related complications. Aspirin has been shown to be an effective chemoprophylaxis option but in lower risk patients.[5] This emphasizes the importance of a comprehensive risk assessment tool that can help identify the appropriate lower risk patients for aspirin chemoprophylaxis. Although some practitioners may view risk assessment as a cumbersome, time-consuming process, Fuentes et al created a patient-friendly tool that was shown to provide accurate patient assessment, taking the patient 5 minutes to complete, and then on average, 6 minutes for the health professional to finalize.[6] The importance of completing this document prior to the operative day cannot be overemphasized. Having the patient complete the form with their family ahead of time and subsequently double checked by an appropriate health-care provider are key elements in this process. Important issues regarding family history of thrombosis and past obstetrical complications that may reflect the presence of the antiphospholipid syndrome are best obtained using this process. These elements are powerful risk factors associated with the development of postoperative thrombosis. One can understand that the presence of these high-risk factors may influence the choice of postoperative anticoagulant prophylaxis.

Utilizing evidence-based literature, including national guidelines[1,2] and contemporary studies,[5,7-10] our orthopaedic department identified prominent VTE risk factors in order to move to a user-friendly risk-stratification model. In August 2015, we finalized a chemoprophylaxis protocol that risk-stratified patients to either low risk or high risk for postoperative VTE. Patients were considered high risk if they met at least one of the following criteria: VTE within prior year, morbid obesity (body mass index [BMI] > 40) with additional comorbidities, active malignancy, bilateral staged joint arthroplasty, and inherited or acquired thrombophilia. Inherited thrombophilia included but was not limited to factor V Leiden, protein C and S deficiencies, antithrombin deficiency, and prothrombin 20210A mutations; acquired thrombophilia included but was not limited to antiphospholipid antibody syndrome (Lupus anticoagulant, Anticardiolipin antibodies).[11] Patients without any high-risk comorbidities were considered low risk.

Using a risk stratification model based only on selected, individual high-risk factors has limitations. The model does not account for the cumulative effect of risk factors such as age, weight, mobility, and certain comorbidities which could potentially lead to undertreatment of certain patients. Furthermore, VTE chemoprophylaxis based on a weak individual risk factor could lead to overtreatment of some patients.

The Caprini risk assessment model (RAM) has been validated in over 250 000 patients in more than 100 clinical trials worldwide. The Caprini RAM assigns a weighted number to various known risks factors for VTE. Risk factor weighing is used to calculate the risk for an individual patient. These results may be used to determine aspects of chemoprophylaxis such as selection of the appropriate agent and duration of therapy.[11] The RAM was created to track a number of important risk factors for thrombosis, since it has been shown that as the number of risk factors increases so does the incidence of thrombosis.[12] Although the Caprini RAM has been validated in preoperative patients with hip fracture [13] as well as following foot and ankle procedures,[14] insufficient data are available to support its use in joint arthroplasty.

This study was designed to compare the Caprini RAM in the arthroplasty patient with our department risk stratification and chemoprophylaxis protocol. Our goal was to validate the Caprini RAM to determine whether this is a more accurate way to identify high-risk patients than our current department risk stratification protocol. This will allow for a more appropriate and individualized chemoprophylaxis regimen to lower the risk of VTE and justify the use of anticoagulants such as direct oral anticoagulants (DOACs) compared to aspirin in high-risk patients. This tool can also identify those patients who are low risk where aspirin can be effectively used.

Methods

This was a retrospective, institutional review board-approved, cohort study of all primary total hip arthroplasty (THA), primary total knee arthroplasty (TKA), THA revision, TKA revision, and staged bilateral arthroplasty patients at a single institution by 12 surgeons. The study period was from September 1, 2015, to December 31, 2016. On September 1, 2015, our orthopaedic department adopted a chemoprophylaxis protocol based on risk stratification. Patients were identified using a hospital registry of all arthroplasty patients. All data were obtained through the electronic health record. Patients were excluded if they required therapeutic doses of anticoagulants, had a contraindication for treatment with aspirin or a DOAC, the arthroplasty was due to a hip fracture, or if the surgeon opted out of the stratification-driven protocol. Staged bilateral arthroplasty was included. The "staged" procedure, or second side, was performed on postoperative day (POD) 5. This allows for bilateral surgeries to be performed during 1 hospital admission, with the patient cleared for the second surgery 1 day prior (patient must ambulate 100 feet or more; hospitalist, anesthesia and any necessary specialists clear the patient; negative doppler for lower extremity DVT; all blood tests and parameters are optimized).

The chemoprophylaxis protocol based on department risk stratification was consistent for all patients. Patients were

risk stratified on POD 0. The only cause for change in risk classification was cancellation of a staged case. Standardization of VTE chemoprophylaxis did not allow for surgeon bias in drug selection. Chemoprophylaxis was started on the morning of POD 1. The THA, THA revision, TKA, and TKA revision patients assessed as low risk were prescribed enteric coated (EC) aspirin 325 mg twice daily for 6 weeks. The THA and THA revision patients assessed as high risk were prescribed prophylactic doses of a DOAC (rivaroxaban or apixaban) for 35 days (per prescribing information).[15,16] The TKA and TKA revision patients assessed as high risk were prescribed prophylactic doses of a DOAC (rivaroxaban or apixaban) for 12 days (per prescribing information)[15,16] followed by EC aspirin 325 mg twice daily for 4 weeks for a total of 6 weeks of chemoprophylaxis. Incidence of VTE following TJA remains elevated for 5 to 6 weeks (specifically, 35 days) postoperatively, and our surgeons advocate the need for extended prophylaxis.[17,2] Concurrent antiplatelet agents were permitted. High-risk patients prescribed daily low-dose aspirin therapy prior to surgery were continued on aspirin concurrently with the DOAC; however, the dosage did not exceed 81 mg daily. Rivaroxaban was the treatment option used in 2015. In January 2016, apixaban replaced rivaroxaban as the protocol-driven DOAC for high-risk patients based on emerging safety data showing lower incidence of bleeding with apixaban versus rivaroxaban.[18,19] All chemoprophylactic decisions were based solely on the department protocol, and the Caprini score was calculated by retrospective chart review.

The Caprini RAM version 2013 was utilized for this study[20] (Figure 1). This version differs from preceding versions in that it includes additional risk factors not tested in validation studies but shown in the literature to be associated with thrombosis. These identified risk factors include BMI above 40,[21,22] smoking,[23,24] diabetes requiring insulin,[25,26] chemotherapy,[27,28] blood transfusions,[29,30] and length of surgery over 2 hours.[31,32] The Caprini RAM was completed by specially trained medical students via review of the presurgical assessment history, medical clearances, medical consults, and hospital charts. The Caprini RAM was completed for every participant both preoperatively and predischarge to ensure that any changes in the patient's postoperative course were captured by the tool. The statistical analysis for the Caprini score was evaluated using the final predischarge Caprini score. The Caprini RAM was completed retrospectively and therefore had no influence on chemoprophylaxis selection. Ultimately, we sought to validate a risk assessment schema that would best identify high-risk patients who would benefit from traditional anticoagulants.

Preoperative and postoperative protocols were consistent for all patients. Spinal anesthesia was used unless there was a medical contraindication. Intravenous or intra-articular tranexamic acid (TXA) was administered in the operating room (OR) unless the patient had an inherited or acquired thrombophilia or an allergy to TXA. Intermittent pneumatic compression devices were applied in the OR and continued postoperatively while the patient was in bed. Early ambulation following joint arthroplasty began on POD 0. Patients were seen by a physical therapist within 4 hours of discharge from the post-anesthesia care unit and began their ambulation. Only acute medical events were a valid reason to postpone early ambulation on POD 0.

The primary efficacy outcomes were (1) symptomatic VTE events confirmed by objective testing, (2) all-cause mortality, and (3) return to the OR for a bleeding event, all within 60 days of surgery. Routine duplex ultrasounds were only performed on staged cases the day prior to the second arthroplasty. The incidence of PE, symptomatic DVT, return to OR for bleeding, and all-cause mortality were identified using a prospectively maintained database. The DVT was classified as either proximal or distal.

Major bleeding was defined as a postoperative drop in hemoglobin (Hgb) of $\geq$2g/dL or the administration of $\geq$2 units of autologous red blood cell transfusions. Postoperatively medical care was managed by the hospital, a medical doctor specializing in the care of hospitalized patients. The blood transfusion protocol was consistent for all patients. Patients received allogeneic blood transfusions when the Hgb was $\leq$7 g/dL. For Hgb >7 g/dL to <8 g/dL, patients were treated only if they were exhibiting clinical symptoms related to the anemia or if there was a rapid decline in Hgb. For Hgb $\geq$8 g/dL, patients were treated if they were exhibiting clinical symptoms of anemia.

Statistical Analysis

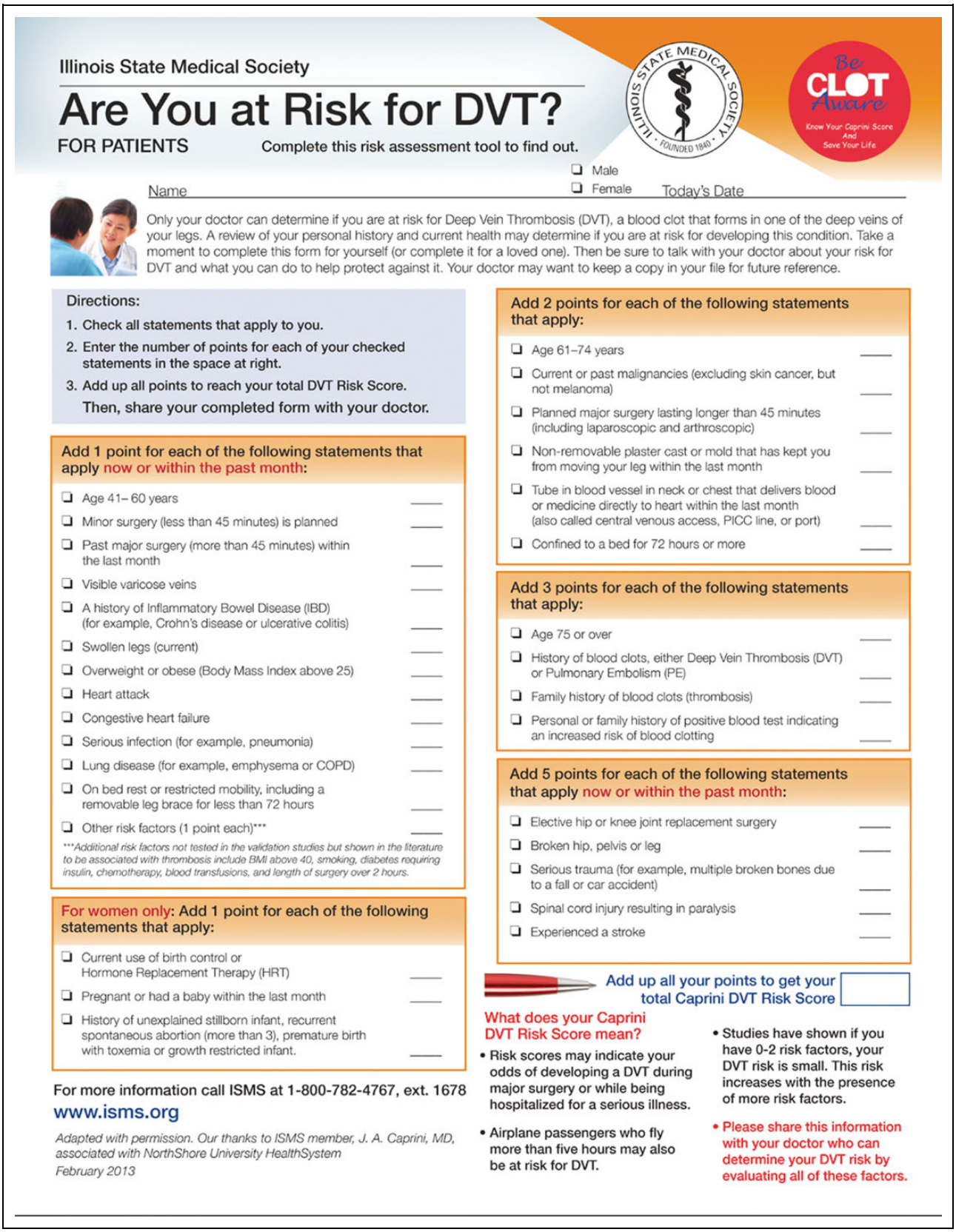
The primary objective was to characterize the degree of association between Caprini score and the department risk stratification classification. Using the risk stratification category as the "reference gold standard," a Caprini "cutoff" point could be determined that would maximize sensitivity and specificity. Univariable logistic regression analysis with Caprini score as a predictor and risk stratification as binary outcome (high or low) was carried out. Analysis of the resulting receiver–operating characteristic curve (ROC) was performed to identify the optimal cutoff Caprini score based on Youden index.[33] The Youden index is a measure of the discriminatory performance of a decision rule, compared to that of simply flipping a coin. The Caprini score corresponding to the largest Youden index was considered as the optimal cutoff value. Based on this cutoff, sensitivity and specificity of the Caprini score relative to risk stratification were computed.

The obtained cutoff Caprini score was also used to compute the sensitivity and specificity and corresponding 95% confidence intervals (CIs) for VTE occurrence.

Summary statistics for the study sample are presented as median, lower quartile, and upper quartile for measured variables and frequencies with percentages for categorical variables. Analysis was conducted using SAS version 9.4 (SAS Institute, Inc, Cary, North Carolina).

Results

The retrospective chart review identified 1078 patients who met inclusion criteria (Table 1). The distribution of the final Caprini Score is shown in Figure 2. The final predischarge



Illinois State Medical Society

Are You at Risk for DVT?

FOR PATIENTS Complete this risk assessment tool to find out.

Be CLOT Aware — Know Your Caprini Score And Save Your Life

❑ Male ❑ Female

Name Today's Date

Only your doctor can determine if you are at risk for Deep Vein Thrombosis (DVT), a blood clot that forms in one of the deep veins of your legs. A review of your personal history and current health may determine if you are at risk for developing this condition. Take a moment to complete this form for yourself (or complete it for a loved one). Then be sure to talk with your doctor about your risk for DVT and what you can do to help protect against it. Your doctor may want to keep a copy in your file for future reference.

Directions:

1. Check all statements that apply to you.
2. Enter the number of points for each of your checked statements in the space at right.
3. Add up all points to reach your total DVT Risk Score.

Then, share your completed form with your doctor.

Add 1 point for each of the following statements that apply now or within the past month:

- ❑ Age 41–60 years ____
- ❑ Minor surgery (less than 45 minutes) is planned ____
- ❑ Past major surgery (more than 45 minutes) within the last month ____
- ❑ Visible varicose veins ____
- ❑ A history of Inflammatory Bowel Disease (IBD) (for example, Crohn's disease or ulcerative colitis) ____
- ❑ Swollen legs (current) ____
- ❑ Overweight or obese (Body Mass Index above 25) ____
- ❑ Heart attack ____
- ❑ Congestive heart failure ____
- ❑ Serious infection (for example, pneumonia) ____
- ❑ Lung disease (for example, emphysema or COPD) ____
- ❑ On bed rest or restricted mobility, including a removable leg brace for less than 72 hours ____
- ❑ Other risk factors (1 point each)*** ____

****Additional risk factors not tested in the validation studies but shown in the literature to be associated with thrombosis include BMI above 40, smoking, diabetes requiring insulin, chemotherapy, blood transfusions, and length of surgery over 2 hours.*

For women only: Add 1 point for each of the following statements that apply:

- ❑ Current use of birth control or Hormone Replacement Therapy (HRT) ____
- ❑ Pregnant or had a baby within the last month ____
- ❑ History of unexplained stillborn infant, recurrent spontaneous abortion (more than 3), premature birth with toxemia or growth restricted infant. ____

Add 2 points for each of the following statements that apply:

- ❑ Age 61–74 years ____
- ❑ Current or past malignancies (excluding skin cancer, but not melanoma) ____
- ❑ Planned major surgery lasting longer than 45 minutes (including laparoscopic and arthroscopic) ____
- ❑ Non-removable plaster cast or mold that has kept you from moving your leg within the last month ____
- ❑ Tube in blood vessel in neck or chest that delivers blood or medicine directly to heart within the last month (also called central venous access, PICC line, or port) ____
- ❑ Confined to a bed for 72 hours or more ____

Add 3 points for each of the following statements that apply:

- ❑ Age 75 or over ____
- ❑ History of blood clots, either Deep Vein Thrombosis (DVT) or Pulmonary Embolism (PE) ____
- ❑ Family history of blood clots (thrombosis) ____
- ❑ Personal or family history of positive blood test indicating an increased risk of blood clotting ____

Add 5 points for each of the following statements that apply now or within the past month:

- ❑ Elective hip or knee joint replacement surgery ____
- ❑ Broken hip, pelvis or leg ____
- ❑ Serious trauma (for example, multiple broken bones due to a fall or car accident) ____
- ❑ Spinal cord injury resulting in paralysis ____
- ❑ Experienced a stroke ____

Add up all your points to get your total Caprini DVT Risk Score ☐

What does your Caprini DVT Risk Score mean?

- Risk scores may indicate your odds of developing a DVT during major surgery or while being hospitalized for a serious illness.
- Airplane passengers who fly more than five hours may also be at risk for DVT.
- Studies have shown if you have 0-2 risk factors, your DVT risk is small. This risk increases with the presence of more risk factors.
- Please share this information with your doctor who can determine your DVT risk by evaluating all of these factors.

For more information call ISMS at 1-800-782-4767, ext. 1678

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Adapted with permission. Our thanks to ISMS member, J. A. Caprini, MD, associated with NorthShore University HealthSystem

February 2013

Figure 1. Caprini risk assessment model (version 2013).

Table 1. Baseline Characteristics: Department Risk Stratification Protocol.[a]

Criteria	Low Risk Aspirin, N = 797	High Risk (DOAC), N = 281
THA	295 (37.0)	46 (16.4)
TKA	449 (56.3)	106 (37.7)
Revision THA	20 (2.5)	1 (0.4)
Revision TKA	32 (4.0)	5 (1.8)
Staged bilateral THA	0 (0.0)	23 (8.2)
Staged bilateral TKA	1 (0.1)[b]	100 (35.6)
Age, years	67.0 (60.0-74.0)	65.0 (58.0-71.0)
Gender, No. (%)	M = 322 (40.4)	M = 89 (31.7)
	F = 475 (59.6)	F = 192 (68.3)
BMI	29.6 (26.2-33.2)	35.8 (29.0-41.9)

Abbreviations: BMI, body mass index; DOAC, direct oral anticoagulant; THA, total hip arthroplasty; TKA, total knee arthroplasty.
[a]Data are presented as median (lower quartile, upper quartile) for continuous variables, and number (%) for categorical variables above.
[b]Patient requested aspirin only.

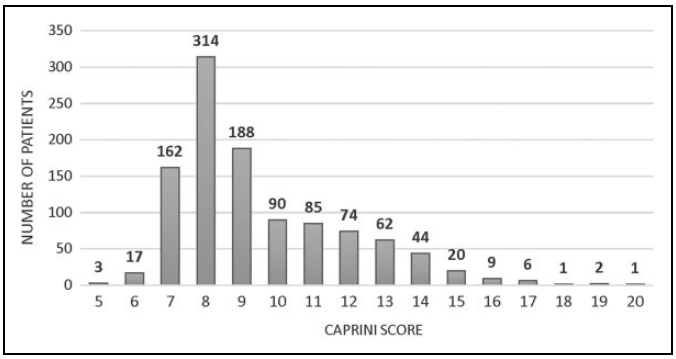

Figure 2. Distribution of final (Predischarge) Caprini score.

Caprini score differed from the preoperative score for 78 (7.2%) patients. The change in score was due to blood transfusions, a postoperative brace, restricted mobility, and cancellation of a staged case. Restricted mobility was defined as inability to ambulate continuously more than 30 feet and also was applied to any patient who was unable to ambulate using both leg muscles.[34] The dynamic, changeable nature of the score is a critically important feature of the Caprini RAM.

The area under the ROC curve was 0.896 (95% CI: 0.874-0.917). The largest Youden index was 0.632, and the corresponding optimal cutoff Caprini score was 10. In other words, patients with a Caprini RAM score of 10 or greater are considered high risk and a score of less than 10 are considered low risk. Based on this cutoff, among the 281 high-risk patients, 234 had a score of 10 or greater yielding a sensitivity of 83% (95% CI: 78%-87%). Similarly, among the 797 low-risk patients, 637 had a score <10 yielding a specificity of 80% (95% CI: 77%-83%; Table 2).

There were 8 patients with symptomatic VTE. There was 1 distal DVT with a CVA in a patient with a newly diagnosed patent foramen ovale, 2 PEs without DVT, 1 proximal DVT, and 4 distal DVTs. Seven of the VTE events were correctly identified as high risk with a Caprini RAM score of 10 or greater, while 7 of the same study patients were considered low risk by our department protocol (Table 3). Of note, the patient who sustained a PE but was considered low risk by department protocol as well as by Caprini scoring (8) was found to have an undiagnosed thrombophilic defect upon hematology workup after developing a second, unprovoked PE months later. If this was known preoperatively, the patient's score would have been 11. This would have resulted in the Caprini score correctly identifying 100% of patients experiencing a VTE. Finally, no staged bilateral arthroplasty patients experienced a postoperative thrombus.

Table 2. Frequency Table of Department Risk Stratification Versus Cutoff Caprini Score of 10 or Greater.

Caprini Score	Department Protocol High Risk	Department Protocol Low Risk	Total
Caprini ≥10	234 (Sens = 83%)	160	394
Caprini <10	47	637 (Spec = 80%)	684
Total	281	797	1078

Abbreviations: Sens, sensitivity; Spec, specificity.

There were no deaths during the 60-day follow-up period. Bleeding analysis included 937 patients. A total of 141 patients were excluded from this analysis. Exclusions included staged cases due to 2 surgeries in 5 days, patients missing POD1 laboratory test results, and patients taking more than 1 antiplatelet agent as these were confounding factors. No patients returned to the OR for bleeding. Bleeding outcomes were not different between the groups: aspirin alone (reference group, n = 745, odds ratio [OR]: 1.00), aspirin plus concurrent antiplatelet agent (n = 45, OR: 2.15, 95% CI: 0.81-5.73; $P = .127$), apixaban or rivaroxaban alone (n = 98, OR: 0.73, 95% CI: 0.26-2.09; $P = .558$), apixaban or rivaroxaban plus aspirin 81 mg (n = 49, OR: 0.73, 95% CI: 0.17-3.11; $P = .671$).

Caprini risk factors relevant to this patient sample were extracted from the Caprini RAM to ascertain their associations with the department risk stratification protocol (Table 4).

Sensitivity and specificity for the departmental protocol were 0.12 (exact 95% CI: 0-0.53) and 0.74 (95% CI: 0.71-0.77), respectively (Table 5). Sensitivity and specificity for the Caprini score were 0.88 (exact 95% CI: 0.47-1.00) and 0.64 (95% CI: 0.61-0.67), respectively (Table 6).

Discussion

It is estimated that 900 000 VTE events resulting in 100 000 premature deaths occur annually in the United States.[35] Both DVT and PE are known complications following TJA, often resulting in significant morbidity and mortality as well as the associated economic burden to the patient and the health-care system.[36] The orthopaedic surgeon is as concerned with postsurgical bleeding as they are with thrombosis, and thus, the challenge persists in the prevention of these complications. Chemoprophylaxis choice should be both safe and effective. To date, no risk assessment methodology has been validated for the TJA patient.

Table 3. VTE Events.

VTE Event	Procedure	Age/Gender	Preop Department Risk Stratification	Discharge Caprini Risk Classification	VTE Prophylaxis
CVA(PFO) Distal DVT	TKA	72/M	Low	11 High	Aspirin
PE 1	TKA	67/F	High	11 High	Apixaban
PE 2	TKA	60/F	Low	8 Low[a]	Aspirin
Proximal DVT	THA	57/F	Low	12 High	Aspirin
Distal DVT	TKA	77/M	Low	11 High	Aspirin
Distal DVT	TKA	80/M	Low	11 High	Aspirin
Distal DVT	TKA	81/F	Low	10 High	Aspirin
Distal DVT	THA	69/F	Low	10 High	Aspirin

Abbreviations: DVT, deep vein thrombosis; PE, pulmonary embolism; THA, primary total hip; TKA, primary total knee; VTE, venous thromboembolism.
[a]Patient later found to have thrombophilic defect which would have resulted in a score of 11, Caprini high-risk group.

Table 4. Caprini Risk Factors.[a]

Caprini Risk Factors (%)	Department Protocol Low Risk Aspirin, N = 797	Department Protocol High Risk (DOAC), N = 281
BMI >40	11 (1.4%)	105 (37.4%)
Current or past malignancies	108 (13.6%)	54 (19.2%)
Chemotherapy	6 (0.8%)	5 (1.8%)
Age >75	183 (23.0%)	40 (14.2%)
History DVT or PE	10 (1.3%)	28 (10.0%)
Family history blood clots	22 (2.8%)	12 (4.3%)
Personal or family history of positive blood test for thrombophilia	1 (0.1%)	18 (6.4%)

Abbreviations: BMI, body mass index; CVA, cerebrovascular accident; DOAC, direct oral anticoagulant; DVT, deep vein thrombosis; PE, pulmonary embolism; PFO, patentforamen ovale.
[a]Data are presented as a number (%) for categorical variables above.

Table 5. Frequency Table of VTE Versus Department Protocol .

Risk Category	VTE	No VTE	Total
Department high risk	1 (Sens = 12%)	278	279
Department low risk	7	792 (Spec = 74%)	799
Total	8	1070	1078

Abbreviations: Sens, sensitivity; Spec, specificity.

Table 6. Frequency Table of VTE Versus Cutoff Caprini Score of 10 or Greater.

Caprini Score	VTE	No VTE	Total
Caprini ≥10	7 (Sens = 88%)	387	394
Caprini <10	1	683 (Spec = 64%)	684
Total	8	1070	1078

Abbreviation: Sens, sensitivity; Spec, specificity; VTE, venous thromboembolism.

Bateman et al, in a retrospective review, evaluated the correlation of the Caprini RAM and VTE incidence following primary TJA in 363 patients. The authors found that the Caprini RAM was not a clinically useful tool for TJA patients.[37] Our review of this publication noted some deficiencies with the completion of the Caprini score. In this article, the preoperative scores were correctly completed only 7% of the time. The authors admitted this was a major concern and they explained this discrepancy was mainly due to incomplete documentation of medical comorbidities and technical error. We feel that for the Caprini tool to be useful in any study, complete data are a prerequisite.

The Caprini RAM is a dynamic tool requiring ongoing evaluation of a patient during their hospital course and the postoperative recovery period. Conversely our department risk stratification protocol was a static tool and thereby did not account for changes in patient status after surgery. Cancellation of a staged case was the only cause for change in risk assessment. This was an inherent fault of the department risk stratification protocol. Continuous evaluation is necessary, as changes in clinical status can result in a change in the score, necessitating an alternate treatment option. Bateman et al completed the Caprini RAM preoperatively, thereby excluding from review any change in the patient's status during the postoperative period.[37] Postoperative occurrences such as blood transfusions, braces, or impaired mobility would increase the Caprini score, warranting further reassessment for appropriate chemoprophylaxis.

Further, bilateral cases were calculated inaccurately. Patients undergoing bilateral or staged cases should be assessed a value of "10" for elective hip or knee arthroplasty as they are undergoing "2" procedures within a month. These authors calculated the Caprini score as 7.9 ($\pm$1.4), thereby giving the same assessment for a bilateral arthroplasty as a unilateral procedure.

In a response letter to the editor of the *Journal of Arthroplasty* from the Caprini group, Bateman et al did not recognize the value of risk stratifying the joint arthroplasty patient population, as they are all categorized as high risk with a score of 5 points.[38] This assumption is based on conclusions drawn by Gould et al, in the 2012 CHEST guidelines for prevention of VTE in nonorthopaedic surgical patients, categorizing any patient with a Caprini score of 5 points or greater as high risk.[39]

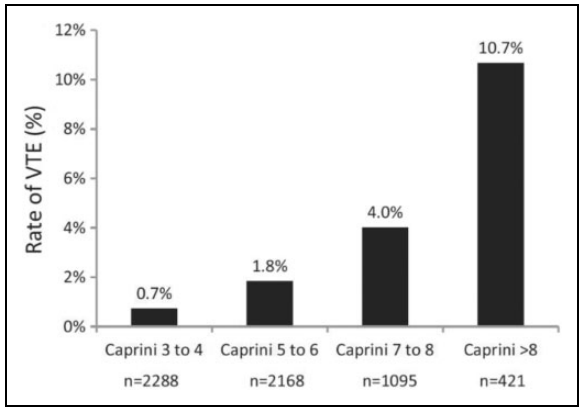

Figure 3. VTE in surgical patients who received no chemoprophylaxis, stratified by Caprini score.

Dismissing the use of the Caprini RAM in this patient population does not allow for identification of patients who would be considered "very high risk." This very high-risk stratification has been successfully recognized in other surgeries. Cassidy et al found that a Caprini score of 8 or greater was considered very high risk for general and vascular surgery, and these patients benefited from 30 days of postoperative low-molecular weight heparin prophylaxis.[40] Pannucci et al, in a meta-analysis, found that patients with Caprini scores of 7 to 8 (OR: 0.60, 95% CI: 0.37-0.97) and >8 (OR: 0.41, 95% CI: 0.26-0.65) had significant VTE risk reduction after surgery with chemoprophylaxis.[12] The incidence of VTE in those not receiving anticoagulant prophylaxis escalated in proportion to the score (Figure 3).

Finally, Luksameearunothai et al, in a study of patients with hip fracture, found that a Caprini score of 12 or greater was associated with a high incidence of preoperative DVT (16.3%). The authors recommended preoperative scans in those with these high scores, since the DVT group showed a significantly higher Caprini score compared to the non-DVT group ($P < .05$). Furthermore, the sensitivity and specificity associated with a Caprini score $\geq$12 points were 93% and 35%, and those with a Caprini score $\geq$13 points were 60% and 73%, respectively.[13]

In the current study, we found that a Caprini score of 10 or greater is considered very high risk. The authors agree that all joint arthroplasty patients are high risk for postoperative VTE and require chemoprophylaxis. With the current availability of multiple treatment options, the identification of very high-risk patients is more imperative than ever. The challenge is to choose the right drug for the appropriate patient.

The ability to risk stratify patients allows us to safely choose distinct chemoprophylaxis agents for postoperative VTE. Aspirin 325 mg twice daily was chosen for our low-risk chemoprophylaxis treatment protocol based on the 2007 AAOS guidelines as well as current literature when the protocol was created. Recent publications have demonstrated both the safety and the efficacy of lower doses of aspirin. Anderson et al, in a large, randomized, double-blind trial, demonstrated the safety and efficacy of aspirin or rivaroxaban for VTE prophylaxis for hip and knee arthroplasty patients.[41] This was the first clinical trial to compare aspirin to a DOAC in the orthopaedic population. However, Garcia, in an accompanying editorial, discussed limitations that could prevent universal adoption of this treatment protocol. Garcia noted that since "relatively few patients with previous VTE, morbid obesity, or cancer underwent randomization, we cannot be certain how the 2 prophylaxis strategies would perform in these very high-risk populations,"[42] further highlighting the necessity of individualized risk stratification.

Parvizi et al, in a comparative prospective study, demonstrated that 4 weeks of treatment with low dose of aspirin (81 mg twice a day), both plain and EC, is not inferior to a higher dose of EC aspirin (325 mg twice a day) in the prevention of VTE.[43] However, this study excluded patients felt to be at high risk for VTE based on the authors' modeling system. This model was based on a scoring system whereby patients were stratified to high and low risk. The predictors identified with the highest points were hypercoagulability, metastatic cancer, stroke, sepsis, and chronic obstructive pulmonary disease.[44] These risk factors are all identified in the Caprini RAM.

Comprehensive assessment of the VTE events revealed that occurrence of thrombosis was not influenced by individual high-risk factors, but the cumulative effect of multiple factors that increased the patient's Caprini score. The unique feature of the Caprini score is that certain risk factors are more heavily weighted than others. Therefore, the synergistic effect of individual factors of varying significance, when combined, yield a predictive score which is more accurate than any individual factor. Seven of the 8 VTE events were correctly identified as high risk with a Caprini RAM score of 10 or greater, while the same 7 study patients were considered low risk by our department risk stratification protocol. The patient suffering a PE postoperatively would have been placed in the high-risk Caprini group with a score of 11 if the thrombophilia had been known. Using the Caprini RAM in the arthroplasty patient allows for quantification of patient risk factors. This provides for an accurate patient-centered treatment regimen based on a consistent RAM. As the Caprini RAM is a dynamic tool, continuous monitoring of VTE risk factors is essential in the extended postoperative period. In our study, the mean baseline preoperative score was 9; therefore, additional risk factors could easily increase the cumulative score to 10 or more.

Accurate, consistent completion of the 2013 Caprini RAM imperative for this study. The Caprini RAM in our study was completed by trained medical students. Any questions or concerns regarding scoring were escalated to Dr Caprini. This process led to the development of completion guidelines to ensure consistency and accuracy of the scoring. The final Caprini RAMs were reviewed by one person and any issues or discrepancies were adjudicated by Dr Caprini.

This is a retrospective study, therefore limiting extrapolation of findings. This may be viewed as a weakness. It may also be a strength as no patient was excluded from review. Retrospective database reviews have flaws since it is not known if all of the questions were presented to the patient and to their level of understanding.[45] Family history is often overlooked during

the history process. A history of past VTE or family VTE history is one of the most powerful risk factors responsible for postoperative thrombosis.[46] Unknown or unreported history is always an issue of significance when taking an accurate history and physical. This was evident with the one patient who was assessed as low risk by both the department protocol and the Caprini score. We have subsequently developed a patient friendly form to address this challenge.

Conclusion

The 2013 version of the Caprini RAM correctly identified all but one of the arthroplasty patients who developed a clinical VTE event (8/1078). This tool provided a consistent, accurate, and efficacious method for risk stratification. The Caprini RAM is a dynamic tool, requiring ongoing evaluation of the patient during their hospital course and the postoperative recovery period. Changes in clinical status could result in a change in the score, thereby resulting in a new score and potentially a revised treatment option. Using the 2013 Caprini scoring system in the arthroplasty patient will allow for an individualized chemoprophylaxis treatment assignment justifying the use of a DOAC compared to aspirin in those with a high risk of thrombosis.

Declaration of Conflicting Interests

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