Peripheral Distribution of Thrombus Does Not Affect Outcomes After Surgical Pulmonary Embolectomy

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Background. **Thrombus located distal to the main or primary pulmonary arteries has been previously viewed as a relative contraindication to surgical pulmonary embolectomy. We compared outcomes for surgical pulmonary embolectomy for submassive and massive pulmonary embolism (PE) in patients with central vs peripheral thrombus burden.**

Methods. **All consecutive patients (2011 to 2016) undergoing surgical pulmonary embolectomy at a single center were retrospectively reviewed. Computed tomography angiography of each patient was used to define central PE as any thrombus originating within the lateral pericardial borders (main or right/left pulmonary arteries). Peripheral PE was defined as thrombus exclusively beyond the lateral pericardial borders, involving the lobar pulmonary arteries or distal. The primary outcome was in-hospital and 90-day survival.**

Results. **We identified 70 patients: 52 (74%) with central PE and 18 (26%) with peripheral PE. Preoperative vital signs and right ventricular dysfunction were similar between the two groups. Compared with the central PE cohort, operative time was significantly longer in the peripheral PE group (191 vs 210 minutes, $p < 0.005$). Median right ventricular dysfunction decreased from moderate dysfunction preoperatively to no dysfunction at discharge in both groups. Overall 90-day survival was 94%, with 100% survival in patients with submassive PE in both cohorts.**

Conclusions. **This single-center experience demonstrates excellent overall outcomes for surgical pulmonary embolectomy, with resolution of right ventricular dysfunction and comparable morbidity and mortality for central and peripheral PE. In an experienced center and when physiologically warranted, surgical pulmonary embolectomy for peripheral distribution of thrombus is technically feasible and effective.**

(Ann Thorac Surg 2018;106:778–84)

Acute pulmonary embolism (PE) remains a significant cause of morbidity and death, associated with 60,000 to 200,000 deaths each year in the United States alone [1–4]. Predominantly, these deaths occur patients with a submassive (normotensive with right ventricular [RV] dysfunction) or massive (hypotensive) PE [5–7]. Although the mainstay of treatment for these patients is systemic anticoagulation, the role of adjunctive therapies, including systemic thrombolysis, catheter-based therapy, and surgical pulmonary embolectomy, are rapidly evolving. Surgical pulmonary embolectomy has historically been used as a salvage therapy after failure of thrombolysis; however, multiple studies have recently demonstrated that this operation can result in excellent survival and complete recovery of RV function for patients with a submassive or massive PE [8–11].

Still, previous reports have implied that thrombus distal to the main or primary pulmonary arteries is anatomically inaccessible and, therefore, a relative contraindication to surgical pulmonary embolectomy [12]. These studies have further hypothesized that peripheral thrombus would not result in significant hemodynamic compromise given possible alternative tributaries to forward flow. This sentiment, however, is not well justified in the literature [13, 14]. We hypothesized that submassive or massive PE patients with isolated peripheral thrombus (outside the pericardial reflection) would have similar preoperative clinical characteristics and equivalent postoperative outcomes as patients with central thrombus (inside but not limited to the pericardial reflection) after surgical pulmonary embolectomy.

Accepted for publication Feb 26, 2018.

Presented at the Scientific Sessions of the American College of Cardiology, Washington, DC, March 17-19, 2017.

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0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2018.02.079

Patients and Methods

Patients

With approval of the University of Maryland Institutional Review Board (HP-00066712), a retrospective review of the local Society of Thoracic Surgeons database was performed for all patients who underwent surgical pulmonary embolectomy (procedure code 33910 and 33916) for acute PE from January 1, 2011 to March 1, 2016 at our institution. Patient medical records were manually reviewed to confirm the operative procedure and obtain preoperative, intraoperative, and postoperative variables and outcomes.

PE was identified by computed tomography angiography in all cases. Each computed tomography scan was reviewed by a blinded, independent physician to determine whether the PE was peripheral or central. This methodology was verified by a board-certified thoracic radiologist. Central PE was defined as any thrombus originating within the lateral pericardial borders (main or right/left pulmonary arteries). Peripheral PE was defined as thrombus exclusively beyond the lateral pericardial borders and involving the lobar pulmonary arteries or distal (Fig 1).

RV dysfunction was recorded based on a preoperative and postoperative (before discharge) transthoracic echocardiogram. RV dysfunction (none-severe) was delineated by an independent cardiologist, who quantitatively and qualitatively assessed RV function to obtain an overall assessment of dysfunction.

Patients offered surgical intervention were stratified by submassive or massive PE. Submassive PE was defined, according to the American Heart Association, as patients with a systolic blood pressure exceeding 90 mm Hg but with echocardiographic signs of RV dysfunction or dilation, computed tomography signs of RV dilation, or laboratory findings suggesting myocardial necrosis [7]. Massive PE was defined as patients with a systolic blood pressure of less than 90 mm Hg for at least 15 minutes or requiring inotropic support, not due to a cause other than PE, pulselessness, or persistent profound bradycardia (heart rate <40 beats/min with signs or symptoms of shock).

Indications for Operation, Operative Technique, and Postoperative Management

As previously described, patients referred for a surgical pulmonary embolectomy were offered surgical intervention if their predicted risk of 30-day mortality was 5% or higher [15]; therefore, all patients included in this study had a predicted risk of death of 5% or more. Risk of death for submassive PE patients was based on the Bova score, an internally and externally validated risk model specifically for submassive PE patients [16, 17]. Risk of death for massive PE patients was based on retrospective registry analysis and a PE score index (PESI) score, an internally and externally validated risk model for all PE patients [5, 18, 19].

Operative technique was performed as previously described [15]. Briefly, a median sternotomy was performed, and cardiopulmonary bypass was initiated by bicaval venous and central aortic cannulation. Separate incisions were made into the right and left main pulmonary artery, and thrombus was removed in its entirety up to the subsegmental level by using a combination of careful forceps and suction extraction.

Postoperatively, patients were routinely given low-dose epinephrine for inotropic support and inhaled prostacyclin for pulmonary vasodilation. The inotropic support and inhaled pulmonary vasodilator were weaned as tolerated. Anticoagulation was restarted after total chest tube output was less than 30 mL/h for 3 consecutive hours, initially with a partial thromboplastin time of 45 to 55 seconds for 24 hours and then 60 to 80 seconds. All patients received an inferior vena cava filter, and a transthoracic echocardiogram was performed before discharge.

Clinical Outcomes

The primary outcomes of this study were in-hospital and 90-day survival. Secondary outcomes included the incidence of postoperative stroke, acute kidney injury, as defined by the Society of Thoracic Surgeons, new hemodialysis at discharge, pneumonia, prolonged intubation (>24 hours), tracheostomy, deep sternal wound infection, sepsis, and postoperative RV dysfunction.

Statistical Analysis

Continuous variables are presented as median with interquartile range (IQR) and were compared using the Kruskal-Wallis test. Post hoc, pair-wise comparisons were performed using the Dunn test with the Bonferroni correction for multiple comparisons. Categoric variables are presented as number (%) and were compared using the Fisher exact test. A p value of less than 0.05 was considered statistically significant.

For analysis and presentation purposes, the descriptive terms used by the echocardiographer were converted to numerical values according to the following rubric: none, 0; none-mild, 0.5; mild, 1; mild-moderate, 1.5; moderate, 2; moderate-severe, 2.5; and severe, 3. In addition to reporting the appropriate medians (IQRs), paired preoperative and postoperative measurements of RV dysfunction were compared using the test of marginal homogeneity.

Results

Patient Demographics, Risk Factors for PE, and Preoperative Characteristics

During the study period, 70 patients underwent pulmonary embolectomy: the PE was central in 52 (74%) patients and peripheral in 18 (26%). The most common risk factors associated with PE were deep vein thrombosis (81%), obesity (57%), and a recent operation (36%). Differences in patient demographics, risk factors, or comorbidities between the central PE and peripheral PE groups were not significant (Table 1). All patients had RV dysfunction (median RV dysfunction: moderate) preoperatively, with a median troponin of 0.50 ng/mL and