SURGICAL TECHNIQUE

Bilateral pulmonary thromboendarterectomy with transpulmonary vision with lens for complete organized intravascular thrombotic material resection

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Pulmonary thromboendarterectomy is the definitive treatment for pulmonary thromboembolic pulmonary hypertension. Its incidence is unknown; approximately 5% of patients with episodes of pulmonary embolism may present it. The technical aspects of the procedure can be challenging, requiring pulmonary vascular dissection, profound hypothermia, and circulatory arrest. Just as the determination of patients who benefit from surgery depends largely on the experience of the team. Some technical aspects of the procedure will be reviewed.

***Key words:** Chronic Thromboembolic; Pulmonary Hypertension; Pulmonary Thromboendarterectomy; Thoracoscopy.*

La tromboendarterectomía pulmonar es el tratamiento definitivo para la hipertensión pulmonar tromboembólica. Su incidencia es desconocida; aproximadamente 5% de los pacientes con episodios de embolia pulmonar pueden presentarla. Los aspectos técnicos del procedimiento pueden ser desafiantes, requieren una disección vascular pulmonar, hipotermia profunda y paro circulatorio. Así como la determinación de pacientes que se benefician de la cirugía depende en gran medida de la experiencia del equipo. Se revisarán algunos aspectos técnicos del procedimiento.

***Palabras clave:** Tromboembolica Crónica; Hipertension Pulmonar; Tromboendarterectomia Pulmonar; Toracoscopia.*

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Pulmonary thromboendarterectomy (PTE) remains the preferred option and potentially curative for patients with chronic thromboembolic pulmonary hypertension (CTEPH). The disease is characterized by the organization of intraluminal thrombi, fibrosis and scar tissue-like stenosis with resultant vascular remodeling of the pulmonary vessels. The exact prevalence of CTEPH is unknown, it is suggested that it may occur in approximately 5% of patients after acute pulmonary embolism, making CTEPH one of the most common causes of precapillary pulmonary hypertension (PH).

Although surgery may be potentially curative, there are only about 0.9 to 1 endarterectomy per million population performed in the United States annually. When the diagnosis is made, there is often a delay in referral to expert centers to consider surgery as treatment [1,2]. Training of PTE surgeons to master the techniques of this challenging operation should remain a priority in the treatment of this disease. Acute pulmonary thromboembolism and its chronic sequelae are significant causes of morbidity and mortality in the world. However, the chronic disease process, even when established and symptomatic, is underdiagnosed due to the nonspecific nature of its main symptoms, dyspnea on exercise and fatigue, until right heart failure becomes apparent.

Once chronic PH develops, the prognosis is poor. Once the mean pulmonary pressure in patients with CTEPH reaches 50 mm Hg or more, the 3-year mortality is close to 90%. Thus, despite a better understanding of the pathogenesis, diagnosis, and management, pulmonary embolism and long-term sequelae of CTEPH remain common and often fatal [1].

Pulmonary endarterectomy is a technically demanding operation, currently performed in only a few select centers around the world. Proper patient selection, meticulous surgical technique, and careful postoperative management have contributed to the effectiveness of this procedure. An adequate endarterectomy of all affected segments of the pulmonary artery is essential to clear the affected areas of the pulmonary vasculature.

When performed in an experienced center, the procedure improves PH by removing pulmonary ventilation-perfusion disturbance, significantly improving right ventricular (RV) function and tricuspid regurgitation, which limits thrombus expansion and prevents arteriopathological changes [1].

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Factors involved in patient selection

The evaluation of operability in patients with CTEPH is crucial since surgery can be curative. The evaluation should be performed by an expert interdisciplinary team that includes pneumologists, cardiologists, radiologists, anesthesiologists, and surgeons. It is based on multiple factors, including the severity of the patient's symptoms and the severity of PH and right ventricle dysfunction as well as the relationsh between the severity of this hypertension and the degree of obstruction. Like any other surgical procedure, individual patient factors; comorbidities, technical challenges and level of expectations for long-term benefits figures in decision making [1,2].

An "expert center" is defined as one that performs more than 20 PTE procedures per year with a mortality rate less than 10%. To select patients suitable for surgery, it is necessary, through imaging and hemodynamic studies, to determine the accessibility of the thrombus, the extent of the obstruction of the vessels and the correlation of this obstruction with the hemodynamic parameters. Chronic thromboembolic obstruction is divided according to the Jamieson classification (**Table 1**).

Table 1. Jamieson Classification

TYPE OF LESION	DESCRIPTION
0	No Pulmonary Thromboembolism
I	Central Artery Thromboembolism
Ic	Complete obstruction without pulmonary perfusion
II	Lobar artery thromboembolism
III	Segmental artery thromboembolism
IV	Subsegmental artery thromboembolism

Preoperative evaluation of pulmonary vascular resistance (PVR) is a reflection not only of central or proximal obstruction, but also of existing distal arteriopathy. These patients with PVR > 1100 dynes s cm-5 do not benefit from the surgical procedure because PVR decreasing is often not significant after PTE and the short- and long-term prognosis is poor [2]. When the PVR is >500 dynes/s/cm^{-5}, it has a perioperative mortality of 30%, while if it is <500 dynes/s/cm^{-5}, the mortality is 1%. Severe damage to the lung parenchyma contraindicates PTE [2] (**Table 2**).

Table 2. Patient selection criteria to endarterectomy.

PATIENT SELECTION CRITERIA
Pulmonary obstruction PVR > 300 dynes/s/cm^{-5}
Accessible Lesion
NYHA Functional Classification III or IV
Absence of concomitant sever lung parenchyma disease
Corelation by angiographic image and PVR
Low mortality
Mean pulmonary artery pressure >25 mmHg
PVR < 1100 dynes/s/cm^{-5}
Right ventricular diastolic pressure <15mmHg

PVR= Pulmonary Vascular Resistance. NYHA= New York Heart Association.

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Pulmonary thromboendarterectomy follows four basic principles: a) endarterectomy must be bilateral through a median sternotomy approach; b) use of extracorporeal circulation and periods of circulatory arrest that are usually limited to 20 minutes at a time and supported by cooling to approximately 20ºC; c) identify the plane of endarteric dissection to avoid suboptimal results or pulmonary artery injury; d) a complete endarterectomy.

After performing a median sternotomy, the pericardium is incised in an inverted T-shape. It is cannulated for extracorporeal circulation using high ascending aortic cannulation, cannulation of left cavities by right superior pulmonary vein and bicaval drainage. The patient is cooled to 20°C with extracorporeal circulation and superficial cooling of the head and body [1,2]. The approach to right pulmonary artery is made medial to the superior vena cava, mobilizing it completely. Once the core temperature has reached 20°C, aortic cross-clamping is performed and myocardial protection is placed, with antegrade cold solution. Custodiol is used in our institution. The superior and inferior venae cavae are cinched. A longitudinal incision is made in the center of the right pulmonary artery from below the ascending aorta to just before the edge of the pericardial flexure (**Fig. 1**).

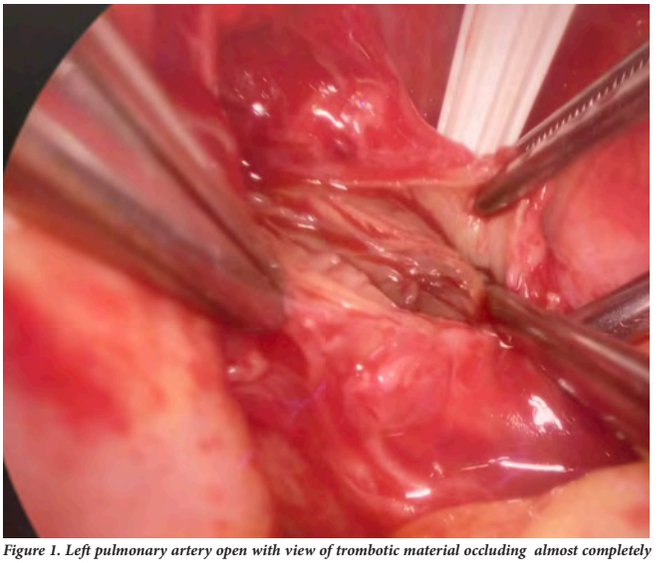

Figure 1. Left pulmonary artery open with view of trombotic material occluding almost completely pulmonary flow

It is necessary to obtain good visualization, an embolectomy without endarterectomy is ineffective for treatment, in most patients with CTEPH, direct examination of the pulmonary vascular bed usually does not show obvious embolic material, so we implement the use of a 5mm lens, with 30º angle for the correct visualization of the endartery (organized intravascular thrombotic material) from the main pulmonary branches, following their dissection to the lobar and segmental branches, with adequate lighting, depth and evidence of adequate removal of endartery (**Fig. 2**).

If the bronchial circulation is not excessive, the plane of the endarterectomy can be found during this early dissection. It is unwise to proceed to circulatory arrest unless visibility is perfect, identification of a correct shot is essential. Once circu-

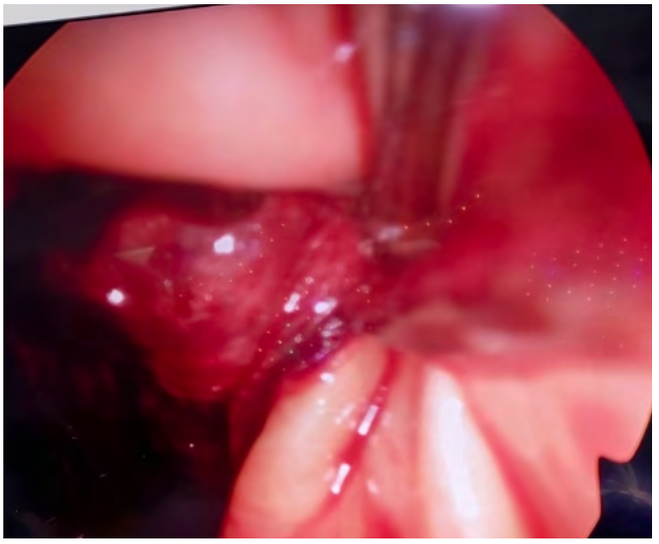

Figure 2. View of the pulmonary artery through a thoracoscopic lens. Acute thrombus in bifurcation of lobar arteries.

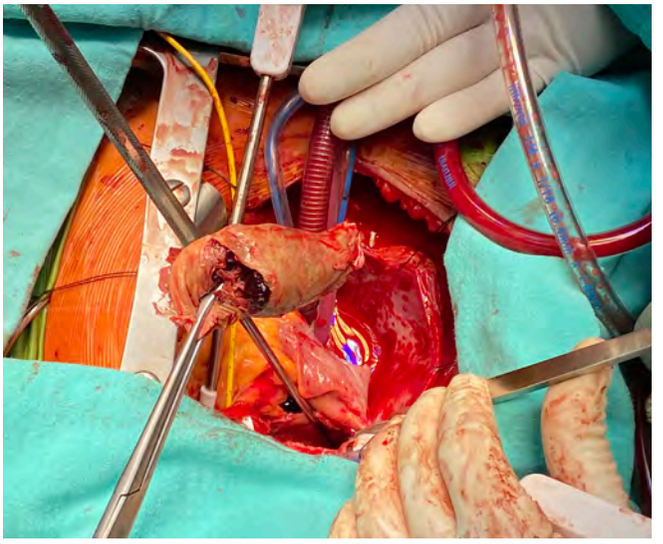

Figure 4. Excision of complete thrombotic material, acute and chronic thrombotic material within the same sample.

latory arrest begins, the patient is exsanguinated. The correct plane appears pearly white, is smooth and silky, lying between the intima and media [1]. We must remember that these stoppage periods do not exceed 20 minutes for each side. During these, the endarterectomy is performed with an eversion technique, carefully pulling the endartery with Madani dissections, and the dissection of the plane is performed with the Jamieson dissector. Because the vessel is everted and the subsegmental branches are being worked on, a perforation here will become completely inaccessible and catastrophic (**Fig. 3**).

It is important that each subsegment be pulled along the endartery line, try not to cut to maintain a constant traction site [1,2].Once the endarterectomy on the right side is complete, circulation is restarted and arteriorhaphy is performed with a continuous 5 or 6-0 polypropylene suture, either the Carrell or over and over technique. After closure of the right arteriotomy, the surgeon moves to the patient's right side. A left pulmonary arteriotomy is performed following the same steps (**Fig. 4**).

After the endarterectomy is complete, warm-up is started. The warm-up period generally takes approximately 90 to 120 minutes, but varies depending on the patient's body mass. If other cardiac procedures, coronary artery surgery or valve surgery are required, they are conveniently performed during the rewarming period [1]. Although tricuspid valve regurgitation is variable in these patients often tricuspid valve repair is not necessary unless there is an anatomic abnormality. When the patient has completely warmed up, extracorporeal circulation has been withdrawn, the placement of the pacemaker cable and closure of the sternotomy continue in the usual fashion for other cardiac procedures.

In our experience, it has greatly facilitated the successful removal of endartery (organized intravascular thrombotic material) through the use of a thoracoscope through the pulmonary artery lumen to ensure proper removal, no residual endartery (organized intravascular thrombotic material) left behind, better visualization of the pulmonary vascular tree at greater depth, and in If there is any complication, identify it in time and devise the most effective method to repair it.

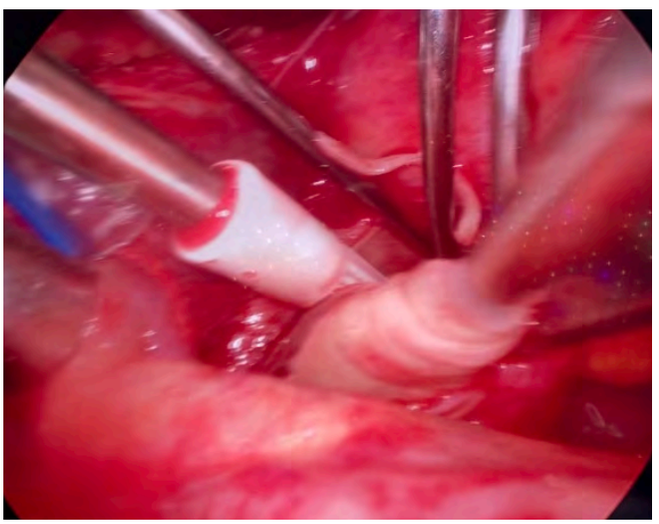

Figure 3. Thromboendarterectomy by refraction of thrombotic material in circulatory arrest.

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