CHAPTER 4

INTRAOPERATIVE MEASURES FOR DVT PROPHYLAXIS

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Deep venous thrombosis (DVT) is the formation of a thrombus in the deep venous system that if untreated can lead to non-fatal or fatal pulmonary embolism (PE). In 1998, the Journal of American Medical Association reported approximately 2 million Americans each year suffer from DVT and it is considered the 3rd most common cardiovascular disease after acute coronary disease and stroke.[1,2] DVT incidence rate after hip and knee surgery has been well documented but the actual incidence after foot and ankle surgery is still unclear.[3-5] In 1996, Nesheiwat and Sergi reported a case of DVT and PE from cast immobilization of an Achilles tendon injury.[6] In 1998, a multicenter study found 0.22% incidence of DVT, 0.92% of DVT following anticoagulation therapy, and a 0.15% rate of PE which were all non-fatal.[3] In 2002, Solis and Saxby reported 3.5% of deep calf clots after foot and ankle surgery, with none resulting in proximal progression or PE.[4] Without many studies reporting significant results of DVT or PE and the existing risks with anticoagulation therapy, the need for routine pharmacologic prophylaxis in foot and ankle surgery has been thought to be unnecessary.[3,4] Anand et al stated anticoagulation therapy should be restricted to those with confirmed DVT.[1]

PHARMACOLOGIC ANTICOAGULATION THERAPY

Despite the controversy in using routine pharmacologic prophylaxis, many foot and ankle surgeons remain cautious due to the potential devastating results of DVT formation. These measures can be divided into primary/secondary prophylaxis, or preperative/perioperative/postoperative prophylaxis, or by pharmacologic/non-pharmacologic prophylaxis. Commonly, a combination of the above including anticoagulation therapy and compression stockings with pneumatic compression devices is used for our surgical patients. Pharmacologic anticoagulation therapy can include aspirin, mini-dose unfractionated heparin, low molecular weight heparin, or warfarin. They can be started pre-operatively and carried throughout the procedure and postoperatively.

Although the benefits of anticoagulation are effective in preventing the extension, embolization, and recurrence of DVT, some patients may need alternative methods of prophylaxis due to the contraindications or adverse effects of these drugs. Also, anticoagulation therapy does not always guarantee the inhibition of clot formation. In 1999 a meta-analysis performed by Westrich et al demonstrated overall DVT rates after total knee arthroplasty of 53% with aspirin, 45% with warfarin, and 29% with low molecular weight heparin.[7] Goldhaber et al reported a higher second DVT rate with prophylaxis failure versus omitted prophylaxis.[8] Most important, anticoagulation therapy has potential for bleeding/hemorrhagic complications at the postsurgical wound or the gastrointestinal and genitourinary systems therefore continuous monitoring is necessary. Major bleeding episodes have been associated with anticoagulation therapy and can result in death, intra-organ bleeding, or a reoperation.

It is controversial whether aspirin is effective in preventing DVT after joint replacements. Francis et al continue to use it prophylactically postoperatively, risking the complications of gastritis and gastric erosions/ulcers.[9]

In addition to bleeding complications, heparin can also cause a rebound increase in clotting potential if stopped abruptly. Heparin also has the ability to cause thrombocytopenia in 1% to 5% of patients,[10,11] and so it is critical to monitor the patient's platelet count daily. A platelet count below 100,000/uL can cause hypercoagulation, stroke, loss of limb, or death. In May of 2002, Lam and Hussain reported such a case of limb loss due to use of heparin.[12] Low molecular weight heparin has equal to greater antithrombotic efficacy, does not require monitoring, and has less bleeding when compared to heparin. It still has the risk of bleeding and also heparin-induced thrombocytopenia.

Warfarin has a great risk of hemorrhage compared to the other lines of anticoagulation therapy. Warfarin is also contraindicated with a long list of drugs, which can either potentate or decrease the anticoagulant effect and bleeding potential. Other adverse effects of warfarin include vitamin K deficiency and warfarin-induced skin necrosis. Another disadvantage of using warfarin is the need for continuous monitoring of prothrombin time.

In 1991, Maynard et al indicated that the majority of DVT formation after total knee arthroplasty is an intraoperative or immediate postoperative event.[13] They reported 86% unilateral DVT were positive within postoperative day 1. Modig et al also indicated most thrombosis development were immediately associated with surgery.[14] Sharrock et al reported DVT as an intraoperative event during total knee arthroplasty when the tourniquet is inflated.[15] There is little literature addressing intraoperative measures for DVT prophylaxis that exclude pre-operative anticoagulation therapy for foot and ankle surgery. For patients who are at risk for developing a DVT but are not candidates for anticoagulation therapy, alternative intraoperative prophylactic measures are discussed.

INTERMITTENT PNEUMATIC COMPRESSION DEVICES

Intermittent pneumatic compression (IPC) devices of the lower extremity are pumping machines that locally and systemically aid in DVT prophylaxis for nonambulating patients. Immobility results in decreased blood flow due to lack of muscle contraction therefore pumping of the venous system in the lower leg. This also leads to blood pooling and accumulation of clotting factors disturbing the natural equilibrium between clotting and fibrinolysis. Current devices differ from each other in location (foot, calf, thigh), total pressure, compression frequency, inflation time, and sequential compression chambers. Intraoperative use of IPC devices is a useful measure in preventing clot formation since early postoperative venograms confirm the majority of DVT formation is an intraoperative or immediate postoperative event.[13-15] In Westrich et al's meta-analysis of DVT prophylaxis literature from 1980 to 1997, IPC was reported to have the lowest incidence of DVT when compared to today's anticoagulation therapy methods for prophylaxis after total knee arthroplasty.[7]

The venous pressure is significantly lower in supine position compared to sitting or weight bearing.[16] For a nonambulating postoperative patient, a compression device needs to exceed the average venous limb pressure with consideration that half the energy delivered by pressure impulse is distributed to the surrounding tissues of the venous system.[17] Present devices including foot, calf, and thigh devices for DVT prophylaxis generate pressures of 160mmHg, 50mmHg, and 30mmHg respectively. The prophylactic benefit is proportional to the surface area compressed and so theoretically, thigh compression should be recommended. These proximal devices have been known to cause discomfort for the patient and compliance becomes an issue. Foot compression can generate enough pressure to increase flow from the plantar venous plexus to the posterior tibial vein, but calf compression is thought to be superior. The volume of blood in the calf is triple that of the foot, and these devices significantly increase the volume of augmentation and peak venous flow velocity compared to foot compression.[18-20] The literature does advocate very short (0.5-1 second) time inflation intervals with these devices.[17] According to a hemodynamic study by Ah-See et al and Liu K et al, smaller inflation time promotes an increase in volume flow and peak flow when comparing to longer inflation times.[21-23] Calf veins are also 3 times of greater capacity compared with the foot plantar venous plexus, so it may take longer to refill the more proximal veins to restore the resting venous pressure. In 2000, Delis et al recommended the frequency of current calf devices 1- to 4-times a minute.[24,25] Studies have proven that sequential inflation in multi-chamber devices offer the highest augmentation and therefore are superior to devices with simultaneous, continuous compression.[24, 26]

IPC devices can increase the peak venous flow velocity to overcome stasis and increase the total volume of deoxygentated blood return. Lower extremity pneumatic compression increases popliteal and femoral venous blood flow by several mechanisms that effect flow and perfusion. Production of venous turbulence in valve pocket areas that tend to advocate clot formation is one rheologic property of IPC. The action of these devices also increases the release of endothelial derived relaxing factor, which inhibits platelet aggregation.[27] IPC also stimulates fibrinolysis by releasing mediators such as urokinase (uPA), a tissue plasminogen activator (tPA).[28-30] In 1997, Comerota et al demonstrated that the effect of IPC was not from an increase in tPA, but an increase in its absolute activity level secondary to the decrease of its inhibitor.[31] Gardner et al. and Tamir et al have shown that pneumatic intermittent compression mechanically resolves venous congestion, which results in reduced pain and edema postoperatively.[32, 33]

GRADUATED COMPRESSION STOCKINGS

Graduated compression stockings are the most common mechanical antithrombotic prophylactic agent used and can maintain the progress of IPC devices in venous return. The specific mechanism in preventing DVT is technically unclear but does affect all three arms of Virchow's triad: stasis, endothelial damage and hypercoagulability. These are achieved by decreasing the diameter of the venous vessels. Venous function is improved by increased linear velocity of blood flow of the superficial and deep veins. Along with increased blood flow through the vein, there is less wall distension and decreased contact time and concentration with coagulant factors. In 1999, Agu et al reviewed 15 randomized controlled trials with graduated compression stockings alone as a prophylactic measure in DVT.[34] These trials revealed an overall increase in the linear velocity of venous flow, a reduction in wall distension and improvement of valvular function. Venodilation predisposes one to DVT by causing intimal tears, which expose thrombogenic subendothelial collagen to activated platelets and clotting factors. Compression stockings have been shown to inhibit venodilation of calf veins by a median of 48% and prevent intimal tears.[35] Jeffery and Nicholaides reported a 60% of DVT reduction rate with sole use of gradient compression stockings and recommend them as a first line prophylactic modality for low risk patients.[36]

The design of graduated compression stockings refers to the application of varying degrees of constant compression to different parts of the leg. The pressure is greatest at the ankle and then decreases in a proximal direction. Today, the current pressure profile is 18, 14, 10, 8 mmHg from ankle to thigh. Sigel et al recommended this profile after reporting graduated compression stockings increase velocity of flow in the common femoral vein, when compared with uniform compression stockings.[37] In regards to thigh-length versus knee-length stockings, clinical trials by Lawrence and Kakkar found no significant difference in deep venous flow velocity between thigh-length and knee-length.[38] Porteous et al. used fibrinogen uptake tests and also found no difference between the thigh and knee-length stockings in preventing DVT.[39] There was even speculation that thigh-length may lie inferior to knee length when Sparrow et al observed that any portion of the stocking over the area proximal to the tibial plateau was ineffective in decreasing pooling, and appeared to compromise the value of the distal portion.[40] Patient compliance with thigh-length stockings is decreased when compared with knee-length, and usually thigh-length are more expensive.

SPINAL ANESTHESIA

In 1969, Shimosato and Elston described the cardiocirculatory dynamics with spinal and epidural anesthesia.[41] Davis and Quince confirmed DVT incidence reduction with spinal anesthesia (46%) versus general anesthesia (76%) in emergency hip surgery.[42] Spinal anesthesia produces a sympathetic block causing vasodilation and increased blood flow to the lower extremity. This can inhibit DVT formation by working against any venous stagnation produced by tourniquet use, positioning, and/or prolonged immobilization during surgery. Thorburn, Louden, and Vallance also reported a reduction in DVT with spinal anesthesia (29%) versus general anesthesia (53%) during routine total hip arthroplasty.[43] They believed that spinal anesthesia gave red blood cells the ability to readily deform and easily pass through smaller diameter vessels. They also found that after spinal anesthesia, there was a large amount of hemodilution postoperatively. This all indicates that intraoperative DVT prophylaxis with the use of spinal anesthesia is due to hyperkinetic blood flow. Foate, Horton, and Davis agreed with this theory of hyperkinetic blood flow with spinal anesthesia during transurethral resection of the prostate.[44]

EPIDURAL ANESTHESIA

Lahnborg and Bergstrom, in 1975, were the first to incidentally notice the association with lumbar epidural anesthesia and lower DVT incidence versus general anesthesia.[45] Their reasoning was increased blood flow to the lower extremity using epidural anesthesia. Their observations were soon followed by randomized studies focusing on the decreased DVT and PE incidence rates related to epidural anesthesia when compared with general anesthesia.

In the early 1980s, Modig et al wrote a series of reports regarding enhanced rheological conditions of lower extremity blood flow comparing prolonged epidural anesthesia into the postoperative period versus general anesthesia with postoperative analgesics.[14, 46] They had published their first correlated study with total hip arthroplasty in reduced DVT incidence with prolonged epidural block (20%) when compared with general anesthesia (73%).[47] They contributed this reduction to their prior investigations on improved rheological conditions (arterial inflow, venous emptying rate, and venous capacity) that were most pronounced at the end of surgery and immediate postoperative period when clotting stimulus is maximal.[14, 47] They also noticed more effective lysis of thrombi during these periods from serum fibrinolysis inhibition with continuous epidural block. In 1983, the clotting cascade factors in blood were investigated to explain this reduction of DVT seen with epidural anesthesia.[48] It was revealed that there were greater concentrations of plasminogen activators (which are responsible for spontaneous fibrinolytic activity) and capacity for release from the venous endothelium when compared to general anesthesia. There was also significantly lower capacity of Factor VIII postoperatively with use of epidural anesthesia than with general anesthesia. The conclusion was the use of epidural anesthesia decreased the inhibition of fibrinolysis. Another follow up study by Modig et al looked at the incidence of DVT and PE with prolonged epidural versus general anesthesia, but now with a larger population. Again, they reported a significantly lower (13%) proximal DVT incidence (13% thigh, 40% combined calf and thigh) with prolonged epidural block versus with general anesthesia (67% thigh, 77% combined calf and thigh), and also a reduction in PE incidence (10% epidural versus 33% general).[14] With general anesthesia, venous empting rate and venous capacity had decreased 3 hours postoperatively to very low, indicating the thrombus formation was immediately associated with surgery. This may signify that DVT formation is either an intraoperative or immediate postoperative phenomenon.

Other studies who reported lower incidence of DVT with epidural anesthesia include Hendolin, Matilla, and Poikolainen studying its effects with open prostatectomy.[49] In 1982, Simpson et al compared different types of anesthesia and fibrinolytic activity to find that conventional epidural anesthesia to the level of T8 enhanced fibrinolytic activity in abdominal hysterectomies.[50] Donadoni et al believed an additional mechanism of epidural anesthesia decreasing DVT was the faster return of normal antithrombin III when compared to general anesthesia.[51] In 1990, Nielsen et al reported less DVT incidence after knee arthroplasty with prolonged epidural anesthesia (2 of 13) versus general (10 of 16).[52] Tuman et al reported less postoperative events (thrombosis of a coronary artery, deep vein, or vascular graft) with general-epidural combination (1 of 12) versus general alone (11 of 12) after vascular surgery.[53] Williams-Russo et al performed a randomized trial between epidural and general anesthesia with total knee replacement and found a decrease of DVT with epidural (40%) versus general (48%) with no difference in PE rate.[54] They later reported no differences between epidural and general anesthesia on thrombin generation or fibrinolytic activity indicating the decrease in DVT from previous studies may result from other postoperative factors.[15] All of the authors mentioned who studied the association with lumbar regional blockade and reduced thromboembolism agree that increased blood flow decreased the patients' risk regardless of any DVT risk factors including advanced age, cardiac disease, varicose veins, obesity, cancer, and previous DVT.[55, 56]

An advantage to using a prolonged epidural block into the postoperative period over general is the possibility of postoperative pain management and shortened rehabilitation. This same concept is also an advantage to spinal anesthesia even though both have been shown to decrease DVT when compared to general anesthesia. Modig et al propose that prolonged epidural blockade DVT prophylaxis can be maintained for a much longer period because it can be carried postoperatively.[14] In addition, if epinephrine in local anesthetic solution is intermittently administered through the epidural line, a more effective DVT prophylaxis is theoretically possible when comparing to spinal or general anesthesia.

There are no studies comparing epidural or spinal anesthesia versus general anesthesia and DVT incidence in foot and ankle surgery. Early postoperative venograms confirm that DVT has been shown to be an intraoperative event in total knee arthroplasty[13,15] and intraoperative or early postoperative in total hip arthroplasty.[14] Similar to orthopaedic surgeries, larger foot and ankle cases where a thigh tourniquet is used can have stagnation of venous flow. A 10-minute obstruction of the venous flow in the presence of thrombogenic stimuli is enough to advocate clot formation.[57] Although spinal or prolonged epidural anesthesia is absent in foot and ankle literature, the same concepts of hyperkinetic lower limb circulation and improved rheological conditions for DVT prophylaxis can apply, and should be considered as an alternative to anticoagulation therapy.

DISCUSSION

DVT is thought to be mainly an intraoperative or early postoperative event. Intermittent pneumatic compression devices with the aid of knee-length graduated compression stockings can be utilized during surgery as a primary mode of DVT prophylaxis for low risk patients. Regarding IPC devices, calf compression devices that are multi-chambered, applying at least 50mmHg of sequential pressure to the calf 1 to 4 per minute with an inflation time of less than 1 second is ideal for DVT prophylaxis. For patients who do not have an opposite leg to wear an ICP, it can be applied to the arm since the effects on decreasing thrombosis formation are systemic.[58] Knee-length graduated compression stockings, worn 2 hours prior to surgery followed by continued use until full mobilization, is ideal for prophylaxis.[59] Spinal and epidural anesthesia have both been proven to significantly decrease the rate of DVT and PE when compared to general anesthesia in various types of surgery, even in the geriatric population for hip fractures.[60] They also have been shown to decrease overall morbidity and mortality.[62] There are also anti-thromboembolic effects of the local anesthetic on leukocytes, platelets, erythrocytes, and plasma protein interactions with red blood cells and endothelial cells. With lidocaine specifically, there is a reduction of adhesion of leucocytes to blood vessels walls therefore preventing endothelial damage to venous structures.[62-65] In vitro, local anesthetics have contact with platelets for a long period of time that results in reduced aggregation when stimulated.[66,67] Henry et al later confirmed this concept clinically with use of 0.5% Bupivacaine plain in epidural anesthesia.[68] The addition of epinephrine to the epidural or spinal mixture, or through IV infusion intraoperatively can also decrease DVT formation. Sharrock et al agreed with Modig et al that epinephrine may enhance fibrinolysis.[48,56] Also, epinephrine has circulatory effects, which increase skeletal muscle blood flow. Multiple studies reported increased lower extremity blood flow was found with the use of epidural anesthesia containing epinephrine when compared to lidocaine plain.[69-71]

Modig et al have been using the same epidural continuous block routine for decades. Prior to anesthesia, an 18-26 ml of 0.5% bupicvacaine with epinephrine (5 micrograms/ml) administered through a lumbar catheter with a subcutaneous injection of 50 mg of ephedrine is given. Throughout the first 24-hour postoperative period, the patients received 4-6 ml of 0.5% bupivacaine with epinephrine every 4 hours per pain or 6-12 ml of 0.25% bupivacaine with epinephrine every 3 hours per pain.[14,48] Nielsen et al also used prolonged epidural blockade but with 2% mepivacain and prolonged for 3 days postoperatively with 0.25% bupivacaine starting at 5mL/h prn pain with concominant use of graded compression stockings.[52] Westrich et al will use a hypotensive epidural with postoperative elastic stockings and aspirin, due to its decreased risk of bleeding complications (versus warfarin or low-molecular weight heparin after epidurals).[72]

Although these alternative prophylactic measures seem safe, there are always associated risks one should consider. IPC devices should not be used in patients with acute DVT or they risk a break of thrombi and PE. They also should not be applied to fractured limbs. When IPC devices are used intraopeartively, care should be exercised in preventing neurovascular compression, compartment syndrome, and peroneal nerve compression.[73,74]

The use of graduated compression stockings are relatively safe, but concern of subcutaneous tissue oxygenation impairment is possible if the pressure is too high for that particular patient, especially with peripheral vascular disease. It has been reported that a stocking with 10mmHg of pressure can reduce 10% of the tissue cutaneous blood flow, with 30mmHg there is loss of 25% of oxygenation, and with 60mmHg there is a 84% drop.[34]

Spinal or epidural anesthesia should not be used in patients with valvular heart disease, such as aortic or mitral stenosis, carotic stenosis greater than 80%, renal failure, immediate use of anticoagulants, and first or second degree heart block.[72] When either type of anesthesia is uesd intraoperatively, the immediate post-operative start of low-molecular weight heparin therapy is contraindicated. An increase risk of spinal bleeding and/or hematoma development has been reported if therapy is started within 12 to 24 hours of spinal anesthesia or epidural line removal.[75-77] Bleeding in an enclosed area such as the spinal canal that does not have the protective mechanisms of the coagulation system can cause major neurologic damage. Intermittent pneumatic compression and compressive stockings can offer systemic prophylaxis to clot formation during this immediate post-operative interval.

CONCLUSION

The literature on DVT and PE associated with foot and ankle surgery suggests that they are rare and that pharmacologic prophylaxis is not warranted. For surgeons who do use routine DVT prophylaxis in patients who are in risk, and want or need alternative measures for their patients, intraoperative non-pharmacologic measures were discussed. IPC devices improve venous function by increasing peak venous flow velocity, increasing venous blood turbulence, and increasing the activity of tissue plasminogen activator. Graduated compression stockings alone or with IPC devices increase the venous velocity flow and inhibit venodilation. Epidural or spinal anesthesias are intraoperative alternative modes of DVT prophylaxis, which seem to produce hyperkinetic blood flow in the lower extremity, reduce tendency to coagulate, and improve fibrinolytic function. The local anesthetic itself with or without epinephrine has been shown to have anti-thromboembolic properties reducing endothelial damage and platelet aggregation. Since prolonged epidural anesthesia is shown to enhance the kinetics of lower limb circulation at the end of surgery and during the immediate postoperative period when clotting stimulus is maximal, this form of anesthesia can prophylax against both the formation and the propagation of DVT with simultaneous pain management.

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