intermittent pneumatic compression for venous thromboembolism prophylaxis in total knee arthroplasty

John K. Morris, MD; Bryce M. Fincham, DO

abstract

Venous thromboembolism (VTE) prophylaxis in total knee arthroplasty (TKA) is controversial. The purpose of this study was to evaluate the efficacy of bilateral intra- and postoperative intermittent pneumatic compression without major anticoagulation as prophylaxis for VTE in TKA.

This retrospective study involved 157 consecutive patients undergoing TKA performed by 1 surgeon who were treated with bilateral intra- and postoperative intermittent pneumatic compression stockings. All patients were followed for at least 6 weeks postoperatively. Postoperative color duplex ultrasound imaging with compression by certified vascular technologists was obtained for 120 patients 2 to 3 days postoperatively. During hospitalization, 2 (1.7%) patients had acute deep vein thrombosis (DVT) diagnosed, 2 (1.7%) had DVT of indeterminate age, and 4 (3.3%) had chronic DVT. During follow-up, 1 (0.8%) patient had an acute DVT diagnosed at 5 weeks postoperatively and 1 (0.8%) had a superficial phlebitis and subsequently had a nonfatal pulmonary embolism 23 days postoperatively. The predominant chemoprophylaxis used was aspirin alone in 107 (89.2%) patients. Epidural anesthesia was used in the majority (n=96; 80%) of patients.

The results of this study support the use of a multimodal approach to VTE prophylaxis in TKA, using bilateral intra- and postoperative intermittent pneumatic compression, epidural anesthesia, early mobilization, and postoperative aspirin without the use of major anticoagulation as an effective, safe VTE prophylactic protocol for patients undergoing elective TKA. The study suggests that the protocol is highly effective, has low morbidity, and is cost effective.
Venous thromboembolism (VTE) prophylaxis following total knee arthroplasty (TKA) remains controversial. Ideally, the prophylaxis should be highly effective, have low morbidity, and be cost effective. Historically, the American College of Chest Physicians (ACCP) guidelines have aggressively recommended anticoagulation as the mainstay of VTE prophylaxis. The American Academy of Orthopedic Surgeons (AAOS) guidelines have supported less aggressive use of anticoagulation, encouraged risk stratification, supported reliance more on individual judgment of treating physicians, and supported the use of intermittent pneumatic compression and aspirin for patients undergoing uncomplicated total knee arthroplasty (TKA).

The primary investigator (J.K.M.) has used a multimodal approach to VTE prophylaxis in TKA using bilateral intra- and postoperative intermittent pneumatic compression stockings, epidural anesthesia, early mobilization, and postoperative aspirin without the use of major anticoagulation. The purpose of this retrospective medical chart review study was to discover whether this multimodal protocol would be efficacious as VTE prophylaxis in patients undergoing TKA. The primary outcome measure was the detection of VTE events.

**Materials and methods**

This retrospective study reviewed 157 consecutive patients undergoing TKA per a protocol approved by the institutional review board. The TKAs were performed by 1 surgeon (J.K.M.) who used bilateral intra- and postoperative single-chamber intermittent pneumatic compression (Flowtron; Huntleigh Health Care, Malapan, New Jersey) on both lower legs. Clinical follow-up was a minimum of 6 weeks, with most patients having follow-up at 1 year. Patients were observed for clinical signs of thromboembolic disease. Later in the series, color duplex ultrasound imaging with compression was obtained on both lower extremities on postoperative day 2 or 3 for 120 patients, who composed the study cohort. Postoperative day 3 was the target day for discharge.

On arrival in the operating room, an unsterile intermittent pneumatic compression stocking was applied to the contralateral lower leg and connected to the compressor unit for the entire procedure. A sterile intermittent pneumatic compression stocking was applied to the operative side lower leg and connected to the compressor after tourniquet deflation. In the case of bilateral TKAs, sterile intermittent pneumatic compression stockings were applied to both lower legs and connected to the compressor unit when the tourniquet was not inflated.

Hemostasis was obtained following tourniquet deflation in all cases. A hemo-vac drain was brought out through a separate anterolateral puncture and left in the lateral gutter for 12 to 48 hours.

Patients were transported to the recovery room, where each recovery bay had a compressor unit. Both lower-extremity intermittent pneumatic compression stockings were then connected to the compressor by the surgeon. Intermittent pneumatic compression stockings continued to be used on the floor where all beds were supplied with compressor units. Epidural catheters were left in place until postoperative day 2 unless they were not functional. Active ankle flexion and extension exercises were instructed and demonstrated by the rounding team and physical therapists.

Patients were prescribed aspirin postoperatively if there was no contraindication to aspirin. The aspirin dosage varied from 81 mg daily to 325 mg twice daily. Platelet counts were monitored postoperatively. Patients who were on preoperative anticoagulation for a medical problem were managed with protocols per their primary care physicians. This usually involved cessation of warfarin 5 days preoperatively with resumption of warfarin at maintenance doses immediately postoperatively. Alternatively, warfarin was discontinued and enoxaparin bridge therapy was administered until 24 hours preoperatively. Then, enoxaparin was started again 48 hours postoperatively, at least 2 hours after epidural catheter removal. When clopidogrel was used in conjunction with aspirin, it was only in patients who had been taking clopidogrel preoperatively. Acute and indeterminate-age deep vein thrombosis (DVT) was treated with 1 mg/kg of enoxaparin on diagnosis with bridging to warfarin, with an international normalized ratio goal of 2 to 3 for 3 to 6 months.

**Results**

Medical charts were reviewed for 157 consecutive patients undergoing primary TKA. Earlier in the study period, routine color duplex ultrasound imaging with compression was not obtained. However, later in the study, it became routine to order color duplex ultrasound on postoperative day 2. This resulted in 120 patients with postoperative color duplex ultrasound obtained during the initial hospitalization on postoperative day 2 or 3; these patients composed the study cohort. Bilateral TKAs (14/120) were performed sequentially. No VTE diagnosis was made in the 37 other patients using traditional clinical signs and symptoms.

Patient demographics are shown in Table 1. Bilateral intra- and immedi-

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### Table 1. Bilateral intra- and immediate postoperative ultrasound imaging with compression for prophylaxis in TKAs | Morris & Fincham

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Total</th>
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<tbody>
<tr>
<td>No. of men (%)</td>
<td>42 (35)</td>
</tr>
<tr>
<td>No. of women (%)</td>
<td>78 (65)</td>
</tr>
<tr>
<td>Average age (range), y</td>
<td>65.7 (42-89)</td>
</tr>
<tr>
<td>Average BMI (range), kg/m²</td>
<td>32.6 (21-61)</td>
</tr>
<tr>
<td>Average No. of medical diagnoses</td>
<td>5.1</td>
</tr>
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</table>

Abbreviation: BMI, body mass index.
ate postoperative intermittent pneumatic compression compliance was 100%. Intermittent pneumatic compression compliance following discharge from the recovery room was not closely monitored. Average intraoperative tourniquet time was 71 minutes. Average blood loss was 113 mL. Epidural anesthesia was used in the majority (n = 96; 80%) of patients. The percentages of additional anesthetics used and surgical averages are shown in Table 2. The predominant chemoprophylactic agents used was aspirin alone in 107 (89%) patients. The frequency of use for alternative chemoprophylactic agents was determined by preoperative medical therapy (Table 3).

Preoperatively, 7 (5.8%) patients had a positive history of VTE. Postoperatively, 4 (3.3%) were prescribed aspirin and 3 (2.5%) were prescribed enoxaparin and warfarin. No patient developed a new postoperative VTE. Ten VTE events occurred in 9 (7.5%) patients (Table 4). Two (1.7%) acute DVTs were detected during the hospital stay: 1 acute ipsilateral gastrocnemius vein DVT without popliteal involvement and 1 contralateral acute femoral vein DVT with ipsilateral chronic femoral vein DVT.

One (0.8%) delayed acute DVT was diagnosed at 5 weeks postoperatively in the ipsilateral popliteal, peroneal, and gastrocnemius veins. The color duplex ultrasound had been negative on postoperative day 2.

Two (1.7%) DVTs were read by the radiologist as indeterminate age: 1 soleus DVT on the left side of a bilateral TKA with a stable appearance on repeat ultrasound and 1 ipsilateral popliteal DVT.

Four (3.3%) chronic DVTs were detected, of which 1 was known preoperatively and another was detected in the ipsilateral limb of a patient with a contralateral acute DVT.

One (0.8%) patient developed a nonfatal pulmonary embolism 23 days postoperatively and was noted to have superficial phlebitis at the time of diagnosis without DVT discovered on the postoperative day 2 color duplex ultrasound.

When considering the number of nonchronic DVTs (including the indeterminate age category), 5 (4.2%) patients developed DVTs as determined by color duplex ultrasound with compression, with 4 of 5 detected during the surgical hospital stay and 1 of 5 suspected clinically at 5 weeks postoperatively and then confirmed with color duplex ultrasound. Of these nonchronic DVTs, 4 of 5 were in the ipsilateral limb of surgery. Comparatively, 3 of 4 chronic DVTs were located in the contralateral limb of surgery. Six patients with nonchronic VTEs underwent 7 TKAs. Average age was 71 years, average tourniquet time was 67 minutes, average number of comorbidities was 4.8, and average body mass index was 31 kg/m². All had aspirin postoperatively. No statistically significant differences were found between the patients who were positive for postoperative VTE and those who were negative with respect to these parameters.

**Discussion**

This study’s results support the efficacy of bilateral intra- and postoperative use of intermittent pneumatic compression without major anticoagulation as an effective prophylaxis for VTE in TKA. Deep vein thrombosis and subsequent pulmonary embolism can be catastrophic clinical events for patients, including those undergoing elective total hip arthroplasty, TKA, knee arthroscopy, patients with lower-extremity trauma, long-distance airline passengers, or patients with decreased mobility. Virchow’s triad of venous stasis, endothelial trauma, and hypercoagulability is often present in varying degrees in high-risk settings. Historically, in the absence of prophylaxis, studies have shown the incidence of DVT to be 50% to 80% in patients undergoing total joint arthroplasty. In the 1960s, the incidence of fatal pulmonary embolism was as high as 2.2%. With modern-day regional anesthetics, surgical techniques, and perioperative care, including rapid mobilization, the rate of fatal pulmonary embolism has dropped to 0% to 0.2%.

In 2000, Westrich et al published a meta-analysis of VTE prophylaxis after

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**Table 2**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
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<tr>
<td>Intraop/PARU IPC compliance</td>
<td>120 (100)</td>
</tr>
<tr>
<td>Average tourniquet time (range), min</td>
<td>71 (51-108)</td>
</tr>
<tr>
<td>Average blood loss (range), mL</td>
<td>113 (50-500)</td>
</tr>
<tr>
<td>Anesthetic, No. (%)</td>
<td></td>
</tr>
<tr>
<td>Epidural catheter ± femoral nerve block</td>
<td>96 (80)</td>
</tr>
<tr>
<td>General anesthetic without regional</td>
<td>16 (13.3)</td>
</tr>
<tr>
<td>General anesthetic + epidural catheter</td>
<td>4 (3.3)</td>
</tr>
<tr>
<td>Spinal anesthesia</td>
<td>3 (2.5)</td>
</tr>
<tr>
<td>Femoral and sciatic nerve blocks</td>
<td>1 (0.8)</td>
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</tbody>
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Abbreviations: Intraop, intraoperative; PARU IPC, postanesthetic recovery unit intermittent pneumatic compression.

**Table 3**

<table>
<thead>
<tr>
<th>Agent</th>
<th>No. (%)</th>
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<tr>
<td>Aspirin</td>
<td>107 (89.2)</td>
</tr>
<tr>
<td>Aspirin + enoxaparin</td>
<td>3 (2.5)</td>
</tr>
<tr>
<td>Aspirin + clopidogrel</td>
<td>3 (2.5)</td>
</tr>
<tr>
<td>Enoxaparin bridge to warfarin</td>
<td>3 (2.5)</td>
</tr>
<tr>
<td>Warfarin</td>
<td>1 (0.8)</td>
</tr>
<tr>
<td>Enoxaparin</td>
<td>1 (0.8)</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>1 (0.8)</td>
</tr>
<tr>
<td>None</td>
<td>1 (0.8)</td>
</tr>
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</table>
TKA. The current study showed a DVT incidence of 4.2% (5/120), which compares favorably to the 17% (86/509) reported in the meta-analysis intermittent pneumatic compression group. The lower incidence in the current study was statistically significant (P = 0.0005), likely due to initiating intermittent pneumatic compression sooner than most studies included in the meta-analysis. Moreover, 100% early compliance existed in the current series, the protocol included aspirin, and most of the patients had epidural anesthesia, which has been shown to have a minor VTE risk reduction effect. Importantly, intermittent pneumatic compression was the most effective single VTE prophylactic measure analyzed by the meta-analysis, which included aspirin (DVT rate, 53%), warfarin (DVT rate, 45%), and low-molecular-weight heparin (DVT rate, 29%) as independent variables.

In 2001, Fitzgerald et al reported the results of a multicenter TKA study comparing the use of enoxaparin with warfarin but excluding the use of intermittent pneumatic compression. Eighty (45%) of 176 patients in the warfarin group and 44 (25%) of 173 patients in the enoxaparin group developed VTE. The efficacy of VTE prophylaxis reported in the study, without intermittent pneumatic compression, appeared deficient in both groups, and the morbidity of the major anticoagulation prophylaxis was high. The use of intermittent pneumatic compression may have improved outcomes in both groups.

Pulmonary specialists usually become involved in the most serious cases involving pulmonary embolism, which can be life threatening. For this reason, the ACCP annually formulates recommendations for VTE prophylaxis. The ACCP has aggressively recommended anticoagulation as the method of choice for VTE prophylaxis, despite a 5% to 10% morbidity from the risk of bleeding. Only recently has the ACCP softened its recommendations to allow for a balance between safety and bleeding, permitting the use of intermittent pneumatic compression and aspirin for VTE prophylaxis in TKA.

Orthopedic surgeons, who generally see and treat the complications of anticoagulation, consider the morbidity rate of anticoagulation to be equally as bad as or worse than the complications of thromboembolic embolic disease. In contrast to the previous ACCP recommendations, the AAOS has published thromboembolic prophylaxis guidelines that support less aggressive use of anticoagulation, encourage risk stratification, involve more individual judgment of the treating physician, and support the use of aspirin and intermittent pneumatic compression for an uncomplicated TKA.

The current study supports the traditional AAOS approach and confirms the effectiveness and safety of intermittent pneumatic compression for prophylaxis following TKA when used in a highly compliant manner. The study protocol and the current AAOS guidelines (intermittent pneumatic compression with or without aspirin, without major anticoagulation) are compatible with the guidelines established by the Surgical Care Improvement Project, as long as the physician clearly states on the patient’s chart that concerns for bleeding were taken into consideration when selecting intermittent pneumatic compression with or without aspirin as the VTE prophylaxis protocol.

The clinical diagnosis of VTE is difficult because symptomatic DVTs only represent 3.4% of the total DVTs as measured by venography. Therefore, historically, clinicians have insisted on venographic evidence to document the incidence of
VTE. However, most hospital radiology departments no longer offer venography as a diagnostic modality and now defer to color duplex ultrasound imaging with compression. Initially, the current authors were not using postoperative color duplex ultrasound imaging with compression. The low accuracy of clinical diagnosis prompted them to use color duplex ultrasound imaging with compression postoperatively later in the series. The diagnostic accuracy of ultrasound varies according to the technique used but approaches the accuracy of venography. 29 In the current study, once the patient was discharged from the hospital, the authors relied on symptomatic clinical presentation to order follow-up color duplex ultrasound imaging. Although this is a common standard of practice, it limited the authors’ ability to accurately document the true incidence of subclinical VTE after the initial hospitalization.

In 1991, Maynard et al 30 reported that 86% of limbs positive for DVT after TKA using venography were positive within 1 day postoperatively. This highlights the close temporal relationship of VTE in TKA to the intra- and immediate postoperative time periods and provides the rationale for the necessity of VTE prophylaxis in this critical time period. For this reason, the current authors’ protocol called for 100% compliance with bilateral intra- and immediate postoperative intermittent pneumatic compression use. Maynard et al’s 30 data suggest that other current recommendations for VTE prophylaxis that do not start anticoagulation until 24 to 48 hours postoperatively begin prophylaxis well after clots have already formed.

Intermittent pneumatic compression has a history of showing some VTE prophylaxis benefit but was generally believed to not be dependable enough to be used as the sole method of VTE prophylaxis. However, in 1992, Comerota et al 31 demonstrated that the lack of compliance was the principal cause of the mixed results. When the compliance was high, intermittent pneumatic compression was highly effective. 31 In the current study, the surgeon created 100% compliance during the critical intra- and immediate postoperative time periods, a time of maximal venous stasis secondary to anesthesia-induced muscle inactivity.

In 1999, Hooker et al 25 reported the use of bilateral intra- and postoperative intermittent pneumatic compression in a series of patients undergoing total hip arthroplasty. Using duplex imaging, they demonstrated a DVT rate of 4.6% and a symptomatic pulmonary embolism rate of 0.6%. These results have been reproduced by others. 26,27 The results of these studies reinforce 2 things: regardless of the chemoprophylaxis used, the use of bilateral intermittent pneumatic compression intra- and postoperatively yields a low DVT rate; and the use of warfarin and low-molecular-weight heparin increase wound and bleeding complications. 18,25-27,32

All intermittent pneumatic compression devices reduce venous stasis by their pumping action on a venous system with intact valves and increase circulating fibrinolytic activity, 33,34 affecting 2 of the 3 limbs of Virchow’s triad. Although aspirin does not directly affect the fibrinogen clotting cascade, it has been shown to have a 25% to 30% pulmonary embolism risk reduction benefit through its antiplatelet action. 33 Bleeding complications with aspirin are much less common than with the major anticoagulants, so the risk:benefit ratio makes aspirin a reasonable adjunct to properly applied intermittent pneumatic compression as a VTE chemical prophylaxis of choice in TKA.

The current protocol calls for bilateral single-chamber calf intermittent pneumatic compression intraoperatively when the tourniquet is not inflated and in the recovery room per the surgeon, insuring 100% compliance during this critical time period. Orders are written for postoperative bilateral intermittent pneumatic compression where compression units are available on each bed. Active ankle flexion–extension exercises are instructed and demonstrated by the rounding team and physical therapists. Enteric-coated aspirin is started postoperatively, 325 mg daily, or twice daily if the platelet count is satisfactory and aspirin is not contraindicated. Color duplex ultrasound imaging with compression is done on postoperative day 2. If the color duplex ultrasound results are negative, the patient is discharged on postoperative day 3 if medically cleared. A home intermittent pneumatic compression unit is used for 2 weeks, and aspirin is recommended for 6 weeks if not contraindicated. Postoperative reports of calf pain are aggressively worked up with outpatient color duplex ultrasound. If the color duplex ultrasound is positive, treatment is deferred to the patient’s primary care physician.

A strength of this study was that it confirmed the efficacy of a multimodal approach to VTE prophylaxis in TKA using bilateral intra- and postoperative intermittent pneumatic compression, epidural anesthesia, early mobilization, and postoperative aspirin without the use of major anticoagulation in a large series of patients undergoing TKA. A limitation is the lack of a randomized, prospective trial.

**CONCLUSION**

The results of this study support the use of a multimodal approach to VTE prophylaxis in TKA without the use of major anticoagulation. High compliance of intermittent pneumatic compression use intra- and postoperatively is necessary. The study results suggest that the protocol used is highly effective, has low morbidity, and is cost effective, approaching the ideal VTE prophylactic measures for patients undergoing elective TKA.

**REFERENCES**


