PERT Anesthetic Guidelines For Mechanical Thrombectomy

Pulmonary embolism is the number one cause of preventable in-hospital deaths, with overall average mortality remaining close to 25%. The intermediate high-risk group of pulmonary embolism has the widest range of mortality, from 5-30%, depending on individual risk. The PERT team was started 10 years ago to ensure a core group of experts on treatment and management of pulmonary embolism work together to ensure efficient, expert treatment. PERT is now becoming standard of care in academic and community centers world-wide as it has been proven to shorten time to therapeutic treatments, shorten ICU and hospital length of stay and with reported decreases in mortality. A 1-year trial at KGH has shown a 60% shorter time to thrombolysis, a 10% improvement in mortality and ensured 100% of those in the high-risk category received some sort of advanced therapy. Patients who are not candidates for thrombolysis are considered for mechanical thrombectomy performed in the IVR suite. Initial screening and candidacy for the procedure are assessed by the Pulmonary Embolism Response Team (PERT).

Booking and Expected Duration of Procedure (< 2 hours):

1. **High-Risk PE** *(HD unstable second to obstructive/cardiogenic shock)* = **A-case**, arranged within 1 hour
    a. HD unstable (SBP < 90 and/or vasopressors and/or cardiac arrest)
2. **Intermediate-high risk PE** *(RV dilation and +ve troponin)* = **B-case**, arranged within 4 hours ideally
    a. No vasopressors, SBP > 90 and
    b. Elevated serum troponin > upper limit of normal and
    c. ECHO or POCUS shows evidence of RV dilation and/or
    d. CTPA shows evidence of RV dilation (RV/LV > 0.9, IVS shift to the left)
    e. HR > 110 bpm, SBP 90 – 100 mmHg, HR/SBP > 1 and/or FiO_2 > 4L NP for SpO_2 > 95%
3. **Intermediate-low risk PE** (*RV dilation or +ve troponin)* = **C-case**, arranged within 12 hours ideally
    a. No vasopressors, SBP > 90 and
    b. Elevated serum troponin > upper limit of normal or
    c. ECHO or POCUS shows evidence of RV dilation and/or
    d. CTPA shows evidence of RV dilation (RV/LV > 0.9, IVS shift to the left)
4. **Low risk PE** = **C-case**
    a. No vasopressors, SBP > 90 and
    b. Serum troponin within normal range (if measured) and
    c. ECHO or POCUS does NOT show evidence of RV dilation and
    d. CTPA does NOT show evidence of RV dilation or right heart strain

Patient may be in the ED, ward bed, D4ICU or K2 ICU prior to their procedure.

Billing Code: R836 - pulmonary embolectomy

Pre-Operative Optimization

Patients with high-risk (massive) and intermediate-risk (submassive) PE may present on a spectrum of clinical symptoms, which vary from mild hypoxemia with normal hemodynamics to obstructive shock and impending cardiovascular collapse. The incidence of severe or life-threatening complications

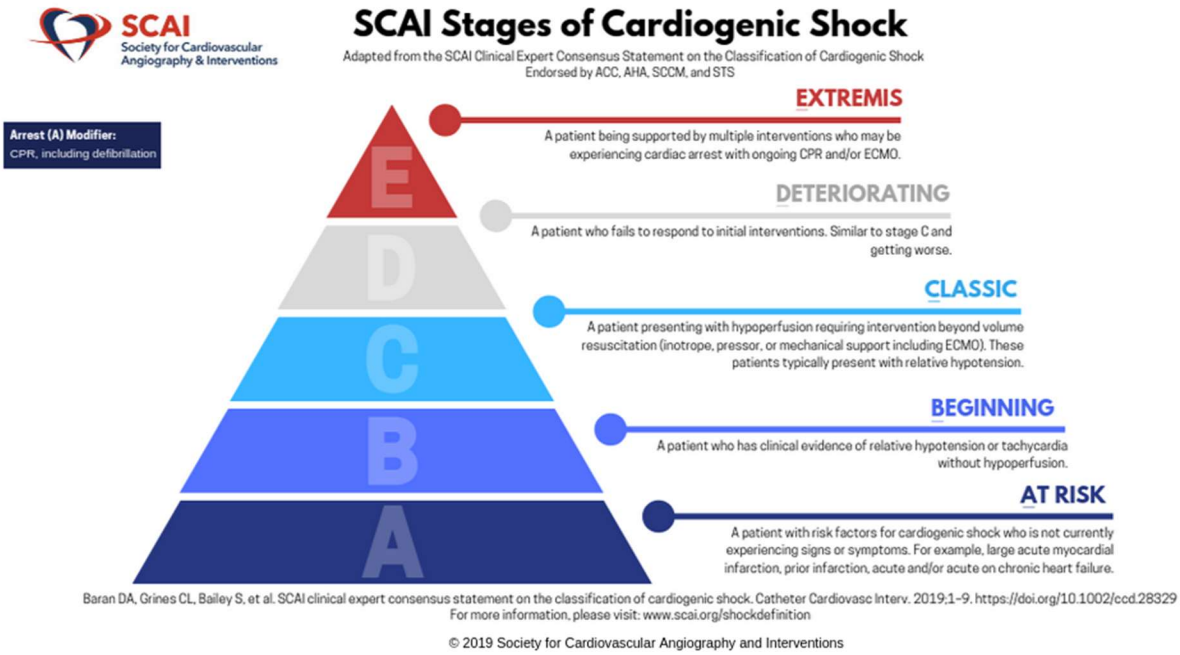
(including death) are estimated at approximately 3%. Despite normal hemodynamics, 1/3 of patients are found to have cardiac index in the cardiogenic shock range.

PERT Team assessment/consult should include the following:

1. Risk categorization (RV:LV ratio, trop/lactate, BNP, FiO_2 requirement, cardiogenic shock, pressor support, end-organ dysfunction)
2. Document PE risk score, BACS score, PMHx, Surgical Hx, allergies, airway exam
3. Risks and contraindications to thrombolysis
4. Ensure patient is therapeutically anticoagulated (Dalteparin Q12H preferred, IV Heparin infusion)
5. CBC, electrolytes, lactate, INR, PT, PTT, type and hold, ECG, and CTPA studies
6. Expedited ECHO with bubble study (usually not available pre-op if presenting acutely)
7. PERT to book case with IVR, obtain initial consent, IVR will obtain their procedure related consent
8. Determine code status peri-procedurally in context of underlying comorbidities and a discussion regarding bailout strategies in the event of deterioration (ie. mechanical circulatory support)
9. If SCAI Stage C – E, open conversation with cardiac surgery regarding candidacy for VV or VA-ECMO (likely post > pre-procedure)
10. Find admitting service (if in ED) and arrange for bed post-operatively with IVR
11. IVR to document post procedure orders and when the plan is to remove the vascular closure device

Weekends – If the IVR attending is called by a service, outside of PERT availability, the IVR radiologist is responsible for the following:

1. Confirm with MRP that the patient has had anticoagulation, and if next dose close to procedure, ensure it is given prior to avoid intraprocedural clot formation
2. Coordinate with service to contact Anesthesia manager/on-call staff and communicate risk criteria to determine booking urgency (ie. A-case, B-case, C-case)



Equipment Set-up:

1. Anesthetic machine
2. Consider having ambu-scope readily available (ie. Regular size to facilitate intubation +/- bronchoscopy and suctioning if required)
3. Satellite cart
4. Crash cart, defibrillation pads and ability to transcutaneously pace
5. Airvo or Optiflow HFNC (recommended in every patient regardless of pre-procedure FiO_2)
6. If non-invasive positive pressure (ie. CPAP or BiPAP) is required, use the endoscopy mask with fixation straps with anesthetic machine – in anesthesia supply room above HFNC circuits (ie. PSVPro 5/5)
7. Flolan, nitric oxide or milrinone inhaled as required (can be administered through HFNC or NIPPV and transitioned to mechanical ventilation)
8. Arterial line
9. Central venous line (should not delay procedure, IVR can access femoral vein if required)
10. Vasopressors (push dose and infusions)
    a. Vasopressin – first-line (0.01 – 0.04u/min)
    b. Norepinephrine – second-line
    c. Epinephrine
11. Inodilators (infusions +/- inhaled)
    a. Dobutamine
    b. Milrinone
12. Anesthetic agents
    a. Etomidate > Ketamine
    b. Propofol, Fentanyl, Succinylcholine, Rocuronium
    c. Lidocaine 4 and 5% for airway topicalization
13. Consider the 'SAVIOR' protocol, ie. LA topicalization, maintenance of SV, appropriate inotropes/vasopressors to augment RV function, intubation with gradual introduction of PPV, avoidance of pHTN exacerbants and optimization of respiratory physiology
14. Lead for fluoroscopy

Patient Considerations:

1. Consider reviewing PERT Activation Form/Consult to understand risk stratification of PE, bleeding risk and contraindications to thrombolysis
2. Therapeutic anticoagulation (usually Dalteparin Q12H), if timing close to procedure, ensure it is given to avoid intra-procedure clot formation
3. If LBBB on ECG, there will be a higher risk of heart block during the procedure
4. Perform bedside POCUS to assess LV/RV function, septal bowing, RVSP, clot in transit, IVC size and collapsibility, and B-line in lungs
5. Potential for anemia/hypovolemia from the filtering of blood aspirated by the catheters, hemorrhage from vascular injuries or perforation of cardiac chambers
6. Maceration of thrombus with distal embolization causing progressive hypoxemia +/- hemodynamic instability
7. Monitor for worsening agitation, confusion or focal neurologic signs with administration of heparin for the procedure which may be a sign of intra-cranial hemorrhage

8. Risk of anaphylaxis from re-injection of blood after being filtered for clots
9. If the procedure is progressing quickly or cannot be aborted, resolution of obstructive shock can be achieved with rapid engagement and aspiration of the pulmonary embolus

Positioning:

1. Patient on IVR suite bed lying flat, supine – if dyspneic, gentle elevation of the head that does not compromise exposure of the groins is usually tolerated (ie. large working sheaths in the femoral veins to facilitate catheters)
2. Arms tucked at patient's side
3. All equipment north of the bed as fluoroscopy arm needs to move freely around patient (ie. crash cart, infusion pumps, HFNC, anesthetic machine, and satellite cart)
4. Defibrillation pads cannot be placed on patient unless there is an emergency as it will obstruct the procedural view obtained on fluoroscopy

Intra-Operative Management

Anesthetic Modality:

1. Anesthesia Assistant notified and present
2. MAC Sedation: Minimalistic approach, Midazolam 0.5 – 1mg +/- Fentanyl 25 – 50 mcg to avoid hypoxia, hypercarbia, acidosis and subsequent increase in PVR and RV afterload
3. GA avoided (HD collapse and cardiac arrest from sympatholysis, vasodilation and PPV) unless:
    a. Relative or absolute contra-indication for sedation – severe agitation/confusion, inability to lie flat, high-risk for aspiration or difficult airway
    b. Progressive HD instability despite pharmacological support
    c. Progressive hypoxemia despite maximal supplemental oxygen therapy
    d. Acute pulmonary hemorrhage (lung isolation may be indicated – single lumen ETT 8.5 – 9.0 ID mm with Arndt 9 Fr. bronchial blocker, able to accommodate Ambu regular scope ED 5.0 mm > DLT)
4. If in cardiogenic shock, may notify cardiac anesthesiologist in house/on call
5. Set time limit for procedure to 30-40 minutes, persisting may result in deterioration in clinical status, especially if chronic clot is present – ie. Instruments through RV into PA may increase the risk of arrhythmias, distal embolization of clot, and PVR/RV afterload elevation

Hemodynamic monitoring and vascular access:

1. Arterial line for continuous BP monitoring, or noninvasive BP monitoring every 3 minutes
2. Large bore IV access for fluid/blood resuscitation and vasopressor administration
3. Disposable defibrillator pads immediately available – cannot put on patient prophylactically as will impede visualization with fluoroscopy
4. Consider central venous access in patients with moderate to severe RV dysfunction, however CVL insertion should not delay procedure. CVL access can be easily established by IVR attending a part of the procedure

Respiratory Support:

1. Maintain adequate oxygenation (SpO_2 > 95%) and avoid hypercarbia
2. High flow nasal cannula (HFNC; Airvo or Optiflow) recommended for all patients, and started at 100% FiO_2 and 40-60L/min as all patients desaturate during the procedure
3. NIPPV can be facilitated with the use of the endoscopy mask used with the anesthetic machine (ie. PSVPro)
4. If intubation is required, adhere to the 'SAVIOR' principles, consider awake, spontaneously breathing intubation with avoidance/minimize anesthetic IV agents, gradual introduction of PPV and prevention of atelectasis and air-trapping

<u>Management of RV Failure - CRRAP Goals:</u>

Acute RV failure caused by pressure overload secondary to the abrupt increase in pulmonary vascular resistance is the main cause of death in acute PE. The mechanisms associated with right ventricular injury leading to obstructive shock are illustrated in Figure 1.

It is important to recognize that even in the absence of hypotension there may be signs and markers of RV dysfunction at presentation. Up to 35% of patients with normal blood pressure are in some form of low-grade cardiogenic shock. Hence the importance of assessing RV function at baseline as part of the preoperative assessment and taking precautions to avoid hypotension and minimize further increases in PVR, which could lead to decompensation during the procedure.

C: Maintain/augment RV contractility (ie. Epinephrine, Dobutamine, Milrinone)

R: High-normal SR, 90 bpm optimal

R: Cardiovert arrhythmias

A: Avoid pHTN exacerbants (hypercarbia, hypoxia, acidosis, pain/agitation, and coughing/bucking), reduce PVR with inhaled pulmonary vasodilators (ie. Nitric oxide or flolan) and/or inodilators (ie. Milrinone), maintain RV perfusion with systolic BP > RVSP or MAP > 65-70 mm Hg, and aim for SpO_2 > 95% (consider R -> L shunt in refractory hypoxemia)

P: Judicious fluid management vs. consider diuresis (may be on CRRT), transfuse as appropriate

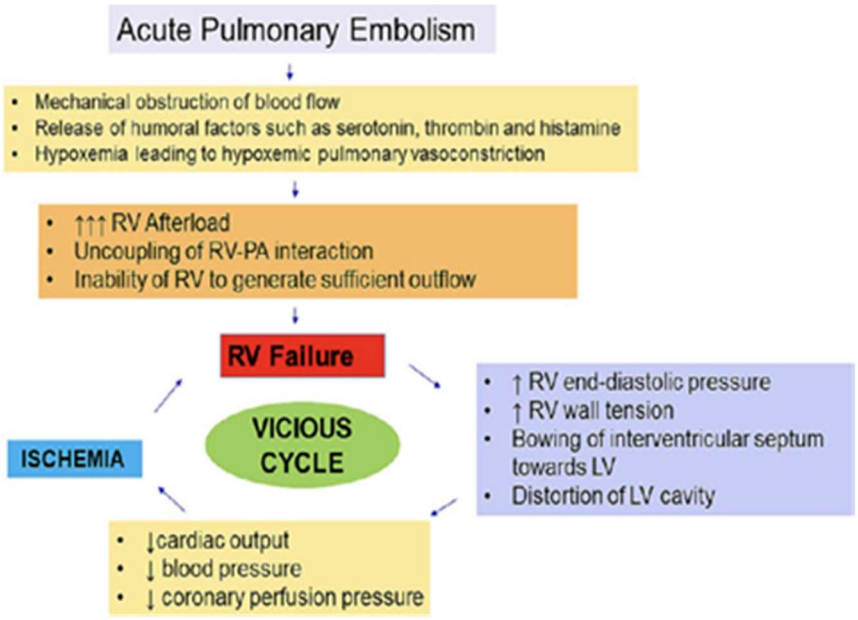


Figure 1: Pathophysiology of RV failure. From: Rossler J et all. Anesthetic management in patients having catheter-based thrombectomy for acute pulmonary embolism: A narrative review. Journal of Clinical Anesthesia 92 (2024) 111281.

Mechanical circulatory support:

1. Mechanical circulatory support (MCS) in the form of VA-ECMO may be necessary in exceptional situations to decompress the RV, improve oxygenation and preserve end-organ perfusion in cases of persistent shock despite optimal medical management, or after cardiac arrest (ie. ECPR)
2. The decision to start MCS is multidisciplinary and in early 2025 (hopefully) will involve the SHOCK team at KGH (cardiac surgery, ICU, ER, cardiac anesthesia and IR). Until then, cardiac surgery is contacted directly
3. These resources are locally available. As mentioned before, consultation with the appropriate stakeholders regarding indication, feasibility and/or safety to proceed should be considered as early as possible and the outcomes of these discussions should be clearly outlined during the time out, so that the proper pathway to cannulation can be urgently activated in case of severe intraoperative deterioration

Post-Operative Management

Disposition:

1. If in ED or a ward bed, most need DAVIES 4
2. If high risk or on vasopressors, they will need to go to KIDD 2

Post-procedure care is usually performed in one of the ICUs. Davies 4 ICU is the most commonly used location post procedure, although patients who started on vasopressors or who develop the need for inotropes or vasopressors during the procedure +/- FiO_2 > 6L should go to the Kidd 2 ICU for monitoring. We expect patients to demonstrate significant clinical improvement after the procedure, but

continuous hemodynamic and/or respiratory support may still be necessary. Patients should be monitored for post-procedural complications such as bleeding from the femoral access site, limb ischemia, systemic embolic events (stroke, mesenteric ischemia), arrhythmias and reperfusion lung injury, which can present as mild pulmonary edema or, in severe situations, alveolar hemorrhage.