

Thromboembolism in Plastic Surgery

Daniel Most, M.D., Jeffrey Kozlow, B.A., Jennifer Heller, M.D., and Michele A. Shermak, M.D.

Baltimore, Md.

Learning Objectives: After studying this article, the participant should be able to: 1. Appreciate the pathophysiology of deep venous thrombosis and pulmonary embolus. 2. Identify patients at risk for deep venous thrombosis and pulmonary embolus before and after surgery. 3. Recognize modalities for diagnosis and treatment of deep venous thrombosis and pulmonary embolus. 4. Recognize what precautions to take to avoid deep venous thrombosis and pulmonary embolus in plastic surgery patients.

Thromboembolism is a dreaded complication of surgery in multiple disciplines, including plastic surgery, and deep venous thrombosis and pulmonary embolus cause significant morbidity, even death. This article provides methods for understanding and preventing deep venous thrombosis and pulmonary embolus in plastic surgery. (*Plast. Reconstr. Surg.* 115: 20e, 2005.)

Thromboembolism is a dreaded complication of surgery in multiple disciplines, including plastic surgery. Deep venous thrombosis and pulmonary embolus cause significant morbidity, even death. Prevention is relatively straightforward, with published guidelines, although even the most aggressive preventive strategies can fail. The plastic surgeon is unfortunately forced to walk a thin line, with thromboembolism on one side and postoperative bleeding complications on the other. The following case presentation highlights the importance of understanding deep venous thrombosis and pulmonary embolus in plastic surgery because of their potentially devastating consequences.

CASE REPORT

A middle-aged woman had undergone open gastric bypass surgery more than 1 year before consultation for skin excision

surgery. She had lost 115 pounds, and her weight had stabilized at 158 pounds. She was hampered by her loose abdominal pannus and inner thigh skin folds, which caused fungal rashes and difficulty with ambulation and exercise. The patient also had a ventral hernia.

The patient's medical history was otherwise negative. She did not smoke, and she rarely drank alcohol. She was physically active and on no medications, and stated that she had no drug allergies. Her family history was noncontributory.

On examination, the patient had a reducible hernia under a well-healed upper midline laparotomy scar. A loose pannus of the inferior abdomen extended 12 cm below her pubis. Her inner thighs also had redundant skin folds.

The patient's preoperative blood work revealed normal hematologic, coagulation, and chemistry (including liver function) values. The chest radiograph and electrocardiogram were also normal. The patient was scheduled for abdominal panniculectomy with hernia repair and inner thigh lift.

At surgery, elastic hose and pneumatic compression garments were applied to the patient's legs. A transverse lower abdominal incision was created, and undermining of skin cephalad around the umbilicus toward the xiphoid was performed. The hernia was repaired primarily without prosthetic material and without significant tension. The abdominoplasty specimen weighed 9.5 pounds, and the inner thigh specimens weighed an aggregate 1.2 pounds. Two closed-system drains were placed under the abdominal skin, and an elastic abdominal binder was firmly, but not tightly, placed over her dressings.

The patient's acute postoperative course was unremarkable. She was maintained on twice-daily heparin, 5000 units subcutaneously, and elastic hose and leg pneumatic pressure garments were continued except when ambulating. She tolerated liquids on her night of surgery and was advanced to a regular diet by the first postoperative day. She was ambulating by postoperative day 2 and discharged home by postoperative day 3, with her drains in place.

The patient was seen in the clinic 1 week later. Her drains were removed because of low output. She was healing well

From the Divisions of Plastic Surgery and Vascular Surgery, Department of Surgery, The Johns Hopkins Medical Institutions. Received for publication May 1, 2003; revised August 21, 2003.

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and was happy with her early results. She was eating well and gradually increasing her activity level. She denied any constitutional symptoms such as fever or breathing difficulties and denied leg stiffness or pain other than discomfort in her inner thigh incisions. Her pain level had decreased, and she only occasionally needed analgesia.

Shortly after her 2-hour drive home, the patient had onset of severe substernal chest pain and shortness of breath. Paramedics transported her to a local hospital emergency department. On arrival, oxygen was administered and intravenous access was obtained. Within minutes, however, the patient, who had exhibited narrow complex tachycardia, rapidly deteriorated into pulseless electrical activity. Advanced cardiac life support was unsuccessful, and the patient was declared dead.

The medical examiner's autopsy of the patient reported a large saddle pulmonary embolus as the cause of death. The patient's repaired hernia and surgical incisions were unremarkable and had been healing normally. No clot was found in the deep leg veins.

PREVALENCE OF DEEP VENOUS THROMBOSIS/PULMONARY EMBOLUS IN PLASTIC SURGERY

Abdominoplasty

Abdominoplasty has one of the highest rates of deep venous thrombosis and pulmonary embolus in plastic surgery. One series found a 1.2 percent incidence of deep venous thrombosis and a 0.8 percent incidence of pulmonary embolus overall.¹ Thromboembolic risk increases when abdominoplasty is combined with other procedures. When combined with intraabdominal procedures such as hysterectomy, incidences of pulmonary embolus up to 6.6 percent have been reported, whereas others report a composite 1.1 percent risk of pulmonary embolus when combined with other aesthetic procedures.^{2,3} The association of pulmonary embolus and abdominoplasty may be related to interference of superficial venous drainage from the pelvis and legs. Adding suction-assisted lipectomy to abdominoplasty does not increase the risk of deep venous thrombosis or pulmonary embolus.⁴

Suction-Assisted Lipectomy

Thromboembolic complications and liposuction have also been the subjects of research interest. Rao et al.⁵ discovered five deaths after liposuction in New York City between 1993 and 1998, one of which was caused by a saddle pulmonary embolus. Albin and de Campo⁶ published a series of 181 patients, all with more than 5 liters of liposuction aspirate, and found that one patient (0.6 percent) had a deep venous thrombosis and two patients (1.1 per-

cent) developed nonfatal pulmonary embolisms. The largest multicenter series was reported by Grazer and de Jong,⁷ based on a survey administered by the American Society of Aesthetic Plastic Surgery from 1994 to 1998. A database of approximately 496,000 patients from 917 different aesthetic surgeons was created. Interestingly, pulmonary embolus represented the largest single cause of mortality, affecting 4.6 per 100,000 patients (0.005 percent).

Rhytidectomy

Rhytidectomy has also been associated with a small but significant number of deep venous thrombosis and pulmonary embolism cases. Reinisch et al.⁸ surveyed a cohort of board-certified plastic surgeons: 273 responded, reporting a total of 9937 rhytidectomy patients. Overall, 0.35 percent of the patients developed deep venous thrombosis and 0.14 percent developed pulmonary embolus, with one fatality. As with many studies, reported prophylactic techniques varied from nothing to elastic bandages wrapped around legs to lower extremity sequential compression devices. The sequential compression device group had the lowest prevalence of thromboembolic sequelae. Patients requiring anticoagulation for deep venous thrombosis and pulmonary embolus developed facial hematomas, and some required surgical drainage.

Other Plastic Surgery Procedures

Other plastic surgery procedures have been reported to have a low but reportable incidence of deep venous thrombosis and pulmonary embolus. Erdmann et al.⁹ reported one patient of 73 (1.3 percent) who developed a deep venous thrombosis after breast reconstruction with a pedicled transverse rectus musculocutaneous flap. In a series of 12,805 patients undergoing head and neck surgery including oncologic resection, 34 (0.3 percent) developed postoperative deep venous thrombosis, and 24 (0.2 percent) of these patients had disease that progressed to pulmonary embolus.¹⁰

To help put these rates of deep venous thrombosis and pulmonary embolus in perspective, one should consider the reported rates of thromboembolism in related surgical specialties. For example, orthopedics has one of the highest rates of pulmonary embolus and deep venous thrombosis, even with prophyl-

laxis. Elective hip replacement has an incidence of pulmonary embolus of 2 to 3 percent; hip fracture fixation, 4 to 7 percent.¹¹ Aggregate general surgery procedures including cancer resections have a reported pulmonary embolus incidence of 0.1 to 0.8 percent, and this incidence rises to 3.5 percent in obese/bariatric patients, even with prophylaxis.¹² One autopsy series of 10 patients who died after gastric bypass surgery revealed three deaths directly attributable to pulmonary embolus, whereas all but two of the remaining patients had previously unsuspected pulmonary emboli. All 10 patients had been on subcutaneous heparin and pneumatic stocking prophylaxis.¹³

EPIDEMIOLOGY

The overall incidence of deep venous thrombosis in the United States is 84 to 150 per 100,000 per year, or 250,000 cases per year. One million patients are tested annually in the United States for suspicion of deep venous thrombosis, and approximately 25 percent have the diagnosis confirmed.¹⁴⁻¹⁶

The incidence of pulmonary embolus in the United States has a wide reported range, from 125,000 to 400,000 cases per year.¹⁷ Pulmonary embolism is responsible for approximately 150,000 deaths per year and is the third most common direct cause of death in the United States.^{18,19} Pulmonary embolus causes approximately 5 percent of all perioperative deaths.²⁰ In a landmark multicenter study, the Prospective Investigation of Pulmonary Embolism Diagnosis, 60 to 70 percent of all autopsied hospital patients were found to have one or more pulmonary emboli present, 70 percent of which were undiagnosed before death.²¹

Pulmonary emboli, if diagnosed and treated early, carry a mortality rate of 2 to 8 percent. Even with aggressive treatment, 10 percent of pulmonary embolus patients will have recurrent pulmonary embolus, and the death rate in this group approaches 45 percent.²² The caveat to statistics is that many patients have subclinical deep venous thrombosis and pulmonary embolus with few if any symptoms, and they often improve spontaneously. The true incidence and prevalence of these diseases are therefore difficult to determine.

RECOMMENDATIONS FOR PREVENTION

Faced with the potential morbidity and mortality from thromboembolic events, McDevitt,²³ through the American Society of Plastic Sur-

gery Task Force on Deep Venous Thrombosis Prophylaxis, established guidelines for prophylaxis in plastic surgery. These principles were reviewed recently.²⁴

Briefly, individuals who are candidates for plastic surgery should be stratified according to their risk of deep venous thrombosis/pulmonary embolus into a low-risk, moderate-risk, or high-risk category. The low-risk category represents patients without known risk factors who require surgical procedures of 30 minutes or less and are under the age of 40. Moderate-risk patients are aged 40 or older; or require procedures lasting longer than 30 minutes; or take oral contraception or hormone replacement therapy. Although general anesthesia for less than 30 minutes does not cause significant venous pooling, a linear increase in the risk of deep venous thrombosis occurs with surgical time greater than 1 hour.²⁵ High-risk patients are those who would fall into the moderate-risk category but have additional risk factors, such as malignancy, immobilization, obesity, and hypercoagulable states (Table I).^{11,14-19}

Recommendations were proposed according to risk stratification. Low-risk patients require comfortable positioning on the operating table, with slight knee flexion provided with a pillow under the knees, to enhance popliteal venous return. External pressure on the legs or constricting garments should be avoided. Moderate-risk patients require the same measures, plus intermittent pneumatic compression garments worn before, during, and after general anesthesia until fully awake. These patients are asked if possible to stop taking risky medica-

TABLE I
Risk Factors for Deep Venous Thrombosis and
Pulmonary Embolus

Virchow's triad (stasis, hypercoagulability, vascular injury)
Immobilization (such as from surgery or a fracture)
Malignancy
Thrombophlebitis
Pregnancy, and for 6 to 12 weeks postpartum
Extremity trauma
Hormone replacement therapy or oral contraceptives
Smoking
Obesity (body mass index >30)
Recent myocardial infarction or cerebrovascular accident
Previous history of deep venous thrombosis/pulmonary embolus
History of radiation therapy (especially pelvic)
Antiphospholipid antibody syndrome
Homocystinemia
Polycythemia
Other hypercoagulable states (e.g., abnormal proteins C or S; factor V Leiden; abnormal factors VIII, IX, X)

tion at least 1 week before surgery, although it is unclear in the literature whether propensity for deep venous thrombosis/pulmonary embolus normalizes in this time. High-risk patients require the same measures as the other two categories, plus a preoperative hematology consultation and consideration for low-molecular-weight heparin 2 hours before surgery and daily until the patient is ambulatory. Prophylactic anticoagulation, however, is considered optional in procedures with a high risk for hematoma. The majority of aesthetic procedures fall into this category.

The increasing popularity of herbal remedies in the general population has been linked to multiple medically relevant side effects, including abnormally increased or decreased (prothrombotic) bleeding times. Some herbal preparations have had multiple reports of associated deep venous thrombosis, including that of the liver (Budd-Chiari syndrome).²⁶⁻²⁹

Intermittent Pneumatic Compression Devices

Nearly ubiquitous, intermittent pneumatic compression devices (sequential compression devices) represent a relatively simple, noninvasive method of prophylaxis. The perioperative deep venous thrombosis risk ratio is approximately 0.28 compared with the risk when not using these devices.³⁰⁻³² Sequential compression induces fibrinolysis, augmentation of venous return, and endothelial release of antiplatelet aggregation factors.³³⁻³⁵ Sequential compression devices may be placed on the arms or legs, depending on the planned surgical procedure, and devices are available that only cover the ankles. These devices can be sterilized and placed intraoperatively, although it is best to have them operational before anesthetic induction.³⁶ A promising technology that may eventually replace external compression entirely is electrical foot and calf muscle stimulators.³⁷

SEQUELAE OF DEEP VENOUS THROMBOSIS

Although 50 percent of deep venous thromboses originating intraoperatively will resolve spontaneously, some deep venous thromboses will lead to further complications, including the most dreaded complication, a pulmonary embolism.³⁸ In patients with symptomatic deep venous thrombosis, 88 percent had above-knee involvement and 12 percent had only below-knee involvement.³⁹ It is suggested that 36 percent of untreated below-knee deep venous

thromboses will extend above the knee within 1 week.⁴⁰ Although below-knee deep venous thromboses can embolize without proximal involvement, it is most often above-knee deep venous thromboses that embolize and cause pulmonary complications. The rate of pulmonary embolism in patients with untreated proximal deep venous thrombosis is suggested to be near 50 percent; however, studies show that with current treatment regimens, the risk of pulmonary embolism in patients with treated proximal deep venous thrombosis is less than 5 percent.^{38,41,42} The recurrence rate of deep venous thrombosis alone following treatment approaches 10 percent in patients with risk factors for deep venous thrombosis and is much lower (3 percent) in patients without risk factors.³⁸

Fewer than 10 percent of deep venous thrombosis patients develop severe postphlebotic leg syndrome, a debilitating constellation of symptoms including edema, pain, leg ulcers, and skin induration similar to that seen in patients with venous insufficiency; up to 35 percent of patients may show milder symptoms.^{43,44} Therapy is only modestly successful, consisting of long-term use of sequential compression devices and surgical venous reconstruction and/or thrombectomy.⁴⁵

SEQUELAE OF PULMONARY EMBOLUS

Roughly 10 percent of patients with acute pulmonary embolus die within 30 to 120 minutes of embolization, usually before medical help is available.⁴² The presence of shock at presentation increases the associated mortality.³⁸ Of those obtaining prompt medical care, 2 to 8 percent of patients who survive initially will die despite treatment.¹⁵ For effective therapy, aggressive early treatment is required. Of those who survive the acute stages of pulmonary embolus, approximately 5 percent will continue to have significant right-sided heart failure after 1 year, a disabling and often lethal disease.⁴⁶

WORK-UP OF DEEP VENOUS THROMBOSIS AND PULMONARY EMBOLUS

Patients with deep venous thrombosis or pulmonary embolus demonstrate a range of signs and symptoms, from subtle to florid, with obvious distress. A careful history and physical examination are often accurate tools in diagnosis. Clinically suspicious patients ultimately are diagnosed with deep venous thrombosis approximately 80 percent of the time, whereas

low-suspicion patients are diagnosed only 5 percent of the time.⁴⁷

Signs and symptoms of deep venous thrombosis^{14,15} and pulmonary embolus^{15,16,18,20} are listed in Tables II and III, respectively. Of note, "classic" symptoms are only present approximately 25 percent of the time in patients with deep venous thrombosis.¹⁴ Initial workup of deep venous thrombosis includes physical examination and Doppler ultrasound studies of the legs, with follow-up studies as clinically indicated. In patients with suspected pulmonary embolus, the workup is more extensive and must occur in a more critical time frame. For patients clinically suspected of having a pulmonary embolus, the diagnostic pathway includes the workup for deep venous thrombosis combined with serologic studies, an electrocardiograph, and chest radiography. More specific imaging modalities, such as ventilation-perfusion scan, spiral chest computed tomography scan, or pulmonary angiography, must be considered and will vary based on clinical presentation and test availability.

Serologic Studies

Serologic studies are helpful adjuncts in the workup, although their role as primary diagnostic tools is still under development. The standard workup for pulmonary embolus includes room air arterial blood gas analysis, checking for hypoxia, and/or checking for an increased alveolar-arterial oxygen pressure gradient. Although arterial blood gas is widely accepted as routine for a pulmonary embolus workup, Robin and McCauley⁴⁸ in their study published in *Chest* in 1995 demonstrated that 20 percent of patients with angiographically documented pulmonary embolism have a normal alveolar-arterial oxygen pressure gradient. Moreover, it is possible to have a large pulmonary embolus with a normal alveolar-arterial difference in partial pressure of oxygen on room air. This demonstrates that one cannot rely exclusively on an arterial blood gas analysis to either rule in or to rule out a pulmonary

TABLE II
Deep Venous Thrombosis: Signs and Symptoms

Leg edema	
Leg tenderness in the absence of trauma or infection	
Skin discoloration or ulceration	
Calf pain on ankle dorsiflexion (Homan's sign)	
"Palpable cords" (thrombosed veins) in the legs	

TABLE III
Pulmonary Embolus: Signs and Symptoms

Dyspnea	73%
Pleuritic pain	66%
Cough	43%
Leg swelling	33%
Leg pain	30%
Hemoptysis	15%
Palpitations	12%
Wheezing	10%
Angina-like pain	5%

embolus. Of course, an arterial blood gas analysis is helpful to determine the presence of hypoxemia and whether supplemental oxygen is required.

Checking fibrin D-dimer levels as a marker of thrombosis may be useful in the workup of deep venous thrombosis and pulmonary embolus, with an overall composite sensitivity of 90 percent and a specificity of 75 percent (variable, depending on type of assay used).⁴⁸ Perhaps the strongest role for this test is helping to rule out deep venous thrombosis in patients for whom the surgeon has a low clinical suspicion for thromboembolic disease. Another serologic study in development is measurement of antithrombin III levels, which are diminished in patients with thrombosis. This modality remains promising but unproven.^{49,50}

Chest Radiography

A chest radiography series is indicated in nearly every patient with a suspected pulmonary embolus. Eighty-six percent of pulmonary emboli will have an associated finding on chest radiography, but quite often the finding is subtle and nonspecific. Perhaps the strongest use of the chest radiography series is to rule out other potential causes of shortness of breath or chest pain, such as pneumonia or congestive heart failure. The findings with pulmonary embolus on chest radiography are nonspecific

TABLE IV
Chest Radiography Findings in Pulmonary Embolism

Normal	14%
Atelectasis or parenchymal density	68%
Pleural effusion	48%
Pleural-based opacity	35%
Elevated diaphragm	24%
Prominent central pulmonary artery	15%
Westermarck's sign (decreased pulmonary vascularity with an enlarged hilar pulmonary artery on the affected side)	7%
Cardiomegaly	7%
Pulmonary edema	5%

and include atelectasis, pleural effusion, opacification, and an elevated diaphragm (Table IV).²²

Doppler Ultrasound of the Legs

As discussed in the Prospective Investigation of Pulmonary Embolism Diagnosis study, the sensitivity and specificity of Doppler ultrasound examination in the diagnosis of deep venous thrombosis depend on the level of clinical suspicion and the presence or absence of leg symptoms such as swelling and pain.²¹ In patients with leg symptoms, the sensitivity and specificity are approximately 95 percent and 96 percent, respectively. In the absence of leg symptoms, however, these rates drop to 62 percent and 75 percent, respectively. Caveats with respect to the role of Doppler ultrasound in patients with pulmonary embolus include the fact that less than 50 percent of patients with pulmonary embolus will have leg signs or symptoms, and less than 30 percent of patients with pulmonary embolus will have abnormal ultrasound results. Doppler ultrasound is therefore more of a screening examination for deep venous thrombosis alone and less useful in the setting of suspected pulmonary embolus. Because below-knee deep venous thrombosis can propagate above the knee (usually within 1 week), if the initial ultrasound study was negative even though there was a high clinical suspicion for deep venous thrombosis, it is recommended that the study be repeated in 7 days.³⁹

Another factor to consider is the upper extremity deep venous thrombosis, which recently has come under increasing scrutiny as a source of local and systemic thrombosis. Although far less common than lower extremity deep venous thrombosis, the upper extremity can also be the focus of thromboembolic disease, especially when indwelling vascular access devices or a history of upper extremity trauma is present.⁵¹

Ventilation-Perfusion Scan

Graded as high probability, intermediate probability, low probability, nearly normal, or normal, ventilation-perfusion scan results can be combined with the clinical level of suspicion of pulmonary embolus to *sometimes* provide fairly rapid, accurate results. The term "sometimes" is used, because only when the ventilation-perfusion scan results are of high probability or normal (i.e., the extremes of ratings) are they clinically useful.²¹ For example, a high-

probability scan, coupled with an 80 percent or greater level of clinical suspicion, accurately predicts pulmonary embolus 87 percent of the time. Patients with a normal study, coupled with a low (0 to 19 percent) level of clinical suspicion, have a pulmonary embolus less than 5 percent of the time. Patients with ventilation-perfusion scan readings in the intermediate range require another confirmatory imaging modality, usually a pulmonary angiogram. The advantages of the ventilation-perfusion scan are its easy availability and minimal invasiveness. Disadvantages include potential radiation exposure in pregnant patients and the frequency of intermediate/indeterminate results.²²

Spiral Chest Computed Tomography and Magnetic Resonance Imaging

Increasingly used for the diagnosis of pulmonary embolus, the spiral chest computed tomography scan offers a rapid, minimally invasive means of obtaining a definitive answer and is slowly replacing the ventilation-perfusion scan. Infarcted areas of lung will appear as a pleural based, triangular density with convex borders and a linear strand at the apex. Emboli themselves can also often be seen within vascular lumens. Occasionally, spiral computed tomography will miss central clots in the middle and lingular pulmonary arteries because of their nearly horizontal branch points from the hilum. Sensitivity for pulmonary embolus has been estimated to be 53 to 100 percent, and specificity 81 to 100 percent, with variation caused by equipment, imaging technique, and interpreter skill. Six to 30 percent of patients with subsegmental clots will not have detectable findings on computed tomography.⁵²⁻⁵⁴ As with the other types of studies, in the setting of high clinical suspicion with negative computed tomography findings, it is recommended that a pulmonary angiogram be obtained.

The use of thoracic magnetic resonance imaging to diagnose pulmonary embolus is still considered investigational though promising. The estimated sensitivity is 75 to 100 percent, with a specificity of 87 to 100 percent.^{55,56} Less available than computed tomography and currently requiring a longer scan time, magnetic resonance imaging may prove particularly useful in the pregnant patient.

Pulmonary Angiography

Pulmonary angiography is still considered the standard for pulmonary embolus diagnosis. The most invasive of imaging modalities, it also offers sensitivities and specificities of greater than 95 percent.^{57,58} Disadvantages include radiation exposure, occasional errors in over-interpretation from dye-filling artifact, and, infrequently, cardiac arrhythmia, site hematoma, and dye reaction. Ironically, pulmonary angiography may *cause* deep venous thrombosis in 2 to 4 percent of patients because of local vascular trauma in the groin.^{59,60}

TREATMENT OF PULMONARY EMBOLUS/DEEP VENOUS THROMBOSIS

The immediate institution of heparin in pulmonary embolus greatly reduces mortality and should not be delayed if a high level of clinical suspicion exists. In the acute setting of a pulmonary embolism, hemodynamic support coupled with intravenous heparin or thrombolytic therapy is most appropriate. For stable patients, unfractionated heparin has been the traditional treatment of choice, although increasingly, low-molecular-weight heparins are being used. Both work through the augmentation of antithrombin III and prevent fibrinogen conversion to fibrin. At the time of this writing, the only low-molecular-weight heparins approved by the U.S. Food and Drug Administration for deep venous thrombosis/pulmonary embolus treatment were enoxaparin and tinzaparin. The advantages of low-molecular-weight heparin over unfractionated heparin are multiple. The weight-adjusted subcutaneous dosing has highly predictable clinical effects; long-term use has been associated with less osteopenia, and heparin-induced thrombocytopenia occurs less frequently. Lastly, outpatient therapy both in the short and long term is safe and effective with low-molecular-weight heparin for both deep venous thrombosis and pulmonary embolus.⁶⁰⁻⁷⁰

Warfarin therapy remains the mainstay of long-term deep venous thrombosis and pulmonary embolus treatment. Warfarin therapy is begun 1 to 3 days after heparin is started. The latter is needed initially because warfarin inhibits protein C and protein S, inhibitors of factors V and VIII, faster than other clotting factors and is therefore initially prothrombotic. The typical recommended international normalized ratio target range is 2.0 to 3.0. Although a 6-month course of therapy is recommended,

shorter courses of therapy are being investigated.^{71,72}

A strong disadvantage of warfarin is the risk of bleeding, especially in patients with risk factors such as previous gastrointestinal ulcer disease, hypertension, and stroke. The risk for patients younger than 65 years of age with no other risk factors has been estimated at 3 percent, but it increases to 42 percent in those 65 years and older with multiple risk factors.⁷³⁻⁷⁵ Warfarin also cannot be used for pregnant patients who risk fetal chondromalacia.⁷⁶ Unfractionated heparin and low-molecular-weight heparin are therapeutic mainstays in the pregnant patient. Anticoagulation with warfarin may begin in the postpartum period.

Patients who cannot tolerate heparin or warfarin, such as those who are pregnant or have heparin-induced thrombocytopenia, are candidates for therapy with direct thrombin inhibitors based on the leech-produced anticoagulant hirudin. These drugs include lepirudin danaparoid, and Argatroban (GlaxoSmithKline, Brentford, Middlesex, United Kingdom).⁷⁷⁻⁷⁹ Disadvantages include high cost, need for parenteral administration, unpredictable clinical responses, and difficulty monitoring their level of effect with standard tests. Lastly, reversal of these agents can be problematic, as no pharmacologic antidotes are currently available. Lepirudin and danaparoid are removable by means of hemodialysis, whereas Argatroban has a very short half-life and clears rapidly.⁷⁶

Thrombolytic Therapy

Thrombolysis is the current standard of care for patients with clinical manifestations of a massive pulmonary embolus with hemodynamic instability, with syncope, hypotension, hypoxemia, or heart failure.⁸⁰⁻⁸³ Thrombolytics restore perfusion to the lung and decrease pulmonary hypertension. They must be administered early, typically in the emergency department, unless absolute contraindications exist, such as a history of gastrointestinal bleeding, recent surgery, trauma, pregnancy, or hemorrhagic stroke. Thrombolysis has been shown to be safe in pregnancy.^{84,85} Currently, applications for nonmassive pulmonary embolus are being developed. Timely thrombolysis has been shown to greatly reduce the acute and chronic sequelae of pulmonary embolus and may obviate surgical thrombectomy in some patients.

Caval Filters

Inferior vena cava filters help prevent recurrent pulmonary embolus in the short term but increase the risk of recurrent deep venous thrombosis over the long term in the absence of anticoagulation.⁸⁶ They can be quite useful and effective, but patients may require lifelong anticoagulation unless one of the newer, retrievable filters is placed.⁸⁷ The most frequent indication for an inferior vena cava filter is for patients in whom anticoagulation is contraindicated in the short term, such as those who need urgent surgery, have active bleeding elsewhere, or have severe thrombocytopenia.^{88,89} Future filters may be developed with anticoagulant (e.g., heparin) coatings, which may further increase their effectiveness.^{90,91}

Surgery

Currently less prevalent because of the role of thrombolytics and interventional radiology, surgery is indicated in the unstable pulmonary embolus patient in whom thrombolysis has failed. Pulmonary embolectomy can save the lives of patients with massive pulmonary embolus, although in a consecutive series of 96 patients, the mortality rate was 37 percent.⁹² Cardiac arrest and a history of coronary artery disease were independent predictors of death. Elective pulmonary embolectomy and endarterectomy for chronic thromboembolic pulmonary hypertension can prolong life.⁹³⁻⁹⁵

Endovascular techniques are increasingly being used to treat both pulmonary embolus (by means of catheter-directed thrombolysis or embolectomy) and severe deep venous thrombosis (by means of venous stenting combined with catheter-directed thrombolysis) and may eventually replace the majority of open surgical interventions in thromboembolism. The future role of endovascular techniques is still under investigation.^{96,97}

Pentasaccharides: The Future?

A new class of antithrombotic agents is under investigation, the pentasaccharide inhibitors of activated factor X. Discussed by Turpie et al.,⁹⁸ the experimental drug Org31540/SR90107A was found to be more effective and to have fewer bleeding complications than low-molecular-weight heparin (enoxaparin) for deep venous thrombosis prophylaxis in elective hip replacement patients. An orally available

form of a direct thrombin inhibitor is also undergoing clinical trials in deep venous thrombosis prevention.⁹⁹ Both types of drugs, nonheparins, have the added advantage of preventing heparin-induced thrombocytopenia syndrome.

CONCLUSIONS

Deep venous thrombosis and pulmonary embolus are devastating complications in plastic surgery. Effective therapy exists, although morbid and sometimes lethal sequelae occur despite treatment. The emphasis therefore must be on prevention. Fortunately, these events are rare in most types of plastic surgical procedures. We are aided in deep venous thrombosis/pulmonary embolus prophylaxis by published guidelines for plastic surgeons from the American Society of Plastic Surgeons.¹¹ Even when all current recommendations have been followed, however, there will be the rare patient who develops a deep venous thrombosis or pulmonary embolus. A well-informed and prepared plastic surgeon could save this patient's life.

Michele A. Shermak, M.D.
Division of Plastic Surgery
Johns Hopkins Bayview Medical Center
Suite A640
Baltimore, Md. 21224
masherma@jhmi.edu

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