Türk Göğüs Kalp Damar Cerrahisi Dergisi 2012;20(3):442-449
doi: 10.5606/tgkdc.dergisi.2012.088

Original Article / Özgün Makale

Pulmonary embolectomy and thromboendarterectomy in seven cases

Yedi olguda pulmoner embolektomi ve tromboendarterektomi

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Background: This study aims to reduce the uncertainity related to the prognosis after surgery of the acute pulmonary embolism (APE) and chronic thromboembolic pulmonary hypertension (CTPHT) patients, and to encourage physicians to consider surgical treatment options based on the evidence-based data which suggests that surgery offers the best chance for improvement in these patients.

Methods: Between February 2009 and October 2010, seven cases (3 males, 4 females; mean age 43.8±18.5 years; range 25 to 73 years) who were operated on due to APE and CTPHT were included in this observational and retrospective study. The pre- and postoperative mean pulmonary artery pressure (mPAP), New York Heart Association (NYHA) functional class, and length of stay in the intensive care unit (ICU) and hospital along with the demographic, clinical and operational characteristics of the patients were recorded. Statistical analyses were performed using nonparametric tests due to the limited number of cases. Wilcoxon's test was used to compare the groups.

Results: The mPAP reduced by 20 mmHg (range 5-53) following surgery, and the mPAPs in all the patients, except for the sixth case, decreased below 30 mmHg. The pre- and postoperative mPAPs were 43 mmHg (range 33-68) and 23 mmHg (range 15-37), respectively. This indicated that a significant reduction occurred following surgery (z=-2.36; p=0.018). In addition, the NYHA functional class of the patients improved by one unit following surgery (range I-III). The patients pre- and postoperative NYHA classes were III (II-III) and II (I-II), respectively. The improvement after surgery was significant with a decline in the NYHA class (z=-2.26; p=0.024). The patients also averaged a stay of three days in the ICU (range 2-14) and 9.5 days (range 5-27) in the hospital.

Conclusion: Our study results suggest that physicians should not be reluctant to choose the surgical option and should endeavor to improve the quality of life of their patients through a detailed preoperative assessment and proper patient selection.

Key words: Acute pulmonary embolism; chronic thromboembolic pulmonary hypertension; functional capacity; mean pulmonary artery pressure; pulmonary thromboendarterectomy.

Amaç: Bu çalışmanın amacı, akut pulmoner emboli (APE) ve kronik tromboembolik pulmoner hipertansiyon (KTPHT) olgularının cerrahi ile belirgin olarak düzeldiklerini öngören kanıta dayalı veriler temelinde cerrahi sonrası seyir ile ilgili belirsizliği azaltmak ve bu olgularda cerrahi tedavi seçeneklerini dikkate alan doktorları cesaretlendirmektir.

Çalışma planı: Bu gözlemsel ve geriye dönük gerçekleştirilen çalışmaya Şubat 2009 ile Ekim 2010 tarihleri arasında, APE ve KTPHT tanısı ile ameliyat edilen yedi olgu (3 erkek, 4 kadın; ort yaş 43.8±18.5 yıl; dağılım 25-73 yıl) dahil edildi. Hastaların ameliyat öncesi ve sonrası ortalama pulmoner arter basıncı (mPAP), New York Heart Association (NYHA) fonksiyonel sınıfı, yoğun bakım ünitesi (YBÜ) ve hastanede kalış süresi, demografik, klinik ve ameliyat özellikleri kaydedildi. Olgu sayısının yetersizliğinden dolayı istatistiksel analizler, parametrik olmayan testler ile yapıldı. Grupların karşılaştırılmasında Wilcoxon testi kullanıldı.

Bulgular: Cerrahi sonrasında bütün hastalarda mPAP'da 20 mmHg (dağılım 5-53) düşüş sağlandı ve altıncı olgu hariç tüm olguların mPAP'ları, 30 mmHg'nın altına çekildi. Ameliyat öncesi ve sonrası mPAP'ları, sırasıyla 43 mmHg (dağılım 33-68) ve 23 mmHg (dağılım 15-37) idi. Bu durumda cerrahi sonrasında anlamlı bir düşüş elde edildi (z=-2.36; p=0.018). Buna ilaveten, cerrahi sonrasında hastanın NYHA sınıfındaki iyileşmesi 1 (dağılım 1-3) birimdi. Hastaların ameliyat öncesi ve sonrası NYHA sınıfları sırasıyla III (II-III) ve II (I-II) idi. Ameliyat sonrası NYHA sınıfındaki düşüş ile birlikte cerrahinin iyileştirme üzerine etkisi anlamlıydı (z=-2.26; p=0.024). Yoğun bakım ünitesi ve hastanede ortalama kalış süreleri, sırasıyla üç (dağılım 2-14) ve 9.5 (dağılım 5-27) gündü.

Sonuç: Çalışma bulgularımıza göre, ayrıntılı bir ameliyat öncesi değerlendirme ve uygun hasta seçimi ile hekimler, cerrahi seçeneğin kararında çekimser olmamalı ve hastaların yaşam kalitesini artırmak için çaba harcamalıdır.

Anahtar sözcükler: Akut pulmoner emboli; kronik tromboembolik pulmoner hipertansiyon; fonksiyonel kapasite; ortalama pulmoner arter basıncı; pulmoner tromboendarterektomi.

Available online at
www.tgkdc.dergisi.org
doi: 10.5606/tgkdc.dergisi.2012.088
QR (Quick Response) Code

Received: January 28, 2011 *Accepted:* August 1, 2011

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Acute pulmonary embolism (APE) is the third leading cause of death worldwide with an overall mortality rate of 17.4% within 90 days.[1] The operative mortality rate for a surgical embolectomy is stated to be 20-50% because it is usually performed on moribund patients and is often followed by prolonged resuscitation.[2,3] Because of this, a surgical embolectomy is seldom performed today, even though it is a viable option for the management of these patients. On the other hand, a surgical embolectomy performed in cases of APE has also been stated to reduce the progression to chronic thromboembolic pulmonary hypertension (CTPHT).[4]

This type of hypertension, in which pulmonary vasculopathy is the major pathophysiological mechanism, is a rare complication of an APE episode and has an incidence rate ranging from 0.5-3.8%.[5] Echocardiographic evaluation of survivors of the first episode of APE at one year revealed a 44% persistence rate of PHT and right ventricular (RV) dysfunction.[6] In cases with a mean pulmonary artery pressure (mPAP) of more than 50 mmHg, the two-year survival rate was less than 20%.[7] Kunieda et al.[8] stated the survival rate in cases with an mPAP of 50 mmHg as 6.8 years. While Matsuda et al.[9] reported a 7.8% in-hospital mortality rate after a pulmonary thromboendarterectomy (PTEA), the survival rate, including in-hospital death was 90.9% at three years. Together with hemodynamic improvement, Saouti et al.[10] also pointed out the improvement in New York Heart Association (NYHA) class.

Persistent PHT after PTEA is believed to result from concomitant pulmonary vasculopathy.[11] Post-PTEA PHT not only remains a critical and consistent determinant of perioperative risk but also predicts long-term survival.[12,13] The type of disease is another predictor of outcome. For example, when type 3 and 4 disease is compared with type 1 and 2, a longer need for inotropic support and length of hospital stay is required and higher levels of mPAP and pulmonary vascular resistance occur.[14] In cases with symptomatic CTPHT, the reported perioperative mortality rate for PTEA ranges from 5-11%, but these ratios are lower in medical centers with experience performing this procedure.[15,16] While PTEA is the only option that provides an immediate and permanent cure for this devastating disease, it is rarely performed today.[9,10,15,17,18]

Although currently there is an unwillingness to perform this troublesome surgical procedure, the aim of this article is to present PTEA as a viable alternative for selected patients with low functional capacity in which an obvious improvement in hemodynamic compromise is possible.

PATIENTS AND METHODS

This observational study was performed retrospectively, and only cases of APE and CTPHT (three males and four females; mean age 43.8±18.5 years; range 25 to 73 years) reported between February 2009 and October 2010 were included in the study. Pre- and postoperative mPAPs, NYHA functional classes, length of intensive care unit (ICU) and hospital stays, demographics, and clinical and operational characteristics were obtained from the archives. The results of the postoperative mPAPs and NYHA functional classes were assessed one month after discharge.

Table 1. Demographic, clinical and operative characteristics of cases

Case number	1	2*	3	4	5	6**	7
Age, gender	41/F	65/M	29/F	44/F	73/F	30/M	25/M
Disease type	2	1, APE	APE	1	APE	4	2
Preoperative mPAP (mmHg)	68	48	36	43	33	42	55
Postoperative mPAP (mmHg)***	15	29	15	23	22	37	30
NYHA class (pre- and postoperative)	3/1	3/2	4/1	3/2	3/2	3/exitus	3/2
Postoperative D-shaped pattern	imp.	p.imp.	imp.	imp.	imp.	not imp.	imp.
Core temperature (C°)	18	28/28	32	32	38	18	18
Total cardiopulmonary bypass	+	+/+	–	–	–	+	+
Aortic cross-clamp time (minute)	61	54/50	–	–	–	75	70
Total circulatory arrest time (minute)	37	-/-	–	–	–	30	35
Cardiopulmonary bypass time (minute)	112	78/68	49	21	17	140	135
Postoperative nitric oxide usage	–	+	–	–	–	+	+
Length of intensive care unit stay (day)	3	14	2	3	2	3	5
Length of hospital stay (day)	5	20	27	7	6	exitus	12

* Case 2 had a redo pulmonary thrombectomy; ** Case 6 presented serious right ventricular failure and died on postoperative day three; *** Stated postoperative mPAPs were assessed one month after discharge; APE: Acute pulmonary embolism; mPAP: Mean pulmonary artey pressure; NYHA: New York Heart Association; p.imp.: Partially improved.

Statistical analyses were performed with the Statistical Package for the Social Sciences version 15.0 (SPSS Inc., Chicago, Illionois, USA). Due to the inadequate number of cases, nonparametric tests were performed. The results of descriptive statistical analysis are stated as median with minimum and maximum values. The comparison between the two groups was commenced using the Wilcoxon test. Values of p less than 0.05 were considered statistically significant.

Seven cases (two with type 2 disease, two with type 1, one with type 4, and two with APE) had undergone surgery. Case 2 had a postoperative surgical embolectomy after surgery for type 1 disease. The clinical and operative characteristics of the cases along with the demographics are revealed in Table 1. All cases were treated with lifelong warfarin after discharge with a targeted international normalized ratio (INR) range of 2.5-3.5.

All surgical procedures began through median sternotomy. The surgical plan depended on the type of disease. Total cardiopulmonary bypass (CPB) was not performed nor was an aortic cross-clamp applied in cases with type 1 CTPHT and APE, except for the patient in case 2. This variance in surgical management was due to the difference in management protocols of the attending surgeons. In cases with type 2 and 4 disease, surgery was performed under deep hypothermic total circulatory arrest. Again, the deviations in core temperature (moderate hypothermic to normothermic) used during surgery for APE was due to the different management protocols of attending surgeons. Pulmonary arteriotomies in all cases were initiated from the pulmonary trunk 1-2 cm above the pulmonary valve and were extended through the left pulmonary artery beyond the pericardial reflexion until the subsegmental level was reached. A right pulmonary arteriotomy was initiated as a separate incision between the aorta and the superior vena cava and was extended beyond the pericardial reflexion identical to the one on the left side.

The reason for admission for case 1 was dyspnea over a period of six months without a history of venous thromboembolism (VTE). Arterial blood gas (ABG) analysis revealed the following: pH: 7.46, pO_2: 71.8, pCO_2: 33.7, and O_2 saturation: 95.3%. Doppler ultrasonographic evaluation of the lower extremities

Figure 1. The transverse **(a)** and frontal **(b)** plane computed tomography angiogram of case 1 is shown with indicators revealing the filling defects at the right pulmonary arterial branch. **(c, d)** Reveal the appearence of the endarterectomized material. The indicators show the lober (*), segmental (+) and subsegmental (#) levels.

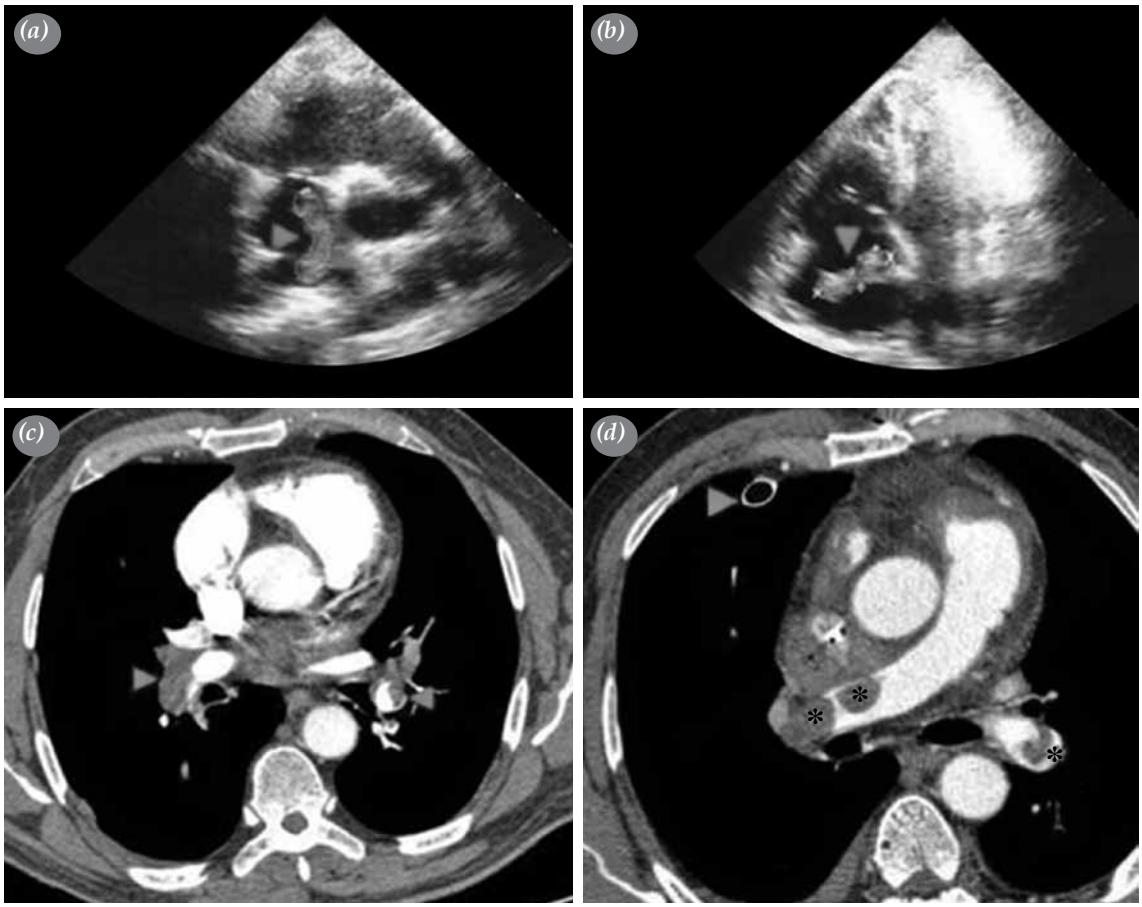

Figure 2. The echocardiogram **(a, b)** and transverse CT angiogram **(c, d)** of case 2 is shown. ▶ points to the mobile thrombus echogenity in **(a)** and **(b)**, and ▶ in **(c)** and * in **(d)** reveal the filling defects. ▶ in **(d)** indicates the left chest tube.

showed a lack of deep vein thrombosis (DVT). A transthoracic echocardiographic (TTE) evaluation revealed typical bounce movement at the base of the interventricular septum and a D-shaped pattern along with an mPAP of 70 mmHg. Upon right heart catheterization, the cardiac index was 2.3 l/min/m^2, the mPAP was 68 mmHg, the pulmonary vascular reactivity test with adenosine was negative, and pulmonary vascular resistance was 598.47 dyn-sn-cm-5. As revealed in Figure 1, filling defects at the bilateral pulmonary arterial tree on computed tomography (CT) angiogram together with the bilateral endarterectomy material indicated type 2 disease.

Case 2 was referred to us for etiological evaluation of syncope. He had been complaining of paroxysmal dyspnea for three months. Arterial blood gas analysis showed to following: pH: 7.5, pO_2: 63.1, pCO_2: 21.1, and O_2 saturation: 92%. A TTE evaluation (Figures 2a, b) determined an mPAP of 48 mmHg, a D-shaped pattern, and a heterogen mobile right atrial density which was prolabing to the right ventricle (RV) at diastole. As shown in Figure 2c, CT angiogram revealed filling defects at the bilateral pulmonary arterial and lobal levels. The surgical procedure began with a right atriotomy, followed by a right ventriculotomy and a pulmonary arteriotomy due to the association of a mobile right atrial density due to the pulmonary vascular filling defects. During the right atriotomy, no thrombus material was detected, and it was thought that it had progressed into the RV. When it was not detected through a right ventriculotomy, it was thought to have embolized into the pulmonary vasculature, and the operation carried on with standard pulmonary arteriotomies. Bedside TTE on postoperative day five revealed an mPAP of 32 mmHg and a partially improved D-shaped pattern. Due to his clinical situation, inhaled nitric oxide (NO) was supplied throughout the course of the intubation period. Under heparinization on postoperative day seven, left lower limb swelling developed. Doppler evaluation pointed to an acute thrombus at the calf and popliteal level. On postoperative day nine, sudden onset dyspnea, desaturation, and hemodynamic compromise developed.

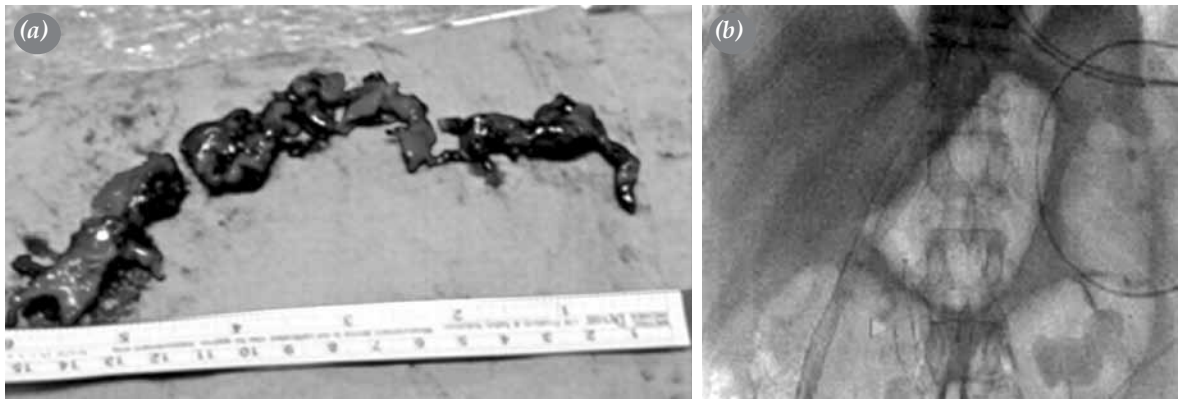

Figure 3. Thrombectomy material **(a)** and inferior vena cava filter **(b)** of case 2.

Emergent CT angiogram showed filling defects in the main pulmonary arteries (Figure 2d) and an emergency surgical embolectomy was performed together with the implantation of an inferior vena cava filter (Figure 3). The case was heterozygous for methylenetetrahydrofolate reductase (MTHFR) A1298C.

In case 3 with portal vein thrombosis, selective thrombolysis through superior mesenteric artery catheterization had been performed previously. On the third day of thrombolysis and the seventh day of heparinization, retroperitoneal hematoma along with left lower limb swelling developed. He had a history of VTE along with heterozygous Factor V Leiden (FVL) and prothrombin G20210A (PT) mutations. A Doppler ultrasonographic evaluation revealed an acute thrombus at the calf extending to the common femoral vein. After a short period of time, he developed sudden onset dyspnea with hypotension. Arterial blood gas analysis revealed the following: pH: 7.44, pO_2: 65, pCO_2: 22.6, and O_2 saturation of 90.5%. Transthoracic echocardiography pointed to a thrombus bound with a slim portion of the septa to the right atrial wall and a mobile thrombus in the main pulmonary artery. The RV was dilated and the mPAP was 36 mmHg. He emerged to the operating room under deep hypotension. A surgical embolectomy revealed fresh thrombus (Figure 4).

Case 4 had complained of left calf swelling for one month and an effort dyspnea for three days. Her Doppler ultrasonography revealed an occluded left popliteal vein with an acute thrombus extending to the superficial femoral vein. A TTE evaluation showed a D-shaped pattern with a dil-ated RV and an mPAP of 43 mmHg. A magnetic resonance angiogram pointed to the occlusive changes along with a loss of visualization at the left pulmonary vasculature.

Case 5 had been admitted to the emergency department with retrosternal pain which had been diagnosed as acute coronary syndrome and had been evaluated with coronary angiography that revealed noncritical stenosis. After a while, she had complained of chest pain and shortness of breath. Arterial blood gas analysis revealed the following: pH: 7.5, pO_2: 66.4, pCO_2: 28.4, and O_2 saturation: 91%. A TTE evaluation showed RV dilatation with a D-shaped pattern and an echogen thrombus in the common pulmonary artery along with an mPAP of 33 mmHg. An urgent surgical embolectomy was performed (Figure 5).

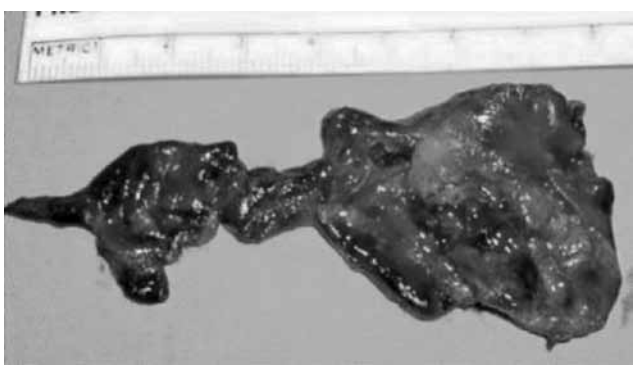

Figure 4. Thrombectomy material of case 3.

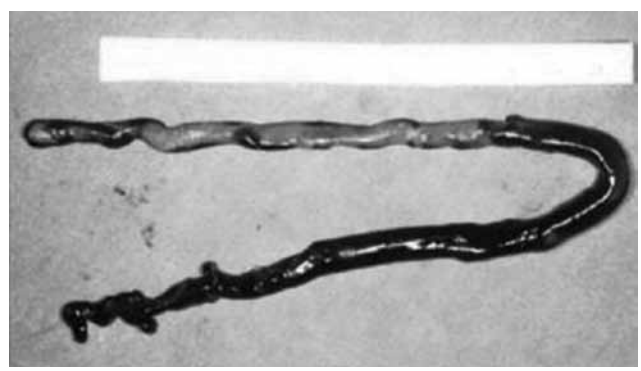

Figure 5. Thrombectomy material of case 5.

With a history of pulmonary embolism, case 6 was referred with symptoms of NYHA class III heart failure. A TTE evaluation revealed an mPAP of 42 mmHg along with a D-shaped pattern and an extremely dilated RV. He was homozygous for FVL and MTHFR C677T. At his operation, the type 4 disease was very extensive and stiff making it difficult to remove, and the endarterectomy had to be extended to the segmental levels. Disconnection from CPB was associated with serious RV failure. Inhaled NO was commenced in the operation room, but the patient died on postoperative day three.

Case 7 had a history of DVT and had been complaining of progressive effort dyspnea for three years. Arterial blood gas analysis showed the following: pH: 7.49, pO_2: 96, pCO_2: 21.8, and O_2 saturation: 96%. He was homozygous for FVL. Transthoracic echocardiography found an mPAP of 55 mmHg along with a D-shaped pattern and RV dilatation. His CT angiogram revealed type 2 disease. While early postoperative bedside TTE revealed an mPAP of 38 mmHg, he was managed with NO through the intubation period. His TTE evaluation revealed an mPAP of 30 mmHg along with an improvement in RV dilatation and the D-shaped pattern.

RESULTS

All cases, except for the one with type 4 disease, benefited from the surgery. The median mPAP decrease was 20 mmHg (range 5-53), and the mPAP in all the cases dropped below 30 mmHg, except for case 6 (Figure 6). The median of the mPAPs before and after surgery were, 43 mmHg (range 33-68) and 23 mmHg (range 15-37), respectively, and the decline achieved with surgery was significant (z=-2.36; p=0.018). As revealed in Figure 7, the median improvement in NYHA class for the patients was one (I-III). The median value of pre- and postoperative NYHA classes were, III (II-III) and II (I-II), respectively. The improving effect of surgery, as revealed in the decrease in NHYA class, was significant (z=-2.26; p=0.024). The preoperative D-shaped pattern of the RV was improved in all cases, except for cases 2 and 6. The median value of length of stay in the ICU and hospital was three days (range 2-14) and 9.5 days (range 5-27), respectively.

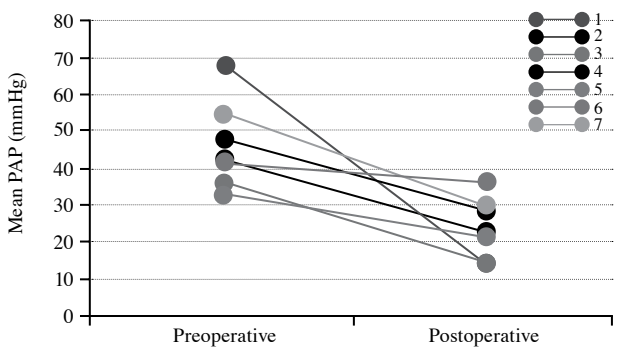

Figure 6. Improvement of the mPAP with surgery; the median of the mPAPs before and after surgery were 43 (33-68) and 23 (15-37) mmHg, respectively. The median value of the mPAP drop was 20 (5-53) mmHg, and the decline achieved with surgery was significant (z=-2.36; p=0.018).

DISCUSSION

It is ironic that the heart-lung machine is rarely used today in the treatment of APE since this actually stimulated its creation by John Gibbon.[19] When we take a look at guidelines, the American College of Chest Physicians (ACCP) Consensus Committee[20] mentioned surgical embolectomy only as *"... open embolectomy ... depends* upon the experience of the physician and the availability of the procedure". The 1998 update[21] of this report and the British Thoracic Society (BTS) guidelines[22] do not even mention surgical embolectomy. The guidelines published by the European Society of Cardiology Task Force in 2008 stated the indications of surgical embolectomy for APE as the following: *(i)* patients with acute, massive PE, *(ii)* patients with contraindications to thrombolytic treatment, and *(iii)* patients' lack of a response to intensive medical treatment and thrombolysis. In our opinion, these criteria are not objective, valuable, or concrete, and they allow for the decision regarding surgery to be made according to the opinions of the physicians.[23] We think that with their article, Hoeper et al.[11] have slightly clarified the indefiniteness of surgical management of APE.

The undervaluation of a surgical embolectomy for APE seems to be due to the published high

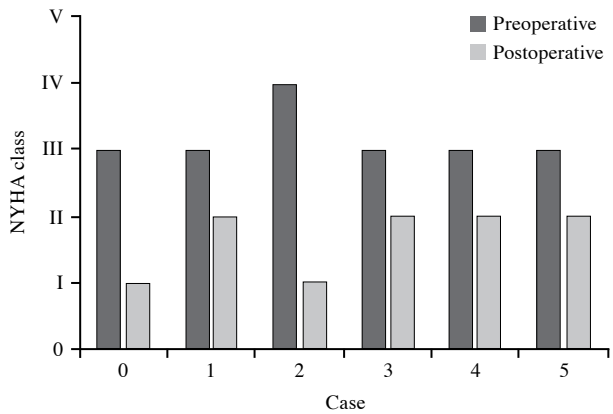

Figure 7. Improvement of NYHA Class with surgery; The median value of the pre- and postoperative NYHA classes were III (II-III) and II (I-II), respectively. The median of improvement in the NYHA class was I (I-III), and the improving effect of surgery as revealed in the decline in the NHYA class was significant (z=-2.26; p=0.024).

mortality rates, which make it difficult to argue for its benefits because of the natural history and the vague, aforementioned indications.[2,3] On the other hand, with rapid diagnosis, careful patient selection, and improved surgical techniques, high survival rates of 89% at 10 months have been achieved.[24] Debates continue regarding whether or not the complexity of the surgical procedure is worth the risk and whether there are enough postoperative care facilities that have sufficient experience to care for patients who undergo this procedure. Although these are legitimate concerns, they should not preclude the necessity of surgical embolectomies for certain patients.

In our cases, only case 6 died because his type 4 disease was very extensive and stiff which made it difficult to remove. Furthermore, only a 10 mmHg drop on his mPAP was achieved. Our significant results regarding the decrease in the mPAP (p=0.018) resemble those found in the literature.[10,17,25,26] Moreover, our significant improvement in the NYHA functional class (p=0.024) is also parallel with the results of Saouti et al,[10] Narayana Iyengar et al[25] and Ishida et al.[26] The inadequate number of cases in our retrospective study is a drawback; therefore, larger case series are needed for further investigation.

In conclusion, we believe that in selected cases, a PTEA/embolectomy clearly improves the functional capacity of the patient.[25] In our opinion, reducing the mPAP below 30 mmHg is essential.[7,8,12] Pulmonary angiography can play a crucial role in optimal patient selection along with confirming the diagnosis and classification of the type of disease.[16] Close follow-up of cases who survived the APE episode with regard to their persistence of PHT is also necessary.[6,12] In cases with progressively worsening symptoms, PTEA should strictly be considered. We think that a drop of one unit in the NYHA class or a decline in the mPAP below 30 mmHg demonstrates satisfactory results and indicates improved quality of life.[12,25] As a result, with good preoperative assessment and patient selection, clinics and physicians should not be reluctant to choose PTEA.

Acknowledgement

As a correspondence, I'd like to thank to my estimable academics in giving me the opportunity for managing this article.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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