Balloon Pulmonary Angioplasty for Chronic Thromboembolic Pulmonary Hypertension (CTEPH): Has it become mainstream?

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"Developing Effective Solutions to a Devasting Illness"

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What is Chronic Thromboembolic Disease?

• Acute Pulmonary Embolis
• Incomplete resolution (>3 months AC)
• Loss of pulmonary vascular bed
• Progressive pulmonary hypertension (mean PA >25)
• Right heart failure

Evaluation for CTEPH – The most curable form of Pulmonary HTN!

1) Acute PE patients with persistent CP symptoms after 3 months of anticoagulation
2) All patients with pulmonary hypertension
3) Unexplained exertional dyspnea with or without history of thromboembolic event

Diagnosis of PH should be considered in all patients with unexplained dyspnea...and CTEPH in all patients with PH

Natural History of CTEPH

Small vessel changes
(Adaptive vascular remodeling)

(rectal, intramuscular, pulmonary hypertension (risk), reduced surr. capacity)

Acute PE

Resolved and
persistent surr. capacity
MRC, MLR

CTEPH

ACUTE

RECOVERY

CT Angiogram: detection of PH/RV size and function
Lung VQ Scan: detection of perfusion defects
CTEPMR/CMR:
CTEPMR Diagnosis: CTE location

CTEPH: Pulmonary Angiogram
Natural History

Surgical Principles - PTE
- Well established
- Median sternotomy
- Cardiopulmonary bypass
- Circulatory arrest
- Bilateral endarterectomy
- Identification of the plane
- Complete endarterectomy

Case
- 48 yo w obesity, on OCPs
- Developed dyspnea and cough after a flight 2 years ago
- Dyspnea progressively worse
- treated for asthma with multiple steroid tapers, inhalers
- Re-presented w/syncope, hypoxic
- Large R main PA PE, RV enlargement, RVSP 98 mmHg
- EKOS CDT, slight improvement in symptoms
- 3 months Eliquis → still w/severe dyspnea

- Underwent successful PTE
- Hemodynamics post op normalized
Assessment of operability
- Right heart catheterization
  - Confirmation of pulmonary hypertension
  - Assessment of risk
  - Anticipated benefit from PTE: Do the hemodynamics match the burden of obstruction
- Imaging to assess location of chronic thrombus
  - CTA, pulmonary angiogram, MRA
  - The more proximal the better
- Patient related factors
  - Age, co-morbidities
  - Patient preference

Role of PTE for CTEPH
- Surgery with complete Pulmonary ThromboEndarterectomy (PTE) – likely best Rx
  But:
  - Surgery technically challenging...excellent outcomes requires access to an expert center (limited)
  - Some patients inoperable or lesions inaccessible

Specific Postoperative Complications After PTE
- Reperfusion pulmonary edema
  - Noncardiogenic pulmonary edema due to reperfusion
  - 10-15% of patients
  - Higher risk in patients with more severe PH
  - Oxygenation defect
  - Cognitive impairment due to DHCA

Balloon Pulmonary Angioplasty
- First described in 2001 by Feinstein et. al.
- Initial high complication rates (pulmonary hemorrhage & death)
- Advances over safer
- Primarily Japan, UC San Diego
Patient presentation
- 42 year old male with PMHx of PE (2011) while residing in India
  - Initially tx with Warfarin for 4 years
  - Subsequently switched to Xarelto (stopped taking in May 2017)
  - Admitted with dyspnea in 9/2017 and was found to have severe pHTN on TTE
  - Evidence of CTEPH on V/Q scan

Patient presentation (cont.)
- Hemodynamics
  - RA 9, PA 123/33 [69], PCWP 16, PVR 10.1 WU
  - CO 5.3 L/min, CI 2.9 L/min/m²
- Deemed appropriate surgical candidate for PTE
- Refused surgery
- Started on Riociguat 0.5 mg TID
- Decision to proceed with balloon pulmonary angioplasty
BPA #1 Rt lung

BPA #1 Rt lung - RUL selective injection

BPA #2 – 1st Left Lung session

BPA #3 – 2nd Right Lung session

BPA #4 – 2nd Left Lung session

BPA #6 – 6/2018 (3rd Left Lung session)
**Hemodynamics**

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>BPA 1 (post)</th>
<th>BPA 2 (post)</th>
<th>BPA 3 (post)</th>
<th>BPA 4 (post)</th>
<th>BPA 5 (post)</th>
<th>BPA 6 (post)</th>
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<tbody>
<tr>
<td>PA (s/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>s/d</td>
<td>32/12</td>
<td>22/12</td>
<td>21/13</td>
<td>15/11</td>
<td>16/13</td>
<td>16/13</td>
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<tr>
<td>PA mean</td>
<td>88/47</td>
<td>57/28</td>
<td>47/25</td>
<td>33/19</td>
<td>30/13</td>
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<tr>
<td>PVR (wu)</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
<td>0.8</td>
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<tr>
<td>PVR (d)</td>
<td>3.3</td>
<td>3.2</td>
<td>3.5</td>
<td>3.4</td>
<td>3.7</td>
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<tr>
<td>Baseline</td>
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<td>65</td>
<td>65</td>
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<tr>
<td>PA (mean)</td>
<td></td>
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<tr>
<td>RA</td>
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<td>2</td>
<td>4</td>
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<tr>
<td>PCWP</td>
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<td>12</td>
<td>12</td>
<td>12</td>
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</table>

- Following 7 sessions of BPA
  - Marked improvement in functional capacity
  - Resolution of chest pressure
  - Off O2 and back at work

**EKG (12/6/17) – pre - BPA**

**EKG (6/25/18) – resolution of right axis deviation**

**PA (mean)**

**PVR (dynes)**
Complications

- Death
- Hemoptysis (intra/post-procedure)
- Pulmonary hemorrhage
- Reperfusion pulmonary edema
- Pseudoaneurysm formation

Hemoptysis

- Incidence - Variable and operator/lesion dependent
- Management - dependent on severity
- Reverse anticoagulation (mild cases)
- Protamine 20 – 30 mg
- Close monitoring
- O2 sat
- Hemodynamic status
- Measures to lower PAP(?)
- ?continue procedure or stop?

Management

- Reverse anticoagulation (mild/self-limited cases)
- Protamine 20 – 30 mg
- If massive bleeding
  - Selective intubation of unaffected lung
  - Tracheal blocker of the affected lung
  - Swan Ganz to tamponade the bleeding vessel
  - Exclude the branch
    - Coil
    - Plug
### Complications

<table>
<thead>
<tr>
<th>Study</th>
<th>No.</th>
<th>Edema</th>
<th>Artificial Resp.</th>
<th>other</th>
<th>Death</th>
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<tr>
<td>Feinstein (Boston)</td>
<td>18</td>
<td>11/18 (61%)</td>
<td>3/17 (17%)</td>
<td>1 (6%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Sugimura (Sendai)</td>
<td>12</td>
<td>6/12 (50%)</td>
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<td>0</td>
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<tr>
<td>Mizoguchi (Okayama)</td>
<td>88</td>
<td>4/88 (4.5%)</td>
<td>4/88 (4.5%)</td>
<td>1 (1.2%)</td>
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<td>Kobayashi (Tokyo)</td>
<td>29</td>
<td>15/29 (52%)</td>
<td>15/29 (52%)</td>
<td>1 (1.2%)</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td>Inami (Tokyo)</td>
<td>54</td>
<td>33/54 (61%)</td>
<td>1 (2%)</td>
<td>5 (9.3%)</td>
<td>1 (2%)</td>
</tr>
</tbody>
</table>


### Who should be considered for BPA?

**Patient selection and goals**

- Non-surgical candidates
- Location of lesions
- Patient refusal
- Severe comorbidities unrelated to pulmonary hypertension
- PH severity out of proportion to obstruction
- Recurrent CTEPH after surgery

Targeted clinical outcomes:

- Pulmonary Hemodynamic /Return of PV reserve
- Functional Status/Improved Quality of Life
- Reduction/Cessation of PH targeted medical therapy
- Abatement of Supplemental O2 needs

### Treatment Algorithm

1. CTEPH diagnosis
2. Continue lifelong anti-coagulation
3. Treatment assessment by an expert CTEPH team
4. Operable
5. Non-operable
6. Pulmonary endarterectomy (treatment of choice)
7. Targeted medical therapy with or without BPA

### Lesion Suitability

- Ring-like stenosis
- Web-like stenosis
- Subtotal occlusion
- Total occlusion

- BPA Most Successful
- BPA least Successful


Multidisciplinary planning meeting prior to case
- Determine necessary patient preparation
  - Anticoagulation Management
  - Testing
  - Interval of Procedures
- Procedure planning
  - Imaging
  - Guidance
  - Technique and equipment

76 y.o. F with CTEPH
- HFrEF, Breast Ca, HTN, HLD
- DVT/PE 11/2018, GI bleeding, s/p IVC filter, CTEPH
- Transferred from OSH with ADHF and worsening RV dysfunction.
- Persistent SOB even after diuresis, significant decrease in functional capacity.
- TTE: LVEF 55 - 60%, severe RV dilation, moderate RV dysfunction, PAP 44 mmHg

Lt Lower Lobe

Check List for Team BPA
- Interventional cardiologist, pulmonary vascular medicine, CT surgery
- Credentialing, Training and Proctoring
- Equipment
- 24 hours telemetry/IMU
- Outcomes and Quality Assurance
- ICU for any intra-procedural adverse events
- Limit procedure contrast to 400cc and radiation to 2 Gry

Conclusions: Is BPA “Mainstream”?
- CTEPH occurs in up to 3% of patients with an acute PE
- PTE is current definitive treatment of choice at present
- Default therapy if feasible

Conclusions: Is BPA “Mainstream”?
- PTE vs. BPA decision should be a multidisciplinary approach
- Experienced centers find some previously labeled inoperable patients operable
- Main issues to consider for surgery vs. BPA
  - Location of obstructions (proximal/segmental vs. segmental sub-segmental)
  - Does degree of disease match hemodynamics?
  - Is there suspected small vessel vasculopathy
  - What are the patient co-morbidities?
Conclusions: Is BPA “Mainstream”?  

**Role of BPA?**
- inoperable disease
- segmental/subsegmental disease
- post PTE residual disease

**NOT YET!**

**Implementation of BPA:**
- Should be physiology based: perfusion scans and hemodynamic measurements
- Requires significant technical refinement and development of dedicated equipment
- Requires dedicated program/team and skilled/careful operator...no cowboys/girls allowed!

**Future investigation for BPA**:
- optimal patient selection/acquisition of objective adjudicated data
- standardized technique and procedural endpoints
- long-term patency and clinical success
- randomized controlled trials

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