MHIF FEATURED STUDY:

AKI

DESCRIPTION: To evaluate the efficacy of postsurgery treatment with ASP1128 (investigational medication) in subjects at risk for acute kidney injury (AKI) following coronary artery bypass graft (CABG) and/or valve surgery. ASP1128 is a potent and highly selective PPARδ modulator, that is believed to have protective effects on kidney cells that are under cellular stress as a result of ischemia, inflammation and oxidative stress following coronary artery bypass graft and/or valve (CABG/V) surgery. In addition, ASP1128 will reduce inflammatory responses and increased oxidative stress systemically which is expected to reduce the immediate consequences of stress responses following CABG/V surgery.

CRITERIA LIST/QUALIFICATIONS:

**Inclusion**
- Subject undergoing non-emergent open chest cardiovascular surgery with use of CPB (i.e., CABG and/or valve surgery [including aortic root and ascending aorta surgery, without circulatory arrest])

**Exclusion**
- On another investigational medication
- GFR < 30
- Prior kidney transplant
- Known or suspected glomerulonephritis
- Endocarditis or active infection
- Subject has moderate/high risk of developing AKI following surgery (must have 2 risk factors):
  - Risk factors: age > 70, eGFR < 60, CHF, DM, proteinuria/albuminuria
  - Surgery off pump
  - IV Drug abuse
  - Chronic liver disorder
  - LVAD

CONDITION: Preventing AKI post OHS

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Coming soon: Please Refer Patients!
PULMONARY ARTERY EMBOLISMS

Benjamin Sun, MD
Abbott Northwestern Hospital

History

- Giovanni Battista Morgagni
  - (25 February 1682 – 6 December 1771)
  - Italian Anatomist
  - ‘Father of modern pathology’
  - Identified the presence of large clots in the pulmonary arteries found at autopsy in patients who had died suddenly
  - “Where is the disease?”
History

- Rudolph Virchow
  - (13 October 1821 – 5 September 1902)
  - German physician, pathologist
  - Studying Jean Cruveilhier’s doctrine
    - “That the essence of inflammation is coagulation of the blood in the veins in the capillaries” i.e phlebitis.
  - 1859: “[T]he detachment of larger or smaller fragments from the end of the softening thrombus which are carried along by the current of blood and driven into remote vessels. This gives rise to the very frequent process on which I have bestowed the name of Embolia.”

- Virchow’s Triad
  - Blood stasis
  - Endothelial injury
  - Hypercoagulability

History

- Friedrich Trendelenburg
  - (24 May 1844 – 15 December 1924)
  - German Surgeon
  - Identified the acute mortality of this disease in 9 patients, Leipzig Germany.
  - “Perfected a surgical procedure in a calf using a left parasternal thoracotomy through which the pulmonary artery was opened and the embolus was removed”
  - He treated two patients with this procedure but unfortunately both patients died
History

• Martin Kirschner
  • (28 October 1879 – 30 August 1942)
  • German Surgeon
  • Student of Trendelenburg
  • March 18, 1924, performed the first successful pulmonary artery embolectomy after a routine hernia operation
  • “Trendelenburg Operation”

History

• Alton Ochsner, Sr.
  • (May 4, 1896 – September 24, 1981)
  • US Thoracic Surgeon
  • Started the Ochsner Clinic
  • Was present at the meeting where Dr. Kirshner presented the Trendelenburg operation.
  • Due to very poor outcomes with only 10 survivors over 300 procedures, he advocated for prophylactic approaches
    • Wrapping the legs
    • Early ambulation
    • Electrical stimulation of calf muscles
    • Head down position
    • Anticoagulation
    • Ligation of the inferior vena cava to prevent pulmonary embolism
Types

- Infectious
- Occult
- Sub segmental
- Sub Massive
- Massive

Risk Factors

- Age
- Obesity
- Immobility
  - Air travel
  - Post procedural
  - Orthopedics
- Trauma
  - Orthopedic
  - Vascular
- Hypercoagulability
  - Dehydration
  - Malignancy
  - Oral contraceptives
  - Tobacco use
Incidence

- **DVT**
  - 53-162 per 100,000 population
- **PE**
  - 39-115 per 100,000 population
  - Est 300,000 deaths in U.S per year

Predisposing Factors

<table>
<thead>
<tr>
<th>Strong risk factors (OR &gt; 10)</th>
<th>Moderate risk factors (OR 2 – 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of lower limb</td>
<td>Arthroscopic knee surgery</td>
</tr>
<tr>
<td>Hospitalization for heart failure or atrial fibrillation/flutter</td>
<td>Autoimmune diseases</td>
</tr>
<tr>
<td>(within previous 3 months)</td>
<td>Blood transfusion</td>
</tr>
<tr>
<td>Hip or knee replacement</td>
<td>Central venous lines</td>
</tr>
<tr>
<td>Major trauma</td>
<td>Intravenous catheters and leads</td>
</tr>
<tr>
<td>Myocardial infarction (within previous 3 months)</td>
<td>Chemotherapy</td>
</tr>
<tr>
<td>Previous VTE</td>
<td>Congestive heart failure or respiratory failure</td>
</tr>
<tr>
<td>Spinal cord injury</td>
<td>Erythropoiesis-stimulating agents</td>
</tr>
<tr>
<td></td>
<td>Hormone replacement therapy (depends on formulation)</td>
</tr>
<tr>
<td>Weak risk factors (OR &lt; 2)</td>
<td>In vitro fertilization</td>
</tr>
<tr>
<td>Bed rest &gt;3 days</td>
<td>Oral contraceptive therapy</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>Post-partum period</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>Infection (specifically pneumonia, urinary tract infection, and HIV)</td>
</tr>
<tr>
<td>Immobility due to sitting (e.g. prolonged car or air travel)</td>
<td>Inflammatory bowel disease</td>
</tr>
<tr>
<td>Increasing age</td>
<td>Cancer (highest risk in metastatic disease)</td>
</tr>
<tr>
<td>Laparoscopic surgery (e.g. cholecystectomy)</td>
<td>Paralytic stroke</td>
</tr>
<tr>
<td>Obesity</td>
<td>Superficial vein thrombosis</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>Thrombophilia</td>
</tr>
</tbody>
</table>
Pathophysiology of PE

- Acute PE interferes with both circulation and gas exchange
- Right ventricular failure due to acute pressure overload is the primary cause of death in severe PE
- A nonpreconditioned thin-walled RV is generally unable to generate a mean PAP>40 mmHg
- Anatomical obstruction and hypoxic vasoconstriction in the affected lung area leads to an increase in PVR
- PE-induced vasoconstriction, mediated by thromboxane A2 and serotonin release contributes to additional increase in pulmonary vascular resistance
- RV strain and systemic hypotension can result in elevated cardiac biomarkers and systemic epinephrine levels

Presentation

- Acute pleuritic chest pain
- Acute shortness of breath
- Concomitant syncope
- Hemoptysis
- Shock
- Cardiac arrest
Differential Diagnosis

- Acute coronary syndrome
- Arrythmia
- Acute dissection
- Pneumonia
- Pleurisy
- Pericarditis
- Diaphragmatic hernia
- Achalasia
- Esophageal Spasm

Diagnostics

- Vitals
  - HR: usually tachycardic
  - BP: usually lower
  - O₂Sat: usually lower
- Physical Exam
  - May or may not have a history or ongoing swelling in a lower extremity
  - Upper extremity thrombus rarely leads to clinically significant PE
  - Isolated calf DVT rarely leads to clinically significant PE
  - Often does not have pleuritic chest pain
  - Anxious
- EKG:
  - Inversion of T waves in V1-V4
  - Right bundle branch block
  - New onset atrial fibrillation
  - Often is non diagnostic
- ECHO
- CT Scan
  - Timing of dye infusion
  - Pulmonary artery
  - Aorta
The revised Geneva clinical prediction rule for PE

<table>
<thead>
<tr>
<th>Items</th>
<th>Clinical decision rule points</th>
<th>Original version</th>
<th>Simplified version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous PE or DVT</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>75–94 b.p.m.</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>&gt;95 b.p.m.</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Surgery or fracture within the past month</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Haemoptysis</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Active cancer</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unilateral lower-limb pain</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pain on lower-limb deep venous palpation and unilateral oedema</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Age &gt;65 years</td>
<td>1</td>
<td>1</td>
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</table>

**Clinical probability**

<table>
<thead>
<tr>
<th>Three-level score</th>
<th>Original version</th>
<th>Simplified version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0–3</td>
<td>0–1</td>
</tr>
<tr>
<td>Intermediate</td>
<td>4–10</td>
<td>2–4</td>
</tr>
<tr>
<td>High</td>
<td>≥11</td>
<td>≥3</td>
</tr>
<tr>
<td>Two-level score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE-unlikely</td>
<td>0–5</td>
<td>0–2</td>
</tr>
<tr>
<td>PE-likely</td>
<td>≥6</td>
<td>≥3</td>
</tr>
</tbody>
</table>

B.p.m. = beats per minute; DVT = deep vein thrombosis; PE = pulmonary embolism.

The Wells Clinical Prediction Rule for PE

<table>
<thead>
<tr>
<th>Items</th>
<th>Clinical decision rule points</th>
<th>Original version</th>
<th>Simplified version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous PE or DVT</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Heart rate &gt;100 b.p.m.</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Surgery or immobilization within the past 4 weeks</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Haemoptysis</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Active cancer</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Clinical signs of DVT</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Alternative diagnosis less likely than PE</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Clinical probability**

<table>
<thead>
<tr>
<th>Three-level score</th>
<th>Original version</th>
<th>Simplified version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0–1</td>
<td>N/A</td>
</tr>
<tr>
<td>Intermediate</td>
<td>2–6</td>
<td>N/A</td>
</tr>
<tr>
<td>High</td>
<td>≥7</td>
<td>N/A</td>
</tr>
<tr>
<td>Two-level score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE-unlikely</td>
<td>0–4</td>
<td>0–1</td>
</tr>
<tr>
<td>PE-likely</td>
<td>≥5</td>
<td>≥2</td>
</tr>
</tbody>
</table>

B.p.m. = beats per minute; DVT = deep vein thrombosis; N/A = not applicable; PE = pulmonary embolism.
Imaging tests for diagnosis of pulmonary embolism

<table>
<thead>
<tr>
<th></th>
<th>Strengths</th>
<th>Weaknesses/limitations</th>
<th>Radiation issues*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CTPA</strong></td>
<td>• Readily available around the clock in most centres</td>
<td>• Radiation exposure</td>
<td>• Radiation effective dose 3–10 mSv[^a]</td>
</tr>
<tr>
<td></td>
<td>• Excellent accuracy</td>
<td>• Exposure to iodine contrast:</td>
<td>• Significant radiation exposure to young female breast tissue</td>
</tr>
<tr>
<td></td>
<td>• Strong validation in prospective management outcome studies</td>
<td>o limited use in iodine allergy and hyperthyroidism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Low rate of inconclusive results (3–5%)</td>
<td>o risks in pregnant and breastfeeding women</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• May provide alternative diagnosis if PE excluded</td>
<td>• contraindicated in severe renal failure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Short acquisition time</td>
<td>• Tendency to overuse because of easy accessibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clinical relevance of CTPA diagnosis of subsegmental PE unknown</td>
<td></td>
</tr>
<tr>
<td><strong>Planar V/Q scan</strong></td>
<td>• Almost no contraindications</td>
<td>• Not readily available in all centres</td>
<td>• Lower radiation than CTPA, effective dose ~2 mSv[^a]</td>
</tr>
<tr>
<td></td>
<td>• Relatively inexpensive</td>
<td>• Interobserver variability in interpretation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Strong validation in prospective management outcome studies</td>
<td>• Results reported as likelihood ratios</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inconclusive in 50% of cases</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cannot provide alternative diagnosis if PE excluded</td>
<td></td>
</tr>
<tr>
<td><strong>V/Q SPECT</strong></td>
<td>• Almost no contraindications</td>
<td>• Variability of techniques</td>
<td>• Lower radiation than CTPA, effective dose ~2 mSv[^a]</td>
</tr>
<tr>
<td></td>
<td>• Lowest rate of non-diagnostic tests (&lt;3%)</td>
<td>• Variability of diagnostic criteria</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High accuracy according to available data</td>
<td>• Cannot provide alternative diagnosis if PE excluded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Binary interpretation (PE vs. no PE)</td>
<td>• No validation in prospective management outcome studies</td>
<td></td>
</tr>
<tr>
<td><strong>Pulmonary angiography</strong></td>
<td>• Historical gold standard</td>
<td>• Invasive procedure</td>
<td>• Highest radiation, effective dose 10–20 mSv[^a]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Not readily available in all centres</td>
<td></td>
</tr>
</tbody>
</table>

**CT Chest Anatomy**

![CT Chest Anatomy Image]
Pulmonary Embolisms

Saddle

Right Side

Patient

Saddle

Left PA
ECHO

McConnell's Sign

Clot in IVC
Clot in transit

Pulmonary Embolism Severity Index

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Original version</th>
<th>Simplified version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Age in years</td>
<td>1 point (if age &gt;80 years)</td>
</tr>
<tr>
<td>Male sex</td>
<td>&gt; 10 points</td>
<td>-</td>
</tr>
<tr>
<td>Cancer</td>
<td>&gt; 30 points</td>
<td>1 point</td>
</tr>
<tr>
<td>Chronic heart failure</td>
<td>&gt; 10 points</td>
<td>1 point</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>&gt; 10 points</td>
<td>1 point</td>
</tr>
<tr>
<td>Pulse rate ≥110 b.p.m.</td>
<td>&gt; 20 points</td>
<td>1 point</td>
</tr>
<tr>
<td>Systolic BP &lt;100 mmHg</td>
<td>&gt; 30 points</td>
<td>1 point</td>
</tr>
<tr>
<td>Respiratory rate &gt;30 breaths per min</td>
<td>&gt; 20 points</td>
<td>-</td>
</tr>
<tr>
<td>Temperature &lt;36°C</td>
<td>&gt; 20 points</td>
<td>-</td>
</tr>
<tr>
<td>Alter mental status</td>
<td>&gt; 60 points</td>
<td>-</td>
</tr>
<tr>
<td>Arterial oxygenation &lt;90%</td>
<td>&gt; 20 points</td>
<td>1 point</td>
</tr>
</tbody>
</table>

Risk strata

- **Class I:** ≤65 points
  - Very low 30 day mortality risk (0–1.6%)
  - Low mortality risk (1.7–3.3%)

- **Class II:** 66–85 points
  - Low mortality risk (1.7–3.3%)

- **Class III:** 86–105 points
  - Moderate mortality risk (3.2–7.1%)

- **Class IV:** 106–125 points
  - High mortality risk (4.0–11.4%)

- **Class V:** >125 points
  - Very high mortality risk (10.0–24.5%)

0 points = 30 day mortality risk 1.0% (95% CI 0.0–2.1%)

≥ 1 point(s) = 30 day mortality risk 19.9% (95% CI 8.5–13.2%)
Classification of pulmonary embolism severity and the risk of early (in-hospital or 30 day) death

Clinical Classifications of PE

Sub Massive
- Acute PE without systemic hypotension
  - (systolic blood pressure >90 mm Hg)
- With either RV dysfunction or myocardial necrosis
- RV dysfunction means the presence of at least 1 of the following:
  - —RV dilation (apical 4-chamber RV diameter divided by LV diameter >0.9) or RV systolic dysfunction on echocardiography
  - —RV dilation (4-chamber RV diameter divided by LV diameter >0.9) on CT
  - —Elevation of BNP (>90 pg/mL)
  - —Elevation of N-terminal pro-BNP (>500 pg/mL); or
  - —Electrocardiographic changes (new complete or incomplete right bundle-branch block, anteroseptal ST elevation or depression, or anteroseptal T-wave inversion)
- Myocardial necrosis is defined as either of the following:
  - —Elevation of troponin I (>0.4 ng/mL) or
  - —Elevation of troponin T (>0.1 ng/mL)

Massive
- Acute PE with sustained hypotension
  - (systolic blood pressure <90 mm Hg for at least 15 minutes)
- Requiring inotropes
- Pulselessness
- Persistent profound bradycardia
  - (heart rate <40 bpm with signs or symptoms of shock).
Therapeutic Options

- Resuscitation
- ECMO
- Anticoagulation
- Thrombolytics
- Percutaneous catheter-directed treatment
- Surgery

Treatment Approach

- Clot Burden
- Location
  - Central
  - Peripheral
- Hemodynamic Stability
  - RV strain
  - Hypoxia (intubation)
  - Inotropes
  - ECMO
- Ability to tolerate thrombolytics
  - Recent surgery
  - Recent bleeding
- What options are available
  - Catheter based
  - Surgery
Thrombolytic regimens, doses, and contraindications

- 9.9% risk of severe bleeding
- 1.7% of cerebral hemorrhage

Percutaneous catheter-directed treatment

- Some encouraging results but mostly case series
- Survival to hospital discharge up to 87%
- One randomized to thrombolytics in intermediate-risk PE
Surgery

- Sternotomy
- Cardiopulmonary Bypass
- Warm and beating
- Open the PA and extract the clot

Survival and recurrence after acute pulmonary embolism treated with pulmonary embolectomy or thrombolysis in New York State, 1999 to 2013

Timothy Lee, BS,1 Shinobu Iwagaki, MD, MS,1 Yueting P. Chiang, MD, MS,1 Natalia N. Egorova, PhD,1 David H. Adams, MD,1 and Joanna Chilwee, MD1

ABSTRACT

Background: Pulmonary embolism (PE) results in more than 250,000 hospitalizations annually in the United States, with high mortality. Outcome data are limited, and reperfusion strategies remain controversial. Here we evaluated the outcomes of thrombolysis and surgical embolectomy in patients with acute PE using a statewide database.

Methods: Among 174,322 patients hospitalized with PE in New York State between 1999 and 2013, we performed a retrospective comparison of 2,111 adults with acute PE who underwent either thrombolysis (n = 1,854; 88%) or surgical embolectomy (n = 257, 12%) as first-line therapy. Patients were identified using a mandatory database. The median follow-up was 6.2 years (range, 0-16.3 years).

The primary study endpoint was all-cause mortality; secondary outcomes included recurrent PE, recurrent deep vein thrombosis, reintervention, and stroke.

Results: In 2,111 patients who underwent reperfusion, there was no difference in 30-day mortality between those who underwent thrombolysis and those who underwent surgical embolectomy (15.2% vs 13.2%; odds ratio [OR], 1.12; 95% confidence interval [CI], 0.72-1.73). Thrombolysis was associated with higher risk of stroke (1.9% vs 0.4%; OR, 4.70; 95% CI, 1.06-20.42) and reintervention (3.8% vs 1.2%; OR, 7.16; 95% CI, 2.17-23.62) at 30 days. Five-year actuarial survival was similar in the 2 groups (72.4% vs 70.3%; 74.5% vs 76.1% vs 95% CI, 70.2%-81.6% vs 70.3%-81.6%), hazard ratio (HR) for death, 1.11; 95% CI, 0.83-1.49). Thrombolysis was associated with a higher rate of recurrent PE necessitating inpatient readmission (3.9% vs 0.9% vs 95% CI, 6.9%-9.4% vs 2.8% vs 95% CI, 1.1%-5.8%; HR, 3.38; 95% CI, 1.40-7.73).

Conclusions: Pulmonary embolism and thrombolysis are associated with similar early and long-term survival, supporting guideline recommendations for embolectomy when thrombolysis is contraindicated. (J Thorac Cardiovasc Surg 2018;155(1084-96))

See Editorial Commentaries pages 1091 and 1093.

See Editorial page 1080.
Surgery vs Thrombolysis 30 day Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Thrombolysis (n = 1554, n (%))</th>
<th>Surgery (n = 257, n (%))</th>
<th>OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>282 (13.2)</td>
<td>34 (13.2)</td>
<td>1.12 (0.72-1.73)</td>
<td>.62</td>
</tr>
<tr>
<td>Recurrent pulmonary embolus</td>
<td>137 (7.6)</td>
<td>22 (8.6)</td>
<td>0.99 (0.61-1.61)</td>
<td>.97</td>
</tr>
<tr>
<td>Recurrent pulmonary embolus necessitating inpatient readmission</td>
<td>46 (2.6)</td>
<td>3 (1.2)</td>
<td>1.20 (0.41-3.76)</td>
<td>.37</td>
</tr>
<tr>
<td>Recurrent deep vein thrombosis</td>
<td>73 (4.7)</td>
<td>12 (4.7)</td>
<td>1.03 (0.53-1.99)</td>
<td>.93</td>
</tr>
<tr>
<td>Reoperation or reintervention</td>
<td>71 (3.9)</td>
<td>3 (1.2)</td>
<td>7.16 (2.17-23.62)</td>
<td>.001</td>
</tr>
<tr>
<td>Stroke</td>
<td>35 (1.9)</td>
<td>2 (0.8)</td>
<td>4.70 (1.08-20.42)</td>
<td>.039</td>
</tr>
<tr>
<td>Major bleed</td>
<td>67 (3.6)</td>
<td>23 (9.0)</td>
<td>0.53 (0.31-0.92)</td>
<td>.024</td>
</tr>
<tr>
<td>Blood transfusion</td>
<td>225 (12.1)</td>
<td>51 (19.8)</td>
<td>0.73 (0.49-1.07)</td>
<td>.11</td>
</tr>
</tbody>
</table>

OR: Odds ratio; CI: confidence interval. *Adjusted using logistic regression analysis, with all patient demographics and baseline characteristics entered as covariates into initial model, and covariates in the final model determined via univariate selection with P = .25 for entry into the model and P = .10 to stay in the model. Illustration or minor variation.

Figure 2

Surgery vs Thrombolysis Recurrent PE


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Surgery vs Thrombolysis Survival

Number at Risk

<table>
<thead>
<tr>
<th></th>
<th>Thrombolysis</th>
<th>Surgical Embolectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 years</td>
<td>1654</td>
<td>251</td>
</tr>
<tr>
<td>1 year</td>
<td>1472</td>
<td>208</td>
</tr>
<tr>
<td>2 years</td>
<td>1296</td>
<td>189</td>
</tr>
<tr>
<td>3 years</td>
<td>1094</td>
<td>164</td>
</tr>
<tr>
<td>4 years</td>
<td>956</td>
<td>135</td>
</tr>
<tr>
<td>5 years</td>
<td>795</td>
<td>112</td>
</tr>
</tbody>
</table>


Surgical pulmonary embolectomy and catheter-based therapies for acute pulmonary embolism: A contemporary systematic review

Praneet Loyalka, MD,
Mahmood Z. Ansari, MBBS,
Faisal H. Cheema, MD,
Charles M. Miller III, MD,
Sudarshan Rajagopal, MD, PhD,
and Keshava Rajagopal, MD, PhD

ABSTRACT

Objective: Mortality in acute pulmonary embolism (PE) is believed to be principally due to the subgroup of patients that are massive. Systemic thrombolysis is the therapeutic mainstay for acute massive PE, despite evidence suggesting limited survival benefits. Both catheter-based therapies (CBT) and surgical pulmonary embolectomy (SPE) are well-accepted alternatives to treat acute PE. However, the comparative effectiveness of these approaches is difficult to study. We conducted a systematic review of CBT and SPE for acute PE.

Methods: The PubMed database was queried for CBT and SPE-related publications between January 1998 and June 2017. A minimum of 10 patients undergoing intervention was required for inclusion, and studies must have excluded patients with massive PE. End points examined included hospital mortality, and additionally for CBT, procedural success rate.

Results: A total of 75 studies (41 of CBT, 34 of SPE) were identified, with 1600 patients undergoing CBT and 1105 undergoing SPE. Patients undergoing SPE were more critically ill than those undergoing CBT (massive PE, 545 vs 1654). Significant differences were noted between the 2 groups, with the mortality rate for CBT being significantly higher than for SPE (14.0% vs 5.6% for CBT, in the entire patient group. However, the mortality rate of SPE in patients with pre-PE CPR was 46.3%, whereas it was 6.3% in those patients without pre-PE CPR. On the contrary, the mortality rate for SPE was 21.4% (189 out of 1094 patients undergoing SPE) versus 10.5% (109 out of 1472 patients treated with thrombolysis). The adjusted odds ratio for mortality for SPE relative to CBT was 2.01, 95% confidence interval 1.22-3.90, p = 0.006. The adjusted odds ratio for mortality for SPE relative to CBT was 2.01, 95% confidence interval 1.22-3.90, p = 0.006. The adjusted odds ratio for mortality for SPE relative to CBT was 2.01, 95% confidence interval 1.22-3.90, p = 0.006.

Conclusions: Both CBT and SPE were associated with satisfactory published outcomes. SPE is associated with greater absolute postprocedural mortality than CBT, but has been undertaken in more critically ill populations. The markedly higher incidence of CBT in SPE accounts for the differential mortality between the patients undergoing SPE and those undergoing CBT. Decisions making with respect to best therapy must take into account potential needs for periprocedural artificial mechanical right ventricular and lung support, institutional experience and outcomes, anticipated therapeutic efficacy and benefit, and approach-specific risks.
Conclusions

• Both had satisfactory outcomes
• Surgical embolectomy
  • Sicker population
  • 21% had preop CPR vs 4% in catheter based (46% mortality with CPR)
  • Advantage for people who may need mechanical support
  • Advantage for central PE and larger embolic burden
• Catheter based Therapy
  • Surgery is contraindicated
  • More peripheral disease
  • Failure rate of 8.3% requiring reintervention
### Abbott Northwestern Data 2018-2019

- In 2018 ANW had 372 PE patients, of those patients:
  - 8% required PERT Activation.
  - 38% had an ICU stay.
  - 16 Catheter directed intervention
    - Survival rate of 19%.
    - 2 PEA arrest during procedure
    - Hemorrhage into brain mass on iv heparin
  - 3 underwent surgical Embolectomy
    - Survival rate of 66%.
    - Complications included:
      - Confirmed massive PE, E-CPR, VA ECMO followed by surgical embolectomy. Decannulated next day. Survived.
      - Massive PE, s/p recent spine surgery. Surgical embolectomy. Survived, d/c'd home
  - 4 received ECMO

- In 2019 ANW had 384 PE patients, of those patients:
  - 9% required PERT Activation.
  - 35% had an ICU stay.
  - 9 Catheter directed intervention
    - Data not complete yet
  - 7 underwent surgical Embolectomy
    - Survival rate of 43%.
    - 3 patients had preoperative EF of 10-15%
    - One received CDI and TPA prior to surgery
  - 9 received ECMO

### IVC Filter

- Long term anticoagulation is contraindicated
- Recurrence for DVT on anticoagulation
- Anticipated need to stop anticoagulation
- Residual clot burden (in IVC or legs) with tenuous pulmonary reserve
- Most will not benefit from an IVC filter
- Retrievable filters preferred
Anticoagulation in patients after PE (without cancer)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapeutic anticoagulation for ≥ 3 months is recommended for all patients with PE⁴⁶⁷</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Patients in whom discontinuation of anticoagulation after 3 months is recommended</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Patients in whom extension of anticoagulation beyond 3 months is recommended</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Oral anticoagulant treatment of indefinite duration is recommended for patients presenting with recurrent VTE (that is, with at least one previous episode of PE or DVT) not related to a major transient or reversible risk factor ⁵⁹⁸</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Oral anticoagulant treatment with a VKA for an indefinite period is recommended for patients with antiphospholipid antibody syndrome ⁵⁹⁹</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Patients in whom extension of anticoagulation beyond 3 months should be considered*</td>
<td>Ia</td>
<td>A</td>
</tr>
<tr>
<td>Extended oral anticoagulant of indefinite duration should be considered for patients with a first episode of PE and no identifiable risk factor ⁶⁰⁰,⁶⁰³ ⁶⁰⁰,⁶⁰⁰,⁶⁰³</td>
<td>Ia</td>
<td>A</td>
</tr>
<tr>
<td>Extended oral anticoagulation of indefinite duration should be considered for patients with a first episode of PE associated with a persistent risk factor other than antiphospholipid antibody syndrome ⁵⁹⁹,⁶⁰⁰,⁶⁰³</td>
<td>Ia</td>
<td>C</td>
</tr>
<tr>
<td>Extended oral anticoagulation of indefinite duration should be considered for patients with a first episode of PE associated with a minor transient or reversible risk factor ⁵⁹⁹,⁶⁰⁰,⁶⁰³</td>
<td>Ia</td>
<td>C</td>
</tr>
<tr>
<td>NOAC dose in extended anticoagulation*</td>
<td>Ia</td>
<td>A</td>
</tr>
<tr>
<td>If extended oral anticoagulation is decided after PE in a patient without cancer, a reduced dose of the NOACs apixaban (23 mg g/d) or edoxaban (10 mg g/d) should be considered after 6 months of therapeutic anticoagulation ⁵⁹⁹,⁶⁰³ ⁶⁰⁰,⁶⁰³</td>
<td>Ia</td>
<td>A</td>
</tr>
<tr>
<td>Extended treatment with alternative antithrombotic agents</td>
<td>Ib</td>
<td>B</td>
</tr>
<tr>
<td>Follow-up of the patient under anticoagulation</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In patients who receive extended anticoagulation, it is recommended that their drug tolerability and adherence, hepatic and renal function, and bleeding risk be reassessed at regular intervals ⁶⁰⁰,⁶⁰³</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>

Prognosis

- Dependent on the severity of the PE
- Overall mortality:
  - 1023 patients=32% at 5 yrs
  - 5% due to PE or recurrent PE
  - 31% due to cardiovascular causes (MI, CHF, CVA)
  - 64% due to non cardiovascular causes (malignancy, sepsis, etc)
- Sub Segmental PE do better
Follow up

Chronic Pulmonary Embolism

- CTEPH: chronic thromboembolic pulmonary hypertension
- Very different entity
- Incidence 0.1-9.1% within 2 years after symptomatic PE event
- Referral bias
- Switzerland registry 0.8% within 2 yrs

Scar tissue
Blocked blood vessels
Right side of the heart has too much pressure
Scar tissue
Narrowed blood vessel
Risk Factors for CTEPH

<table>
<thead>
<tr>
<th>Findings related to the acute PE event (obtained at PE diagnosis)</th>
<th>Concomitant chronic diseases and conditions predisposing to CTEPH (documented at PE diagnosis or at 3–6 month follow-up)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous episodes of PE or DVT</td>
<td>Ventriculo-atrial shunts</td>
</tr>
<tr>
<td>Large pulmonary arterial thrombi on CTPA</td>
<td>Infected chronic I.V. lines or pacemakers</td>
</tr>
<tr>
<td>Echocardiographic signs of PH/RY dysfunction(^a)</td>
<td>History of splenectomy</td>
</tr>
<tr>
<td>CTPA findings suggestive of pre-existing chronic thromboembolic disease(^b)</td>
<td>Thromboembolic disorders, particularly antiphospholipid antibody syndrome and high coagulation factor VIII levels</td>
</tr>
<tr>
<td>Non-O blood group</td>
<td>Hypothyroidism treated with thyroid hormones</td>
</tr>
<tr>
<td>History of cancer</td>
<td>Myeloproliferative disorders</td>
</tr>
<tr>
<td>Inflammatory bowel disease</td>
<td>Chronic osteomyelitis</td>
</tr>
</tbody>
</table>

CTEPH Surgery

- Highly selective patient population with favorable anatomy
- Elective
- Sternotomy
- Cardiopulmonary bypass
- Deep hypothermia and intermittent circulatory arrest
- Heart is arrested
- Technically demanding surgery
- Pulmonary artery endarterectomy
CTEPH Surgery

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Final Thoughts

- Growing population of acute PE
- More will need advanced therapies
- More with circulatory collapse
  - ECMO before needing CPR
- ?Earlier surgery?
- ?Role of catheter based interventions?
- Should we be moving into CTEPH?