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Techniques and Devices for Catheter-Directed Therapy in Pulmonary Embolism

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The clinical presentation of a patient with acute pulmonary embolism (PE) can be classified into 3 categories: low-risk, submassive (presence of right heart strain), and massive (hemodynamic compromise). Massive PE is associated with high morbidity or mortality and typically treated with systemic intravenous thrombolysis. Over the last 2 decades, however, catheter-directed techniques have become an increasingly popular treatment modality for patients with a contraindication to systemic thrombolysis or without clinical improvement after systemic thrombolysis. Furthermore, endovascular treatment for patients with submassive PE has been of great interest due to the significantly increased mortality associated with right heart strain, and prospective clinical trials have demonstrated catheter-directed thrombolysis to decrease right heart strain earlier than systemic anticoagulation alone. This article describes available devices and endovascular techniques used to treat patients with massive and submassive acute PE.

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Introduction

Venous thromboembolic disease is a common condition with high morbidity and mortality. Each year, as many as 300,000-600,000 people could be affected by deep vein thrombosis or PE.[1] Absent a contraindication, all patients with PE are treated with systemic anticoagulation. Patients with massive PE, defined as acute PE with hemodynamic compromise, are typically treated more aggressively due to high associated morbidity and mortality. Historically, the standard of care for this subset of patients was systemic intravenous thrombolysis. Over the last 2 decades, however, catheter-directed techniques have been of great interest to treat patients with massive PE who cannot undergo systemic thrombolysis or in patients who need additional treatment after systemic thrombolysis. Although systemic thrombolysis has proven an effective treatment in patients with massive PE, a randomized, double-blinded clinical trial demonstrated no difference in 30-day mortality of patients with submassive PE (acute PE with right heart strain) treated with systemic thrombolysis vs anticoagulation alone due to an increased rate of bleeding complications with systemic thrombolysis.[2] On the other hand, catheter-directed thrombolysis (CDT) has proven to decrease right heart strain earlier than systemic anticoagulation alone in submassive PE, which is important because right heart strain in the setting of PE has been associated with increased mortality.[3,4] This article describes available devices and endovascular techniques used to treat patients with massive and submassive acute PE.

Clinical Evaluation of the Patient

Virchow's triad describes 3 general categories of risk factors that predispose a patient to deep vein thrombosis or PE—hypercoagulability, endothelial injury, and venous stasis. A focused history will often reveal clues related to one of these 3 key risk factors. Patients without a clear inciting event should receive a thorough work up for a hypercoaguable disorder such as antiphospholipid

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Table Contraindications to Thrombolytic Therapy

Absolute contraindications
Intracranial neoplasm
Recent intracranial or spinal surgery/trauma
History of hemorrhagic stroke or any stroke within 3 months
Active bleeding or bleeding diathesis
Relative contraindications
Severe, uncontrolled hypertension
Nonhemorrhagic stroke > 3 months
Recent surgery (<14 days)
Recent vascular punctures
Age > 75 years

syndrome, antithrombin III or protein C or S deficiency, and nephrotic syndrome. A complete hypercoagulability workup need not happen in the acute period but it should be completed at some point to unmask any inciting factors that would put the patient at risk for future events. The history should also include questions that investigate for high risk features including evidence of hemodynamic compromise, including dizziness and loss of consciousness. Concurrently, the patient should always be evaluated for any contraindications to both systemic anticoagulation and thrombolysis (Table).

Following a focused history, it is critical to evaluate the patient at the bedside. The physical examination often serves as a good primary indicator of whether an invasive intervention will be indicated. In an otherwise healthy patient, hypoxemia at rest or with minimal exertion serves as a sign of clinically significant clot burden. Sinus tachycardia is commonly present as the right heart tries to overcome increased afterload. Asymmetric lower extremity edema suggests the presence of concurrent deep vein thrombosis. The presence of hypotension suggests right heart failure or decreased cardiac output.

An electrocardiogram should be reviewed as routine pretreatment planning to evaluate for the presence of a left bundle branch block (LBBB). Catheterization of the right heart in the presence of a LBBB may precipitate a right bundle branch block thereby causing a complete heart block, which can be a fatal complication. If a LBBB is present, either alternative therapy should be considered or a transcutaneous or transvenous cardiac pacer should be preemptively placed. In addition, helpful biochemical markers include troponin and B-type natriuretic peptide, both of which can indicate right heart strain. Detecting right heart strain is critical in the evaluation of these patients as its presence is an independent marker for increased mortality.[4]

Necessary imaging in the workup of these patients is a computed tomography (CT) angiogram of the pulmonary arteries, transthoracic echocardiogram, and often, a lower extremity duplex. The CT pulmonary angiogram serves to confirm the diagnosis of acute PE. It can also help evaluate distribution of thrombus, establish baseline clot burden, and determine presence of other possible diagnoses that may be confounding the clinical significance of a particular patient's PE. The echocardiogram and CT are both helpful in evaluating for right ventricular dilatation, which indicates right heart strain. A lower extremity duplex can help evaluate the presence and burden of lower extremity thrombus.

Indications for Catheter-Directed Therapy

Patient selection is of paramount importance in treating patients with acute PE. Each patient should be stratified into the "massive" PE, "submassive" PE, or "low-risk" PE. Some interventionalists use the PE severity index to help stratify patients with PE. This tool is a score that helps determine severity of disease by predicting 30-day mortality and long-term morbidity.[5] Patients who receive a higher score may benefit from more aggressive therapy. Traditionally, intravenous tissue plasminogen activator (IV TPA) is used to treat massive PE with a dose of 100 mg of alteplase administered over 2 hours. There is some literature suggesting that in the right hands, catheter-directed therapy may be used first-line as an alternative to IV TPA, although this is controversial.[6] For patients that cannot tolerate systemic thrombolysis, catheter-directed therapy should be considered and part of a step-wise escalation in treatment. Additionally, some patients who receive IV TPA may continue to show evidence of hemodynamic compromise or respiratory distress despite treatment. For these patients, CDT provides an attractive adjuvant therapeutic option.

The immediate goal of CDT is to decrease right ventricular afterload by creating channels of unobstructed blood flow through the pulmonary arteries, thereby decreasing pulmonary artery pressure, right ventricular dysfunction, and improving overall cardiac output. In patients with massive PE, the goal is to prevent death and at minimum "downstage" them from the massive category. In patients with submassive PE, the goal is to prevent long-term morbidity and mortality associated with PE. For successful CDT, thrombolytic must be infused directly within the obstructing thrombus. Multiple studies show that administering thrombolytic proximal to the thrombus provides no significant added benefit as infused thrombolytic will preferentially travel through unobstructed arterial branches rather than through the obstructing thrombus.[7]

Equipment

There are multiple devices available in the US market for use in the endovascular treatment of pulmonary emboli, each with a distinct set of advantages and disadvantages. There are several broad categories of devices that facilitate catheter-directed therapy, which include CDT, rheolytic thrombectomy, fragmentation, aspiration, clot entrapment and removal, and pharmacomechanical combinations.