# EVOLVING SURGICAL TECHNIQUES FOR PULMONARY ENDARTERECTOMY ACCORDING TO THE CHANGING FEATURES OF CHRONIC THROMBOEMBOLIC PULMONARY HYPERTENSION PATIENTS DURING 17-YEAR SINGLE CENTER EXPERIENCE

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## Objective

Pulmonary endarterectomy (PEA) is definitely the treatment of choice for chronic thromboembolic pulmonary hypertension (CTEPH). Since population is rapidly aging, an increasing number of elderly patients are referred for PEA. Moreover, due to the surgeon's learning curve, the crucial border between operable and inoperable patients has been pushed distally over time. Hence, at the same time, we developed alternative strategies for obtaining satisfactory surgical results during PEA, as CTEPH patients were getting more complex and frail.

## Methods

From April 1994 to March 2011, 346 PEAs were performed at our Center. Cerebral protection strategy has changed over time, in order to reduce invasiveness and to get more time to perform PEA in a bloodless surgical field, which is mandatory for a complete removal of all thrombotic materials, especially in patients with distal disease (CTEPH with Jamieson type III lesions, as shown in figure). We started according to the original San Diego technique, adopting a single period of deep hypothermic circulatory arrest (HCA) for each side (Group A, 83 patients). Since 2003 we began to perform shorter (10-15 min) periods of intermittent deep HCA followed by short (≥ 5 min) periods of reperfusion (Group B, 70 patients), monitoring cerebral near-infrared spectroscopy (NIRS). We then combined intermittent periods of HCA with moderate instead of deep hypothermia (Group C, 91 patients). Finally, we further modified such technique performing even shorter (5-7 min) periods of moderate HCA (Group D, 102 patients). In this study we analyzed postoperative outcomes according to the different groups.

## Results

Hemodynamic results after PEA have always been excellent during study period: pulmonary vascular resistances dramatically decreased in all groups, although patients of group C and D were older and had more distal thromboembolic lesions. Operative parameters analysis reflected the changes made to our protocol in order to both reduce invasiveness and obtain satisfactory surgical results. In fact, despite higher preoperative risk, patients of group D had a better outcome in terms of incidence of reperfusion oedema and infections, intensive care unit stay and operative mortality. Furthermore, despite increased total circulatory arrest time, moderate hypothermia and intermittent circulatory arrest allowed a reduced incidence of neurological events (see table for details).

**Conclusions**
In our 17-year experience, short intermittent periods of moderate HCA seem to guarantee the better combination of surgical accuracy and cerebral protection, thus allowing for favourable postoperative outcomes. Therefore, we do support such strategy as the technique of choice during PEA.

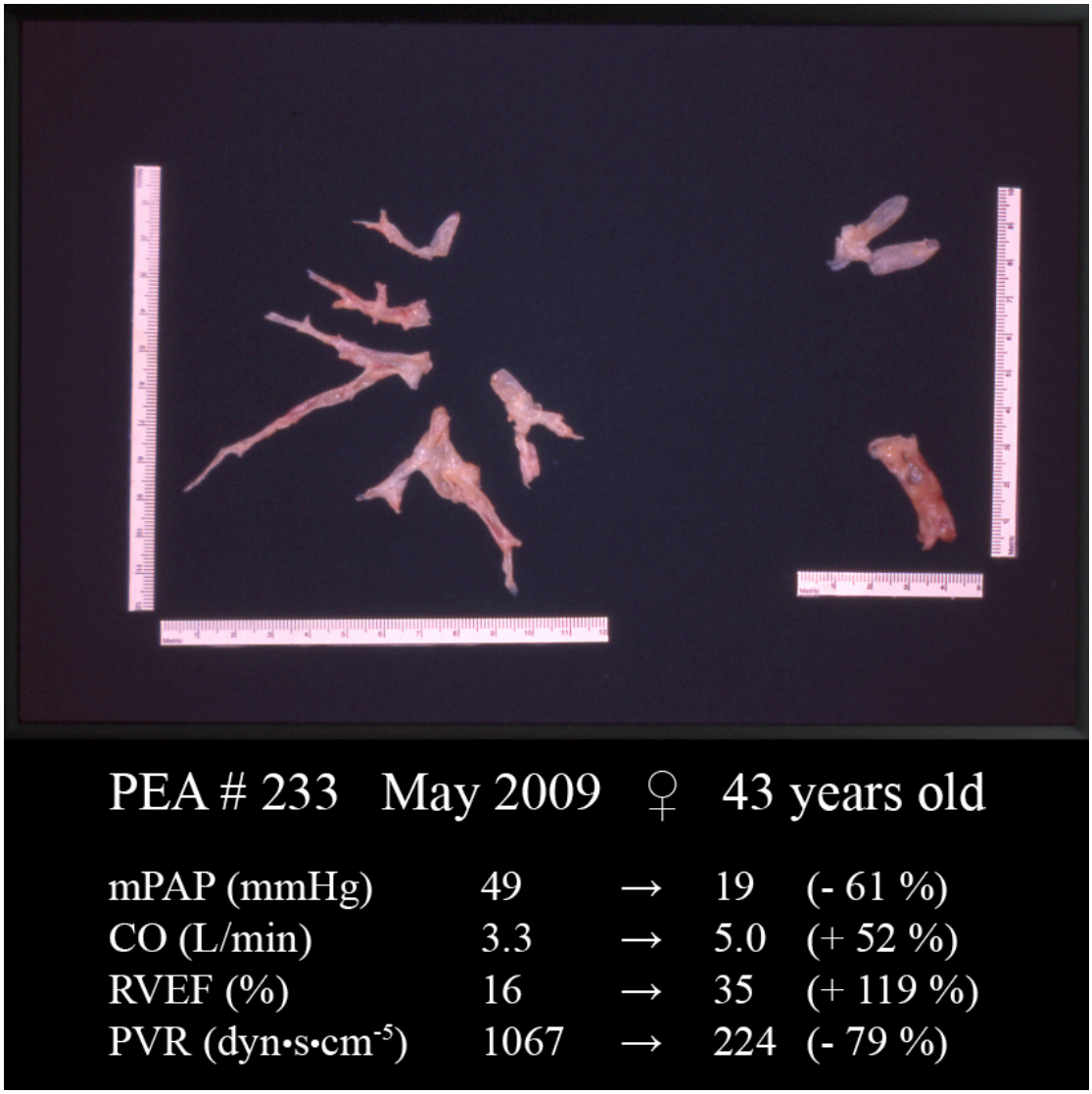


**Figure**: A typical CTEPH Jamieson type III surgical specimen with preoperative and postoperative hemodynamic parameters.
mPAP: mean pulmonary arterial pressure; CO: cardiac output; RVEF: right ventricular ejection fraction; PVR: pulmonary vascular resistances.

| | Group A (83 pts) | Group B (70 pts) | Group C (91 pts) | Group D (102 pts) | $p < 0.05$ |
|---|---|---|---|---|---|
| Mean preoperative PVR | 1166±451 | 1029±531 | 861±441 | 911±416 | A vs. C and D |
| Mean postoperative PVR | 341±237 | 270±179 | 276±129 | 316±202 | A vs. B and C |
| Mean age at PEA (yrs) | 52±15 (17-78) | 56±16 (11-81) | 60±15 (19-84) | 61±15 (24-83) | A vs. B, C and D<br>B vs. C and D |
| Age > 70 yrs at PEA | 10.8 % (9/83) | 22.9 % (16/70) | 34.1 % (31/91) | 37.3 % (38/102) | A vs. B, C and D<br>B vs. D |
| Jamieson III – IV | 21.7 % (18/83) | 27.1 % (19/70) | 26.4 % (24/91) | 31.4 % (32/102) | A vs. D |
| CPB time (min) | 237±77 (105-620) | 309±101 (130-620) | 332±79 (172-640) | 346±84 (115-640) | A vs. B, C and D<br>B vs. C and D |
| Temperature (° C) | 17.5±1.5 (15-25) | 17.9±2.0 (16-28) | 23.3±1.9 (18-25) | 24.0±0.8 (23-29) | A vs. C and D<br>B vs. C and D |
| Total HCA time (min) | 26±15 (0-82) | 51±29 (4-127) | 86±36 (11-192) | 85±36 (0-181) | A vs. B, C and D<br>B vs. C and D |
| Number of HCA | 2.0±0.7 (0-4) | 3.6±1.5 (1-8) | 8.9±3.9 (2-22) | 13.2±4.8 (0-26) | All Groups |
| Median ICU stay (days) | 6 [13-4] (1-76) | 5 [9-3] (1-67) | 5 [8-3] (0-83) | 3 [6-2] (1-76) | A vs. B, C and D |
| Reperfusion oedema | 20.5 % (17/83) | 5.7 % (4/70) | 3.3 % (3/91) | 6.9 % (7/102) | A vs. B, C and D |
| Infections | 31.3 % (26/83) | 44.3 % (31/70) | 30.8 % (28/91) | 11.8 % (12/102) | D vs. A, B and C |
| Neurologic events | 15.7 % (13/83) | 14.3 % (10/70) | 9.9 % (9/91) | 3.9 % (4/102) | D vs. A, B and C |
| Operative mortality | 10.8 % (9/83) | 7.1 % (5/70) | 8.8 % (8/91) | 6.9 % (7/102) | Not significant |

**Table**: Preoperative, operative and postoperative characteristics of CTEPH patients who underwent PEA at our Center, grouped by cardiopulmonary bypass management and cerebral protection strategy.
PVR: pulmonary vascular resistances ($dyn \cdot s \cdot cm^{-5}$); CPB: cardiopulmonary bypass; ICU: intensive care unit.