بسم الله الرحمن الرحیم

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SURGICAL TREATMENT OF PULMONARY EMBOLISM

RISK STRATIFICATION

- PE is classified as low, intermediate (or submassive), and high (or massive) risk based on the anticipated 30-day mortality rate.

RISK STRATIFICATION

- Low risk: normotensive patients without imaging evidence of RV dysfunction or elevated cardiac biomarkers.
- Approximately 40% of all PE patients fall into this category.
- They have excellent short-term prognosis
- Mortality rate approximately 1% to 2% or less.

RISK STRATIFICATION

- Intermediate risk: normotensive patients with either imaging evidence of RV dysfunction or elevated cardiac biomarkers or both.
- This group constitutes approximately 55% of all PEs
- Mortality rate ranges between 3% and 15%.

RISK STRATIFICATION

- High risk: hemodynamically unstable patients with sustained shock or hypotension (<90 mm Hg) or cardiac arrest.
- These patients are rare, approximately 5%
- but in-hospital mortality ranges between 15% and 30% or may exceed 60% for those requiring cardiopulmonary resuscitation.

TABLE 152.2 Pulmonary Embolism Risk Stratification Based on the Pulmonary Embolism Severity Index (PESI)

	PESI SCORING					
Predictor	Original	Simplified	BOVA SCORE		FAST SCORE	
Age	Age in years	1 (if >80 years)	Elevated trop.	2	H-FABP ≥6 or elevated trop.	1.5
Men	10	–	RV dysfunction	2	Syncope	1.5
Cancer	30	1	Pulse ≥110 bpm	1	Pulse ≥100 bpm	2
Heart failure	10	1	Syst BP 90–100 mm Hg	2		
Chronic lung disease	10					
Pulse ≥110 bpm	20	1	Low risk	≤4		<3
Systolic pressure <100 mm Hg	30	1	Intermediate–high risk	>4		≥3
Respiratory rate ≥30	20	–				
Temperature <36°C	20	–				
Altered mental status	60	–				
Saturation <90%	20	1				
Risk						
Very low risk (class I)	≤65	0				
Low risk (class II)	66–85					
Intermediate risk (class III)	86–105	≥1				
High risk (class IV)	106–125					
Very high risk (class V)	≥126					

H-FABP, heart-type fatty acid-binding protein; RV, right ventricle.

TABLE 152.3 Imaging and Laboratory and Clinical Tests for Risk Stratification of Pulmonary Embolism (PE)

	Markers of Non–Low Risk PE	Remarks
Echocardiogram	RV/LV EDD >1 TAPSE ≤1.6 cm TRJV >2.6 m/s^{-1} Estimated RVSP ≤52 mm Hg McConnell sign + IVC collapsibility >50% + RV hypokinesia + Leftward shifting of IVS +	RV dysfunction parameters have been identified as independent predictors of death. With the exception of TAPSE, the complex geometry of the RV and the subjective nature of the measurements are limiting factors.
CT angiogram	RV/LV EDD ≥0.9	RV dilatation has been identified as independent predictor of death. No clear association has been shown for clot burden.
Lower leg duplex	DVT +	Proximal DVT in patients with symptomatic PE is an independent predictor of death (OR 1.9; 95% CI 1.5–2.4).
Troponin	TnT >0.1 ng/mL TnI >0. 4 ng/mL	High troponin levels are independent predictors of death. Limited detection time-window (peak at 8 h). Optimal cutoff values are yet to be defined. High sensitivity assays and age-adjusted values may be more accurate.
BNP	>90 pg/mL	High levels predict death (OR 6.5; 95% CI 2.0–2.1)
Pro-BNP	>600 pg/mL	High levels predict death (OR 6.3; 95% CI 2.2–18.3)
HFAB	>6 µg/lt	Novel biomarker with significant prognostic value for mortality (OR 40.8; 95% CI 11.8–140.1).
PESI	Original: ≥86 (class III–V) Simplified: ≥1	Validated widely used clinical score.

BNP, brain natriuretic peptide; *CI*, confidence interval; *CT*, computed tomography; *DVT*, deep venous thrombosis; *EDD*, end-diastolic diameter; *HFAB*, heart-type fatty acid-binding protein; *IVC*, inferior vena cava; *IVS*, interventricular septum; *LV*, left ventricle; *OR*, odds ratio; *PESI*, Pulmonary Embolism Severity Index; *RV*, right ventricle; *TAPSE*, tricuspid annular plane systolic excursion; *TRJV*, tricuspid regurgitant jet velocity.

TREATMENT

- Anticoagulation
- Thrombolysis
- Surgical Thrombectomy
- Extracorporeal Membrane Oxygenation (ECMO)
- Inferior Vena Cava Filter

ANTICOAGULATION

- Unless contraindicated, all patients with acute PE should receive systemic anticoagulation with the objective of preventing both early death and a recurrent symptomatic or fatal event.
- Anticoagulation should be initiated during the diagnostic workup in patients with intermediate or high clinical probability of PE.
- The standard duration of anticoagulation should cover at least 3 months.

THROMBOLYSIS

- Thrombolysis is reserved for high-risk and selected cases of intermediate-risk PE.
- The greatest benefit is observed when treatment is initiated within 48 hours of symptom onset, but thrombolysis can still be useful in patients who have had symptoms for up to 14 days.
- Thrombolysis → *Systemic Thrombolysis*
- *Catheter-Directed Interventions* → thrombolytic *techniques*
- non thrombolytic techniques

CATHETER-DIRECTED INTERVENTIONS

- CDIs are variable and can be performed with or without thrombolysis.
- CDI without thrombolysis include thrombus fragmentation and/or aspiration techniques, with no lytic agents, for patients with absolute contraindications to thrombolysis; evidence on their efficacy and safety has been growing over the recent years.
- Thrombolytic and nonthrombolytic techniques are complimentary and equally effective when used appropriately

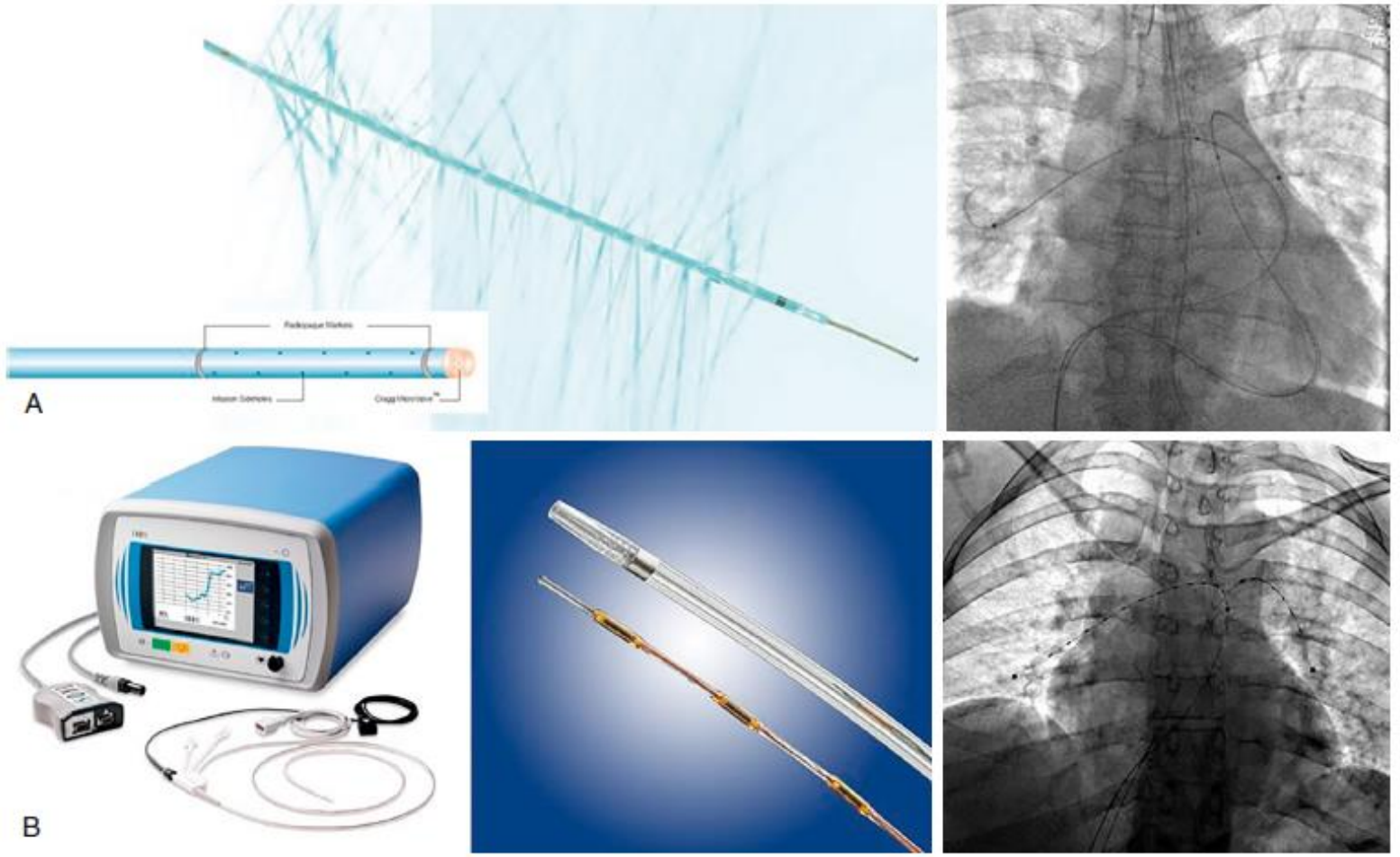


Figure 152.2 Catheter-Directed Thrombolysis. (**A**) Five-French standard multi-sidehole catheter. (**B**) Ultrasound-assisted thrombolysis catheter, EkoSonic (Endovascular System, EKOS Corporation, Bothell, WA). The catheter is composed of a 5.2-F multi-sidehole infusion catheter and a microsonic core wire containing the ultrasound elements.

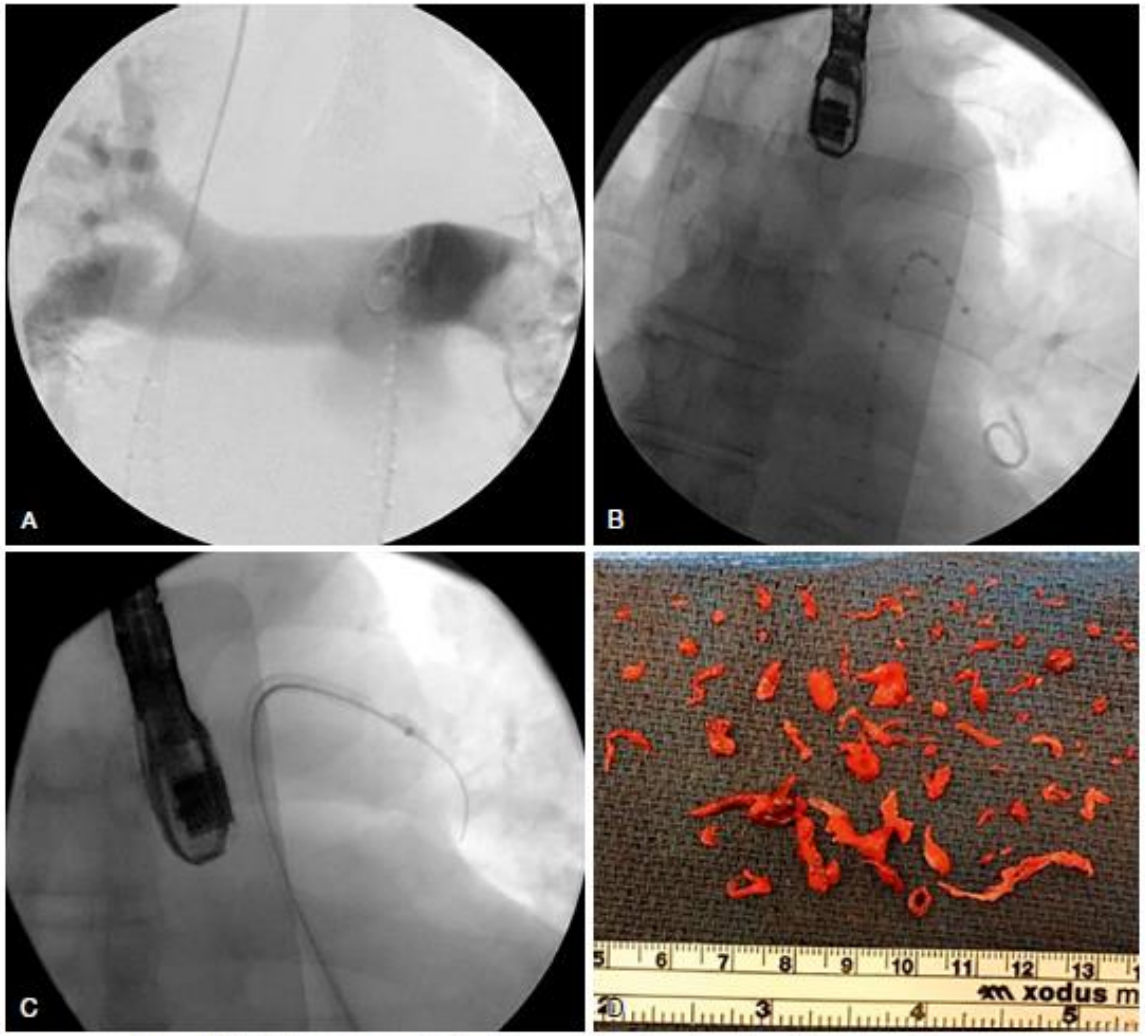


Figure 152.3 Massive pulmonary embolism (right ventricular strain and hemodynamic decompensation) on a patient with recent surgery and with intrapulmonary bleed due to the pulmonary infarct. (**A**) Intraoperative pulmonary angiogram indicating bilateral thrombus (L>R). (**B**) Pigtail rotation within the major clot burden. (**C**) Aspiration thrombectomy using a 10-F Pronto catheter (Vascular Solutions, Minneapolis, MN). (**D**) Extracted thromboembolic material. (Figure obtained with permission from Avgerinos ED, Chaer RA. Catheter-directed interventions for pulmonary embolism. *J Vasc Surg*. 2015;61:559–565.)

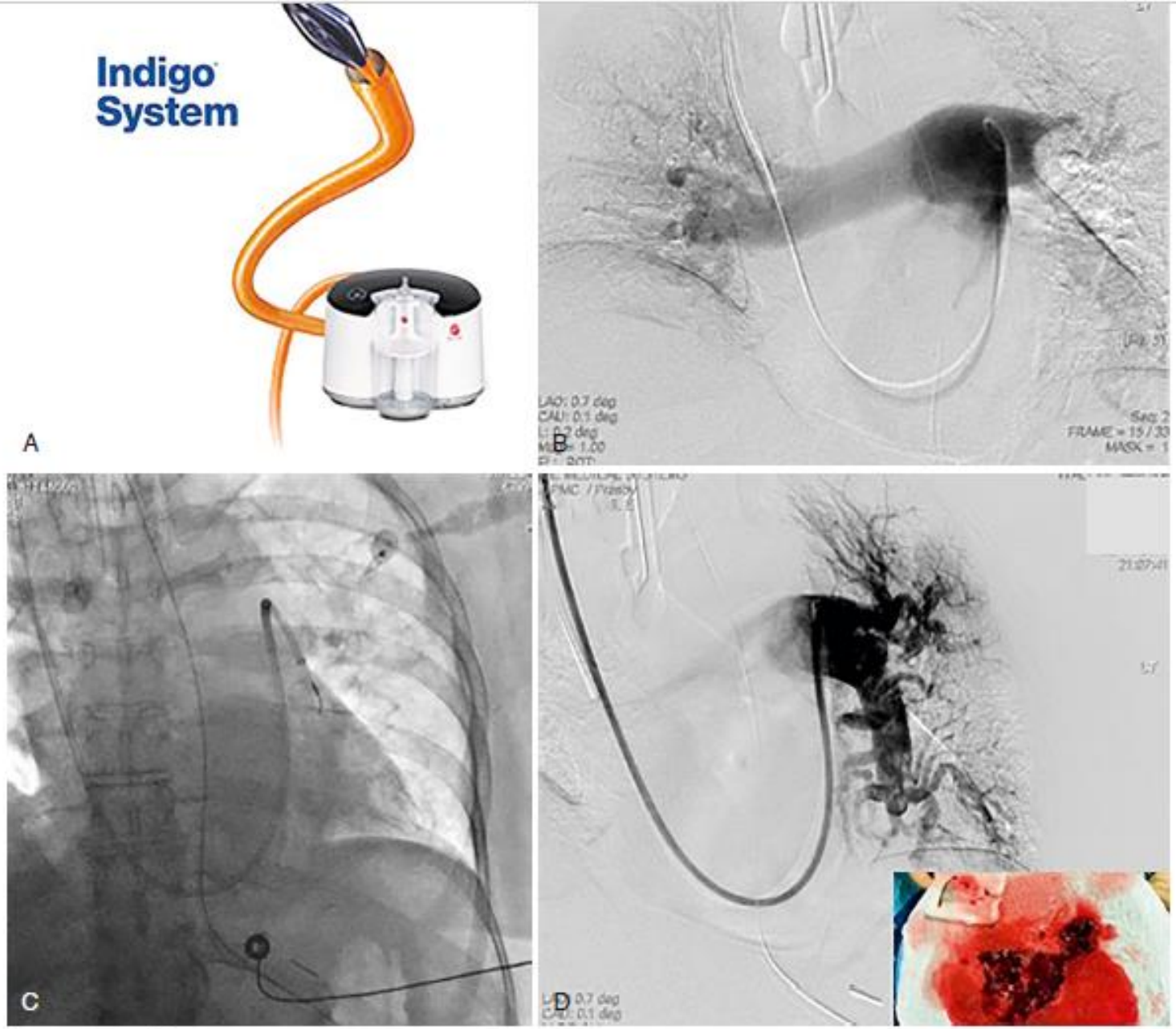


Figure 152.5 High risk pulmonary embolism with refractory shock and the patient on extracorporeal membrane oxygenation. (**A**) CAT-8 Indigo Penumbra suction thrombectomy system. (**B**) Pulmonary arteriogram showing complete left pulmonary artery occlusion. (**C**) Suction thrombectomy using the CAT-8 catheter and the separator wire. (**D**) Widely open left lower lobe pulmonary arterial segments.

SURGICAL THROMBECTOMY

- Traditionally, surgical pulmonary thromboembolectomy is reserved for patients with documented central PE and refractory cardiogenic shock despite maximal supportive therapy and who have absolute contraindications to or have failed thrombolytic therapy.
- Surgical thrombectomy aims to rapidly reduce RV afterload by physically removing proximal pulmonary artery thrombi.

SURGICAL THROMBECTOMY

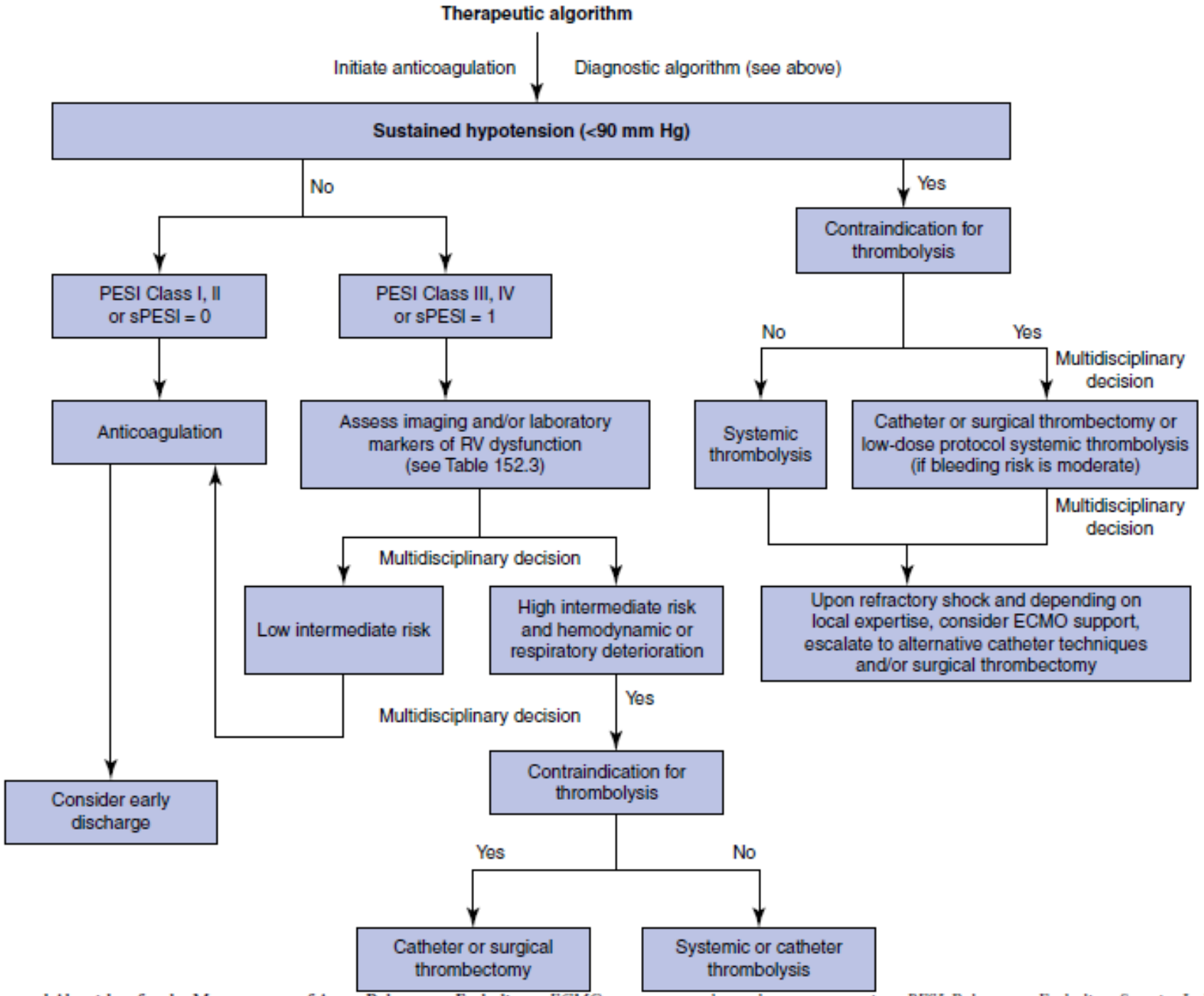
- Surgical embolectomy is performed through a median sternotomy using a normothermic cardiopulmonary bypass.
- Aortic cross-clamping and cardioplegic cardiac arrest are usually not needed.
- The main pulmonary artery is opened and the thrombotic material is extracted. The right atrium and ventricle are also explored for possible thrombi and a patent foramen ovale is closed, if present.

EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO)

- It has been increasingly used in some centers for unstable PE patients who are not responding to other treatment modalities or as a bridge for catheter-based or surgical embolectomy.
- Although it seems reasonable to offer ECMO as a last resort to PE patients who are otherwise expected to die.

INFERIOR VENA CAVA FILTER

- inferior vena cava (IVC) filters are indicated in patients with acute PE who have absolute contraindications to anticoagulant drugs and in patients with objectively confirmed recurrent PE despite adequate anticoagulation



Suggested Algorithm for the Management of Acute Pulmonary Embolism. *ECMO*, extracorporeal membrane oxygenation; *PESI*, Pulmonary Embolism Severity Index;