

# Surgical Management of Acute and Chronic Pulmonary Embolism



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## KEYWORDS

- Pulmonary embolism • Chronic thromboembolic pulmonary hypertension
- Surgical pulmonary embolectomy • Pulmonary thromboendarterectomy

## KEY POINTS

- Patients with proximal pulmonary embolism (PE) who are at increased risk for mortality are potential candidates for surgical pulmonary embolectomy (SPE), a procedure now seeing renewed interest as an option for PE management.
- Outcomes of SPE vary greatly depending on the studied population; survival has improved over time and currently rivals that of systemic thrombolysis based on observational data.
- For patients with chronic PE and associated pulmonary hypertension, pulmonary thromboendarterectomy (PTE) has benefitted from much evolution over the past several decades and is now associated with low morbidity and mortality in experienced centers.
- PTE remains a highly technical surgery requiring multidisciplinary input and planning; with advancements in technique, marked improvements in hemodynamics can be achieved in a greater number of patients.

## INTRODUCTION

Acute pulmonary embolism (PE) is a common clinical condition that results in at least 100,000 deaths yearly in the United States.<sup>1</sup> Acute PE is described as high risk (massive) when otherwise unexplained hypotension is present; these patients have particularly high mortality risk from right ventricular (RV) failure and cardiovascular collapse. Those without hemodynamic instability are labeled as having intermediate-risk (submassive) PE if there is evidence of RV strain or dysfunction. Patients without these features have

low-risk PE and are typically managed with anticoagulation alone with good outcomes.

Patients with high-risk and intermediate-risk PE may be considered for interventions beyond anticoagulation in efforts to decrease short-term mortality risk. This is particularly true of high-risk PE, because associated mortality can be greater than 50%.<sup>2</sup> Available management options vary by center but include systemic thrombolysis, catheter-based thrombolysis or embolectomy, extracorporeal membrane oxygenation (ECMO) support, and surgical embolectomy. In past years, surgical treatment has been reserved for very ill

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patients, usually with either contraindication to or failure of systemic thrombolysis.

After an episode of acute PE, endogenous thrombolysis progressively reduces the embolic burden, with minimal residual thrombus expected in most patients. In some individuals, however, these mechanisms fail and chronic PE develops. After an episode of acute PE, 1% to 4% of patients further develop chronic thromboembolic pulmonary hypertension (CTEPH) from these vascular obstructions with associated impact on RV function.<sup>3,4</sup> When this occurs, time and anticoagulation are insufficient to normalize the vasculature. These patients, however, are candidates for meticulous surgical removal of the obstructive material with endarterectomy.

Surgery can be highly effective in management of appropriate patients with acute and chronic PE. Despite similarity in name, surgical pulmonary embolectomy (SPE) and pulmonary thromboendarterectomy (PTE) are different procedures. Both typically require sternotomy and cardiopulmonary bypass, but removal of the luminal thrombotic material is more straightforward in SPE. PTE requires careful dissection of affected arteries with removal of vascular intima along with thrombus. PTE remains the gold standard for management of CTEPH, although other medical and interventional approaches are also gaining popularity. In contrast, SPE had long been regarded as salvage therapy for acute PE but now sees increasing interest in evolving the technique and indications. This review focuses on the role of SPE and PTE in the management of patients with acute and chronic PE.

## **SURGICAL PULMONARY EMBOLECTOMY FOR ACUTE PULMONARY EMBOLISM**

### ***History***

A surgical approach to acute PE was first developed by Friedrich Trendelenburg in the early 1900s. In 1908 he presented his technique at the annual Congress of the German Surgical Association, reporting on the first unsuccessful use of SPE. The Trendelenburg SPE involved exposure of the pulmonary artery (PA) and aorta via 2 perpendicular incisions over the left sternal border and second rib followed by encircling the vessels with rubber tubing. Tension was placed on the tubing to occlude both vessels, and the PA was rapidly incised with subsequent clot extraction using blunt tipped forceps. The arteriotomy incision was then held together with forceps and a clamp while flow through the great vessels was restored; the incision was then sutured. Arteriotomy and embolectomy were completed in less than 1 minute.<sup>5</sup>

Trendelenburg's 3 reported SPE procedures in humans resulted in removal of thrombus, but death occurred in the operative or early postoperative period. In 1924, Trendelenburg's trainee, Martin Kirschner, performed SPE on a 38-year-old woman who had sudden collapse after hernia surgery. Large thrombi were removed, and the patient fully recovered, marking the first truly successful procedure of its kind.<sup>5</sup>

The development of cardiopulmonary bypass (CPB) was a major advance to successful SPE, although ability to mobilize CPB urgently took some time. SPE on bypass was first achieved by Sharp in 1961<sup>6</sup>; subsequently, performance of SPE significantly increased.<sup>7-9</sup>

### ***Indications for Surgery***

Patients with confirmed, life-threatening acute PE affecting the central vasculature are potential candidates for SPE. In these patients with high-risk or intermediate-risk PE, mortality risk with anticoagulation alone is often unacceptably high. SPE should be strongly considered in such patients with contraindication to thrombolysis (although importantly they must be able to tolerate heparinization for CPB), which is supported by clinical practice guidelines from the American College of Chest Physicians,<sup>10</sup> American Heart Association,<sup>11</sup> and European Society of Cardiology.<sup>12</sup> SPE should also be considered in those deemed to have insufficient time to allow thrombolysis to become effective and in those with thrombus within the right heart or in a patent foramen ovale.<sup>10,11</sup> Treatment failure of systemic thrombolysis is by no means a contraindication to SPE (and is often still an indication for pursuing surgery), although higher surgical site bleeding risk would be expected.<sup>11,12</sup> Meneveau and colleagues<sup>13</sup> demonstrated that surgical embolectomy after failure of thrombolysis yields better outcomes than repeating thrombolytic administration.

Although historically SPE has been used for the critically ill patient with no alternative options, this paradigm may be changing. In a single-center series of 115 patients receiving SPE, 49 patients (43%) had high-risk PE, 56 (49%) had intermediate-risk PE, and 10 patients had other indications for surgery (most commonly right atrial or ventricular mass). Of those with high-risk or intermediate-risk PE, 47% had contraindication to thrombolysis and 6% had failed thrombolysis or catheter-based interventions. The remaining 50 patients underwent SPE due to presence of significant RV dysfunction with central clot, without specific contraindications or preceding trials of other therapies.<sup>14</sup> In another single-center series,

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