Επεμβατικές στρατηγικές στην πνευμονική υπέρταση

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Mortality in PAH

US REVEAL Registry

Annual mortality: 15%, 32%, 43%, 51%

Survival (%)

Time From Diagnosis (years)

No. at Risk:
Full cohort
868 1169 1263 1296 1146 894 575 309

*Despite treatment with approved pharmacotherapies

Lang IM Eur Heart J 2012
Since BAS is performed very rarely, it has not been included in the treatment algorithm.
Rationale for BAS

Chronic RV pressure overload

RV Hypertrophy

↓ RV Dysfunction

↓ RV Dilatation

Right-to-Left Shunt

↓ RV wall stress & O₂ demand

Atrial septostomy

↑ Cardiac output

↑ LV preload
Eisenmenger patients have a more favorable prognosis and hemodynamic profile compared to PAH patients.
Atrial Septostomy

**Atrial septostomy:**
- Palliative
- Creates and maintains ASD to unload RV and improve LV filling.
- Increases in CO offsets the decrease in SAO₂.
- Shunt should decrease SAO₂ no more than 5-10%.
- If the inter-atrial defect is too large, the increased CO may not be able to compensate for the degree of hypoxemia.

**Procedure:**
1. Direct visualization of the septum with TEE or intracardiac echo
2. Septal puncture with a Brockenbrough needle
3. Stepwise serial balloon inflation with noncompliant peripheral balloons while monitor O₂ saturation and LVEDP for 3 min before proceeding to next balloon.
4. Stop point – decrease in O2 saturation > 10%
   - decrease in O₂ saturation < 90%
   - increase in LVEDP > 18 mmHg
5. Expect drop in RVEDP and increase in LVEDP; no change in mPA or Ao
Atrial Septostomy

Procedure has a 24 h mortality = 7.1%
30 d mortality = 14.8%

**Indications**

- Severe PAH (RV failure, syncope) and intractable RH failure despite maximal medical therapy, including optimized PAH-specific agents and inotropes.
- Palliation until lung transplantation
- No other option – developing countries without access to PAH medical therapies

**Atrial septostomy in Primary PAH**

- Current recommendations suggest four exclusion criteria for AS:
  1. RAP >20 mm Hg
  2. SaO2 <90%
  3. Predicted 1 year survival <40%
  4. PVR >55 wood units/m2 (>4400 dyne*s/cm5).

| Reference                  | Proc. | Blade | BDAS | BBAS | Size mm | Immediate death (24 h) | Mortality 1-month | Late deaths | Total deaths | LT (months) | Follow-up months |
|----------------------------|-------|-------|------|------|---------|-----------------------|-------------------|-------------|-------------|-------------|--------------|------------------|
| Nihill et al. [15]         | 14    | 4     | 10   | 8-20 | 2       | 1                     | 2                 | 5           | 1           | 31.5 (0-96) | 0-13 Mo       |
| Sobrino et al. [23]        | 3     | 3     | NA   | 16±6 | 1       | 1                     | 1                 | 1           | 1           | 0-13 Mo     | 0-13 Mo       |
| Kerstein et al. [16]       | 16    | 4     | 12   | 4-18 | 2       | 4                     | 6                 | 2           | 2           | 0-45 Mo     | 0-45 Mo       |
| Rich et al. [25]           | 6     | 4     | 2    | NA   | 2       | NA                    | 1                 | 3           | NA          |             | NA             |
| Thanopoulos et al. [24]    | 6     | 6     | 8.7±12 | 0    |         | 0                     | 22 Mo (4-48)      |             |             |             |               |
| Hayden [26]                | 6     | 6     | NA   | 8.7±12 | 0       | 0                     | 22 Mo (4-48)      |             |             |             |               |
| Sandoval et al. [17]       | 22    | 22    | 10±3 | 2    | 1       | 1                     | 2                 | 5           | 16 Mo (0-36) |             |               |
| Rothman et al. [27]        | 13    | 13    | 10.2±1.3 | 2  | 1       | 2                     | 5                 | 5           | 0-18 Mo     |             |               |
| Kohari et al. [28]         | 11    | 11    | 4-15 | 2    | 1       | 1                     | 4                 | 20 Mo (0-60) |             |             |               |
| Reichenberger et al. [29]  | 20    | 20    | 10.6±1.6 | 4  | 1       | 5                     | 5                 | 0-18 Mo     |             |             |               |
| Kurzyna et al. [30]        | 2     | 2     | 7±1.4 | 1    |         | 1                     | 0-5 Mo            |             |             |             |               |
| Allcock et al. [31]        | 12    | 12    | 15.3±2.8 | 0  |         | 2                     | 2                 | 1           | 0-30 Mo     |             |               |
| Vachery et al. [32]        | 18    | 18    | 15.3±2.8 | 0  |         | 2                     | 2                 | 1           | 0-30 Mo     |             |               |
| Micheletti et al. [33]     | 22    | 2     | 3     | 6.9±2.4 | 0       | 2                     | 2                 | 2           | 2.1 y (1 Mo-6.7 years) |             |               |
| Kurzyna et al. [34]        | 14    | 14    | 6.6±1.6 | 0  |         | 6                     | 7                 | 2           | 8.1 Mo (0.8-20.2) |             |               |
| Giarda et al. [35]         | 11    | 11    | 15.2±2.7 | 0  |         | 9                     | 19                | 3           | 1981-2005 |             |               |
| Law et al. [36]            | 46    | 30    | 5     | 11    | 12.2±2.9 | 2                 | 8                 | 9           | 19           |             | 4-216 days |
| O’Byrne et al. [37]        | 5     | 4     | 1     | NA   | 0       | 0                     |                   |             |             |             |               |
| Lamers et al. [38]         | 7     | 7     | NA   | 11.7±2.2 | 0       | 0                     |                   |             |             | 25.7 Mo (18-31) |               |
| Troost et al. [39]         | 17    | 17    | 4 (3-5) | 1  | 2       | 3                     | 6                 | 4           | 0.7 year (0-5.9) |             |               |
| Fenstad et al. [40]        | 17    | 17    | NA   | 4 (3-5) | 1       | 2                     | 3                 | 6           | 4           | 0.7 year (0-5.9) |             |
| Sandoval et al. [41]       | 50    | 50    | 8.5±2.5 | 1    |         | 1                     | 2                 | 21          | 22          | 58.5±38 Mo  |               |
| Velázquez Martín et al. [42]| 9     | 9     | Mean 11 | 0  |         | 4                     | 4                 | 1           | 18 Mo (9-67) |             |               |
| Bystro [43]                | 11    | 11    | NA   | 8.2±3.8 | 0       | 4                     | 4                 | 2           | 8.2±3.8 Mo  |             |               |
| **Series**                 | 352   | 40 (11.4%) | 273 (77.5%) | 39 (11%) | Mean 10.8 | 24 (6.8%) | 17 (4.8%) | 62 | 102 | 35 |             |
| **Case reports [18,19,44-61]** | 20 | 14 | 6 | 8-18 mm | 3 (15%) | 2 (10%) | 1 | 5 | 1 | 0-60 Mo |             |
| **Total**                  | 372   | 40 | 287 | 45 | 27/372 (7.2%) | 19/372 (5.1%) |             |             |             |             |               |

Adapted from Ref. [22].

Abbreviations: Proc.: procedures; BDAS: balloon dilation atrial septostomy; BBAS: blade-balloon atrial septostomy; LT: lung transplant. Mo: months.
Atrial Septostomy: Survival

Cumulative survival over time after the procedure. The graph shows both actual and calculated survival rates at various time points.
Anastomosis of the left pulmonary artery with the aorta

Alternative to AS based on a similar physiological rationale: to increase systemic output and to decompress the RV

The main difference is that the right-to-left shunt occurs at the post-tricuspid level

The main advantage of a Potts anastomosis over an AS is that it creates a permanent post-cardiac right-to-left shunt that does not lead to arterial oxygen desaturation in the upper part of the body, including the brain and the coronary circulation
Transcatheter Potts shunt creation
Transcatheter Potts shunt

Palliative Potts shunt for the treatment of children with drug-refractory pulmonary arterial hypertension: updated data from the first 24 patients

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Abstract

OBJECTIVES: Palliative Potts shunt has been proposed in children with suprasystemic pulmonary arterial hypertension (PAH).

METHODS: A retrospective multicentre study was performed to assess short- and long-term outcomes after Potts shunt.

RESULTS: From 2003 to 2014, 24 children underwent a Potts shunt [19 surgical, median age: 7.7 years (1.5–17 years), median weight: 19.5 kg (10.2–47 kg) and 5 transcatheter, median age: 8.1 years (2.3–9.7 years), median weight: 22 kg (12.5–31 kg)] for drug-refractory PAH. For the first time in humans, we performed an unidirectional valved Potts anastomosis in a child with suprasystemic PAH on intravenous epoprostenol who experienced repeated central line infections. Severe postoperative complications occurred in 6 patients (25.0%, all from the surgical group) including 3 early deaths (12.5%) related to low cardiac output. After a median follow-up (FU) of 2.1 years (range, 3 months to 14.3 years; 26 years in 7 patients), World Health Organization (WHO) functional class was dramatically improved in the 21 survivors, all being in WHO-functional class 1 or 2 (P < 0.05); none experienced syncope during the FU; none had overt right ventricular failure; mean 6-min walk distance improved from 42.3 ± 10.0% to 81.2 ± 9.7% of adjusted values for age and sex (P < 0.001). BNP and NT-proBNP levels normalized in all; and wearing of intravenous epoprostenol was obtained in all patients who received triple combination as pre-Potts anastomosis therapy. Finally, all survivors caught up to normal growth curves. Arterial oxygen saturation gradient between upper and lower limbs persisted at the last FU (94.7 ± 3.6% vs 81.6 ± 5.1%, P < 0.001). One patient required double lung transplantation 6 years after a surgical Potts shunt.

CONCLUSIONS: Palliative Potts shunt allows prolonged survival and dramatic, long-lasting improvement in functional capacities in children with severe, drug-refractory PAH. The Potts shunt might be considered as a first surgical or interventional step in the management of children with severe, drug-refractory PAH, leaving the door open for further lung transplantation, if needed.

Experience to date:

- Procedural success in 3 of 4 patients
  - 1 death from uncontrolled hemotherax
  - 1 death 5 days post-procedure from pneumonia

Remaining 2 patients alive with symptomatic and functional improvement

Experimental procedure

Outstanding issues:

- Size of shunt
- Long term durability
- Unknown late complications
- Unidirectional covered stent
Pulmonary artery denervation (PADN) is a novel technique under investigation as a treatment for PH. It is thought to work by reducing sympathetic stimulation of the pulmonary vasculature.

Hypoxia within the pulmonary arteries is thought to lead to increase in b1-adrenoreceptor expression on pulmonary blood vessels.

The upregulation of a1-adrenoreceptors and reduction of adrenergic b-receptors is likely to lead to vasoconstriction rather than vasodilation of the pulmonary vasculature.

PH patients have increased levels of sympathetic activity.

It is postulated that baroreceptors are situated close to the bifurcation of the main pulmonary artery and are involved in facilitating a neural reflex as a result of activation by stretch receptors.
Hemodynamic, Functional, and Clinical Responses to Pulmonary Artery Denervation in Patients With Pulmonary Arterial Hypertension of Different Causes
Phase II Results From the Pulmonary Artery Denervation-1 Study

Shao-Liang Chen, MD; Hang Zhang, MD; Du-Jiang Xie, MD; Juan Zhang, MD; Ling Zhou, MD; Alexander M.K. Rothman, MD; Gregg W. Stone, MD

Background—The mechanisms underlying pulmonary arterial hypertension (PAH) are multifactorial. The efficacy of pulmonary artery denervation (PADN) for idiopathic PAH treatment has been evaluated. This study aimed to analyze the hemodynamic, functional, and clinical responses to PADN in patients with PAH of different causes.

Methods and Results—Between April 2012 and April 2014, 66 consecutive patients with a resting mean pulmonary arterial pressure ≥25 mm Hg treated with PADN were prospectively followed up. Target drugs were discontinued after the PADN procedure. Hemodynamic response and 6-minute walk distance were repeatedly measured within the 1-year post PADN follow-up. The clinical end point was the occurrence of PAH-related events at the 1-year follow-up. There were no PADN-related complications. Hemodynamic success (defined as the reduction in mean pulmonary arterial pressure by a minimal 10% post PADN) was achieved in 94% of all patients, with a mean absolute reduction in systolic pulmonary arterial pressure and mean pulmonary arterial pressure within 24 hours of −10 mm Hg and −7 mm Hg, respectively. The average increment in 6-minute walk distance after PADN was 94 m. Worse PAH-related events occurred in 10 patients (15%), mostly driven by the worsening of PAH (12%). There were 8 (12%) all-cause deaths, with 6 (9%) PAH-related deaths.

Conclusions—PADN was safe and feasible for the treatment of PAH. The PADN procedure was associated with significant improvements in hemodynamic function, exercise capacity, and cardiac function and with less frequent PAH-related events and death at 1 year after PADN treatment. Further randomized studies are required to confirm the efficacy of PADN for PAH.

(Circ Cardiovasc Interv. 2015;8:e002837. DOI: 10.1161/CIRCINTERVENTIONS.115.002837.)
Dynamic changes in mean pulmonary arterial pressure (A), pulmonary vessel resistance (B), 6-minute walk distance (C), and N-terminal pro–brain natriuretic peptide (NT pro-BNP; D, after transferred to log data) levels.
Kaplan–Meier survival analysis.
CTEPH is a disease of obstructive PA remodelling as a consequence of major vessel thromboembolism. CTEPH has been reported with a cumulative incidence of 0.1–9.1% within the first 2 years after a symptomatic PE event. The large margin of error is probably due to referral bias, a paucity of early symptoms and difficulty in differentiating acute PE from symptoms of pre-existing CTEPH. Although the exact prevalence and annual incidence of CTEPH are unknown, some data suggest that this condition may occur in approximately 5 individuals per million population per year.
**Recommendations for PEA: ESC/ERS guidelines**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Level&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>In PE survivors with exercise dyspnoea, CTEPH should be considered</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>Life-long anticoagulation is recommended in all patients with CTEPH</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>It is recommended that in all patients with CTEPH the assessment of operability and decisions regarding other treatment strategies should be made by a multidisciplinary team of experts</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Surgical PEA in deep hypothermia circulatory arrest is recommended for patients with CTEPH</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Riociguat is recommended in symptomatic patients who have been classified as having persistent/recurrent CTEPH after surgical treatment or inoperable CTEPH by a CTEPH team including at least one experienced PEA surgeon</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Off-label use of drugs approved for PAH may be considered in symptomatic patients who have been classified as having inoperable CTEPH by a CTEPH team including at least one experienced PEA surgeon</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>Interventional BPA may be considered in patients who are technically non-operable or carry an unfavourable risk:benefit ratio for PEA</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>Screening for CTEPH in asymptomatic survivors of PE is currently not recommended</td>
<td>III</td>
<td>C</td>
</tr>
</tbody>
</table>

**Rationale for PEA**

- Complete removal and clearance of PA obstructions
- Reduces pulmonary arterial pressure
- Improve pulmonary perfusion, oxygenation, RV function and dead space ventilation
- Improve *life expectancy and quality of life*
36% inoperative, 43% not operated
Interventional BPA may be considered in patients who are technically non-operable or carry an unfavourable risk to benefit ratio for PEA

- technically non-operable patients with non-acceptable risk:benefit ratio can also be considered for BPA.
- In some centres medical therapy and BPA are initiated concurrently.

BPA: balloon pulmonary angioplasty, PEA: pulmonary endarterectomy

What is Balloon Pulmonary Angioplasty (BPA)?

- BPA is an interventional treatment that uses a balloon catheter to dilate pulmonary stenosis or obstruction.

- BPA was first developed in the field of pediatric cardiology for treating congenital stenotic pulmonary arteries.

- The development of BPA for the treatment of inoperable CTEPH patients is extremely slow.

- The first attempt to treat inoperable CTEPH case by BPA was performed in 1988. (Voorburg JA, et al. Chest 1988;94:1249-53)
First case series: 13 years later

Averaged 2.6 procedures, 6 dilations
mPAP decreased from 43.0 to 33.7 mmHg
About 60% of patients developed reperfusion edema (one patient died)

25 years later the 1st European publication

Averaged 3.7±2.1 procedures, 20 patients
mPAP decreased from 45±11 to 33±10 mmHg
About 45% of patients developed reperfusion edema (two patients died)
The most representative results with BPA in the management of patients with inoperable CTEPH

<table>
<thead>
<tr>
<th>First Author (year)</th>
<th>Pts</th>
<th>Procedures</th>
<th>Baseline mPAP (mmHg)</th>
<th>mPAP post BPA (mmHg)</th>
<th>Mean change (%)</th>
<th>Baseline PVR (WU)</th>
<th>PVR post BPA</th>
<th>Mean change (%)</th>
<th>n of deaths</th>
<th>Mortality/procedure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feinstein (2001)</td>
<td>18</td>
<td>48</td>
<td>42±12</td>
<td>33±10</td>
<td>-21</td>
<td>*22±9</td>
<td>*17±8</td>
<td>-23</td>
<td>1/2.0</td>
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<tr>
<td>Andreassen (2013)</td>
<td>20</td>
<td>73</td>
<td>45±11</td>
<td>33±10</td>
<td>-27</td>
<td>8.8±4.0</td>
<td>5.9±3.6</td>
<td>-33</td>
<td>2/2.7</td>
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<tr>
<td>Kurzyna (2017)</td>
<td>56</td>
<td>157</td>
<td>50.7±10.8</td>
<td>35.6±9.3</td>
<td>-30**</td>
<td>10.3±3.7</td>
<td>5.9±2.8</td>
<td>-43**</td>
<td>3/1.9</td>
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<td>Velázquez (2016)</td>
<td>21</td>
<td>75</td>
<td>52.4±13</td>
<td>37.8±10</td>
<td>-28</td>
<td>10.4±4</td>
<td>5.5±2</td>
<td>-47</td>
<td>1/1.3</td>
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<tr>
<td>Olsson (2017)</td>
<td>56</td>
<td>266</td>
<td>40±12</td>
<td>33±11</td>
<td>-18</td>
<td>7.4±3.6</td>
<td>5.5±3.5</td>
<td>-26</td>
<td>1/0.4</td>
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<td>Mizoguchi (2012)</td>
<td>68</td>
<td>255</td>
<td>45.4±9.6</td>
<td>24±6.4</td>
<td>-47</td>
<td>11.8±4.6</td>
<td>4.1±1.9</td>
<td>-65</td>
<td>1/0.4</td>
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<tr>
<td>Kimura (2016)</td>
<td>67</td>
<td>405</td>
<td>39.3±11.0</td>
<td>20.0 ± 4.2</td>
<td>-49</td>
<td>9.7 ± 6.8</td>
<td>3.4±1.5</td>
<td>-65</td>
<td>0/0</td>
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<td>Inami (2016)</td>
<td>103</td>
<td>350</td>
<td>41</td>
<td>21</td>
<td>-49</td>
<td>8.7</td>
<td>2.7</td>
<td>-69</td>
<td>1/0.3</td>
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</tr>
<tr>
<td>Ogo (2016)</td>
<td>80</td>
<td>385</td>
<td>42±11</td>
<td>25±6</td>
<td>-40</td>
<td>11±5.3</td>
<td>5.1±2.3</td>
<td>-54</td>
<td>0/0</td>
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</tr>
<tr>
<td>Kawakami (2016)</td>
<td>97</td>
<td>500</td>
<td>45.1±10.8</td>
<td>23.3±6.4</td>
<td>-48</td>
<td>12±5.7</td>
<td>3.9±1.9</td>
<td>-68</td>
<td>4/0.8</td>
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<tr>
<td>Aoki (2017)</td>
<td>84</td>
<td>424</td>
<td>38 ± 10</td>
<td>25 ± 6</td>
<td>-34</td>
<td>7.3 ± 3.2</td>
<td>3.8±1.0</td>
<td>-45</td>
<td>0/0</td>
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<tr>
<td>Ogawa (2017)</td>
<td>308</td>
<td>1408</td>
<td>43.2±11.0</td>
<td>24.3±6.4</td>
<td>-44</td>
<td>10.7±5.6</td>
<td>4.5±2.8</td>
<td>-58</td>
<td>8/0.6</td>
<td></td>
</tr>
</tbody>
</table>

* Values for Total Pulmonary Resistance (TPR) expressed in WU · m²

** Results from 31 patients who completed their BPA treatment or underwent at least 3 sessions

Contraindications of BPA include iodine allergy, as the use of a contrast medium is essential in BPA.

Additionally, in cases with renal dysfunction, the benefits of performing BPA must be weighed against the risks.

Severity of pulmonary hypertension may not necessarily be a contraindication of BPA. Although previous reports have indicated a higher mean PAP at baseline is associated with more frequent complications, the patient prognosis will be worse without effective treatment in cases with severe hemodynamics. BPA can be expected to have more powerful effect in these patients.
Balloon Pulmonary Angioplasty (BPA)
Recognition of the lesions

• Clearly recorded PAG with deep breath is essential in finding out lesions.

• Most frequently observed lesions are “web” and exist in almost all segments.

• Most of “web” lesions only appear slightly hazy in PAGs.

• Following findings will be some help to recognize lesions.
  • lesion distal delayed flow
  • loss of capillary staining in perfused area
  • occurrence of prominent pulsatile movement of lesion proximal artery
Representative PAG of CTEPH patient

- Yellow: lesion distal delayed flow
- Red: loss of capillary staining of perfused area
- Blue: occurrence of prominent pulsatile movement of lesion proximal artery
5 lesion types are recognized in CTEPH

<table>
<thead>
<tr>
<th>Lesion Type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Lesion Type</td>
<td>Ring-Like Stenosis</td>
<td>Web</td>
<td>Subtotal</td>
<td>Total Occlusion</td>
<td>Tortuous</td>
</tr>
<tr>
<td>Number, n</td>
<td>248</td>
<td>1235</td>
<td>342</td>
<td>67</td>
<td>44</td>
</tr>
<tr>
<td>Bifurcation lesion, n (%)</td>
<td>248 (100)</td>
<td>1092 (88.4)</td>
<td>301 (88.0)</td>
<td>61 (91.0)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

**Distribution (upper/middle or lingular/upper)**

<table>
<thead>
<tr>
<th></th>
<th>Right lung, n</th>
<th>Left lung, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size, mm</td>
<td>4.0 (1.5–6)</td>
<td>3.5‡ (1.5–8)</td>
</tr>
<tr>
<td>Inflated pressure, atm</td>
<td>12 (2–22)</td>
<td>8‡ (2–18)</td>
</tr>
<tr>
<td>Success, n (%)</td>
<td>248 (100)</td>
<td>1219 (98.7)</td>
</tr>
<tr>
<td>Complication, n (%)</td>
<td>4 (1.6)</td>
<td>27 (2.2)</td>
</tr>
</tbody>
</table>

**Type of complication**

- Balloon injury, n: 3
- Wire injury/perforation, n: 0
- Dissection of vessels, n: 1

Values are presented as the median and the range. DRD indicates distal reference diameter; %DS, percent diameter stenosis; MLD, minimal lumen diameter; PRD, proximal reference diameter; QVA, quantitative vascular analysis; and RD, reference diameter.
### Complication; Pulmonary injury

<table>
<thead>
<tr>
<th>Complications</th>
<th>Diagnostic Criteria</th>
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<tbody>
<tr>
<td>Pulmonary injury</td>
<td>Hemoptysis</td>
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<td>Chest radiographic opacities</td>
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<td>Chest computed tomographic opacities</td>
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<td>Pulmonary artery perforation</td>
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<td>Pulmonary artery rupture</td>
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• The most frequent and characteristic complication of BPA is pulmonary injury.

• Pulmonary vessel injury caused by the guidewire, guiding catheter, balloon dilation, or contrast medium injection at high pressure may play a role in inducing pulmonary injury in BPA.

• It is necessary to determine how to dilate the lesion to achieve maximal therapeutic efficacy and reduce the risk of pulmonary vessel injury, which could potentially become lethal. To dilate the lesion, balloon size, vessel size, the number of organised thrombi and patient haemodynamics must be considered. Balloon size is the only one of these factors we can control.
Angiographic extravasation findings of contrast medium after BPA

Vascular injury due to procedural complication is the main cause of pulmonary injury.
Right A10 branch
Representative case. (Considered as high-risk and rejected for BPA in France)
Conclusion

• Despite significant advances in pharmacological treatments, PAH remains incurable. Interventional strategies have been categorized as palliative treatments for PAH.

• On the other hand, balloon pulmonary angioplasty is an effective method for treating patients with CTEPH, who could not benefit from first-line surgical therapy.

• Further refinements of BPA strategy to reduce complications, improvements in the simplicity of the treatment, and evaluation of the long-term follow-up results are needed before BPA can be recommended as an established treatment for CTEPH.