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Surgical Management of Pulmonary embolism: Single-center study

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Abstract

Background: Pulmonary embolism (PE) is considered one of the highest risk cardiovascular diseases. It is managed using medical (anticoagulants, thrombolytics) and/or surgical or catheter embolectomy. The indications and outcomes of the surgical embolectomy is a matter of controversy. So, the aim of the present work is to evaluate the outcomes of surgical embolectomy through median sternotomy with cardiopulmonary bypass surgery.

Methods: The current study is a prospective longitudinal cohort study for (17patients) who underwent surgical embolectomy at Assiut University Heart Hospital of Egypt during the period from September 2021 until September 2023. A medical history, full examination, and thoracic echocardiography with pulmonary angiography were performed. All patients underwent surgical embolectomy through median sternotomy.

Results: The study included (17 patients), 5 males and 12 females, ranging from 38 to 60 years of age. Four patients presented with massive PE, and 13 suffered from submassive PE. The mean operative time was 172.65 ± 24.76 min., and the mean clamp time was 42.59±13.70 min. The mean hospital stay for all patients was 8.65±1.22 days, and the mean Intensive Care Unit (ICU) stay was 2.3±0.6 days. Respiratory complications, stroke, and bleeding were present in 23.5%, 11.7%, and 17.6% of cases respectively. while congestive heart failure, fever, and melena were present in 11.76%, 11.76%and 5.88%. Four patients died postoperatively due to stroke (2 patients), bleeding (1 patient), and acute respiratory distress with multiorgan failure (1 patient). The mortality rate reported in our cases was about 24% (4/17 patients)

Conclusion: Surgical embolectomy through median sternotomy and cardiopulmonary bypass had favorable outcomes in cases of submassive PE, especially when other treatments are contraindicated or are not available.

KEYWORDS
Median sternotomy; Pulmonary embolism; Surgical pulmonary embolectomy; Submassive pulmonary embolism

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Introduction

Acute pulmonary embolism (PE) is considered a major cause of both morbidity and mortality. PE represents 5-10% of hospital deaths in developed countries [1]. It is the third most common cause of cardiovascular mortality after myocardial infarction and stroke. Moreover, PE compromises gas exchange and circulation, and is accompanied by an increased release of thromboxane A2 and serotonin, which leads to high right ventricular afterload [2].

There are three categories of PE: high risk (massive), intermediate risk (submassive), and low risk [3]. Massive PE is defined as an obstruction of the pulmonary artery (PA) exceeding 50% of its cross-sectional area and resulting in right ventricular (RV) dysfunction, resulting in sustained hypotension [4]. Intermediate-risk (submassive) PE is diagnosed when there is imaging and/or biomarker evidence of RV dysfunction with no sustained hypotension [5]. Meanwhile, low-risk PE does not meet the criteria of the high and intermediate risk classifications [5].

Pulmonary vascular resistance increases with the clot burden, causing the right ventricular wall to stretch, activating the neurohumoral axis, resulting in inotropic and chemotropic effects. The increased inotropic demand of the myocardium results in RV bowing towards the septum, which reduces the left ventricular output and leads to hemodynamic instability. These effects lead to hypotension, low coronary perfusion, and ischemia. Acute PE manifests with tachycardia, tachypnea, chest pain, dyspnea, hemoptysis, hypotension, neck vein resistance, a palpable loud P2 component of the second heart sound, and infrequent syncope [6]. Acute PE leads to RV dysfunction with a sudden increase in RV afterload and a temporary sparing of the left ventricle, which postpones systemic hypotension, which is a late marker of PE severity [7].

Surgical management of PE includes pulmonary embolectomy, pulmonary thromboembolectomy, and pulmonary thromboendarterectomy. Pulmonary embolectomy is indicated for acute PE with floating clots in the lumen of the PA, while pulmonary thromboembolectomy is performed for subacute massive PE, associated with semi-organized thrombi on the wall of the pulmonary artery [8]. Surgical embolectomy is indicated in chronic cases with well-organized thrombi along the wall of the PA if thrombolytics are contraindicated or failed, and in cases of intermediate high-risk PE with evidence of right heart strain and elevated troponin in the absence of hemodynamic instability [9].

Pulmonary embolectomy is also indicated in patients with surgically accessible clot burden located either at the main bifurcation or the proximal right or left PA [10]. Post-operative morbidity is associated largely with preoperative cardiopulmonary resuscitation (CPR) efforts [3]. The most common morbidities are stroke, renal failure, and postoperative bleeding [3]. To this end, we performed the current study to share our experience regarding surgical pulmonary embolectomy in the management of PE.

Patients and Methods

Study design

Our study was a prospective longitudinal cohort study carried on at Assiut University Heart Hospital during the period from September 2021 until September 2023.

All patients received complete medical history taking and thorough clinical examination. In addition, all patients were investigated using computed tomographic pulmonary angiogram (CTPA), chest X-ray, electrocardiogram (ECG), thoracic echocardiography, arterial blood gas (ABG), cardiac markers, liver and kidney functions, blood sugar, complete blood picture, and coagulation profile, namely prothrombin and partial thromboplastin times. Trans-esophageal echocardiography was performed in the operating room before surgery if needed. Resting transthoracic 2D echocardiography (ECHO, VIVIDS5 instrument, GE Medical System, Horten, Norway) was performed 48 hours after surgery and during each follow-up visit. Pulmonary artery systolic pressure (PASP) was calculated through

the Bernoulli equation using tricuspid regurgitation velocity.

Table 1: Patients' pre-operative characteristics. Continuous outcomes are presented as mean ± SD. Categorical outcomes are presented as frequency (percentage)

Parameter	Result
Age	45.76±6.18
Sex	
Male	5
Female	12
BMI	29.3 ± 3.1
Previous surgery	3 (17.6%)
Contraceptive pills	5 (29.4%)
Stroke	2 (11.7%) cases
Main complaint	Dyspnea +Hypotension
Elevated troponin	17 (100%)
Systolic BP mmHg	95± 8.70
Diastolic BP mmHg	49.82 ± 6.06,
Pulmonary artery systolic pressure (mmHg)	56.41 ± 7.10
Oxygen saturation at room air	90.41 ± 1.33
Heart rate/min	108.59±7.44
Respiratory rate/min	38.06 ± 5.27

We selected patients with a pulmonary clot at the main bifurcation or at the proximal left or right pulmonary artery. All of them were contraindicated for thrombolytic therapy as follows:

Major surgery<2 weeks (7 patients), pregnancy (2 patients), failure of thrombolytic therapy (4 patients), and massive pulmonary embolism with severe hemodynamic instability (4 patients).

Patients with pulmonary clots in the distal left or right pulmonary artery, morbid obesity, end - stage renal disease, severe chronic obstructive pulmonary disease, hepatic dysfunction, and/or cancer patients were excluded from the study.

Anesthetic Management

Morphine 7 mg and promethazine 25 mg IM were administered 30 min preoperatively then heparin was given four hours later. Patients with unstable hemodynamics received a dobutamine infusion of 5 ug/kg/min. After pre-oxygenation, anesthesia was induced with etomidate 0.2 mg/kg and fentanyl 5 ug/kg. Rocuronium 0.9 mg/kg was used as a muscle relaxant with rapid onset and minimal cardiovascular side effects to facilitate tracheal intubation. Maintenance of anesthesia was performed by 50% oxygen and 50% air, fentanyl, and midazolam. The patients were weaned from cardiopulmonary bypass (CPB) using epinephrine 0.025 mg/kg/min, dobutamine 5 mg/kg/min, and nitroglycerine 0.25 mg/kg/min. Finally, the patients were transported to the Intensive Care Unit (ICU) for 8 hours of mechanical ventilation, and the inotropes were tapered then stopped on the second postoperative day.

Surgical technique

According to quoted from Pankaj Saxena et al (2016) [11]. A median sternotomy was performed to expose the pericardium using a sternal retractor. A part of the pericardium was harvested to close the pulmonary arteries (left and right).

Full-dose heparin was used, and aorto-bicaval cannulation was performed then giving cardioplegia to arrest the heart.

A longitudinal incision was made in the main PA and extended into the left PA. The thrombus was extracted using a sump sucker, Russian or gallstone forceps, a Fogarty or Folly catheter. Another separate incision was done in the right PA to remove clots from the RPA and right pulmonary segments. A 5 mm telescope was used to visualize any embolus in the distal left or right PAs and their proximal branches.

An incision in the RA free wall was done to remove any free-floating thrombus in the right atrium (RA) or RV. Thrombus in the abdominal Inferior Vena Cava (IVC) was removed by temporarily clamping, removing the IVC cannula, and under low flow CPB exploring the abdominal IVC through the RA. Femoral venous cannulation was used for CPB if the thrombus was straddling the IVC-RA junction.

Retrograde pulmonary vein (PV) flush was used to remove the thrombus, which has lodged distally through an opening in the left atrium (LA). A Foley catheter was passed into each PV orifice,

the balloon was inflated with 5 cc saline, and saline was injected into the lumen of the catheter to dislodge the thrombi, which were then retrieved through the PA incisions.

The squeezing lung technique was used by opening the left and right pleura and squeezing the lung tissue from downward to upward towards the left and right PA to help dislodge any distal embolus.

Closure of the main and both left and right PAs was achieved using the patient's own pericardium or bovine pericardium, if available, by continuous 5/0 polyproline sutures.

Weaning from the CPB and removing the aorto-bicaval cannulas after taking half-dose protamine. Surgical drains were inserted before wound closure, and the patient was transferred intubated to the postoperative ICU.

Percutaneous IVC filters were placed through the right femoral route only for patients with contraindications to anticoagulation or for patients with recurrent PE on therapeutic anticoagulation.

Post ventilation treatment

Patients received low molecular weight heparin 6–10 hours after surgery and continued until oral warfarin gives target INR therapeutic range, which was then continued for one year. other medications also included the following:
Antibiotics: according to the infection control unit protocol in our ICU.

- Mucolytics
- Pain killer (fentanyl infusion)
- Chest physiotherapy

Statistical analysis

Quantitative variables were expressed as mean ± standard deviation (SD), while qualitative variables were expressed as frequency (percentage). Paired t-test was used to compare between pre and post operative data. Analysis was conducted using IBM SPSS version 22.0 (IBM Corporation, Armonk, Ny).

Ethical approval

The study was approved by the Assiut University Institutional Board (IRB No. 04-2024-300392) and complied with the Declaration of Helsinki. Privacy and confidentiality of all the data were assured. The aim of the study was explained to every patient before the operation, and informed written consent was obtained.

Results

The current study included (17 patients), 5 males and 12 females; 4 presented with massive pulmonary embolism, while 13 suffered from submassive pulmonary embolism. Their ages ranged from 38 to 60 years with a mean ± SD (45.76±6.1). BMI mean ± SD was 29.3 ± 3.1 (Table 1).

ECG showed abnormal ST segment with or without T wave inversion, right axis deviation, and right bundle branch block (RBBB) in most of our patients. Echocardiography showed that 14 (82.35%) patients presented with right ventricular dysfunction. Right ventricular strain was determined as RV to LV in diastolic diameter ratio greater than 1.0 or when paradoxical RV septal systolic motion appeared.

CTPA showed that one patient had a clot located in the RA and one patient had a clot in the RV chamber. While 4 cases had thrombosis clots in the main trunk and 11 patients had clots in the right PA branches.

Table 2: Patients' intraoperative characteristics. Continuous outcomes are presented as mean ± SD. Categorical outcomes are presented as frequency (percentage)

Parameter	Results
Operation time (min)	172.65±24.76
Cross clamp time (min)	42.59±13.70
Intubation time (min)	657.47±29.73
CPB (min)	57.65±9.10
Bleeding (ml)	510±97.0
Need for blood transfusion	3(17.6%)
Amount of blood transfusion (ml)	1160±137

CBP: Cardiopulmonary bypass

The mean total operative time was 172.65 ± 24.76. Only three patients required blood transfusion; one received about 2000 cc, the

second received about 800 cc, and the third received about 700 cc, and the mean of blood transfused was mentioned in (Table 2). While one patient suffered intraoperative cardiac arrest and recovered. An IVC filter was inserted for 5 weeks in two cases; one with DVT in distal spheno-femoral and the other case suffered from systemic lupus erythromatosis.

Table 3: Patients` postoperative characteristics. Continuous outcomes are presented as mean ± SD. Categorical outcomes are presented as frequency (percentage)

Parameter	Result
ICU stay (days)	2.3±0.6
Hospital stay (days)	8.65±1.22
Complications	
Congestive heart failure	2 (11.76%)
Bleeding	3 (17.6%)
Melena	1 (5.88%)
Fever	2 (11.76%)
Respiratory complication	4 (23.52%)
Stroke	2 (11.7%)
Deaths at hospital	4 (23.52 %)

ICU: Intensive care unit

The mean postoperative hospital stay for all patients was 8.65±1.22 days, while the ICU stay was 2.3±0.6 days. Moreover, some patients had some complications in the form of Respiratory, stroke and bleeding were recorded in 23.5%, 11.7% and 17.6% of cases, respectively while congestive heart failure, fever and melena were recorded in 11.76%,11.76 and 5.88% of cases. However, the 4 patients with massive pulmonary embolism did not make it and died during their postoperative ICU stay. Two patients refused surgery first; however, thrombolytic therapy failed. By returning to surgery, their hemodynamic status deteriorated, and they died by stroke on the second day of the ICU. An elderly female, (60 years old) with renal impairment and ischemic heart disease), died by bleeding on the third day of ICU. The fourth patient suffered from acute respiratory distress and was admitted in primary hospital for 3 days then referred to our center with sever hemodynamic instability and died on the third day in the ICU due to multi organ failure (Table 3). All patients were followed up for 6 months. Our patients expressed significant postoperative improvements in all their vital signs compared to their preoperative status (Table 4).

Discussion

The current study conveys the preliminary experience of Assiut University Heart Hospital in the management of massive and submassive PE using surgical embolectomy. The preoperative characteristics for all patients were shown in (Table 1). The patients` postoperative main vital parameters, including blood pressure, heart rate, respiratory rate, and arterial pulmonary systolic pressure, dramatically improved compared to preoperative status (Table 4). Moreover, the mean operative time, cross clamp time, and cardiopulmonary bypass time were about 173, 43, and 58 minutes, respectively (Table 2). This is comparable to the results reported by Choi et al. in their meta-analysis of studies published on the use of surgical embolectomy in patients with massive and submassive PE during the period 1989-2019. The meta-analysis included 32 studies with >800 patients who suffered from acute massive and submassive PE and underwent surgical embolecomy. In their meta-analysis, Choi et al. reported mean operative time, cross clamp time, and cardiopulmonary bypass time of 170, 50, and 56 minutes, respectively [12].

Table 4: pre and post-operative comparison of patients' vital signs

Parameter (mean±SD)	**Preoperative**	**Postoperative**	**P-value**
Systolic blood pressure (mmHg)	95±8.70	111.35 ± 7.64	**0.01**
Diastolic blood pressure (mmHg)	49.82 ± 6.06	59.18 ± 6.14	**0.003**
Respiratory rate/min	38.06 ± 5.27	26.12 ± 3.02	**<0.001**
Heart rate/min	108.59± 7.44	98.06 ± 5.08	**0.001**
Oxygen saturation	90.41 ± 1.33	96.76 ± 1.56	**<0.001**
PASP (mmHg)	56.41 ± 7.10	26.71 ± 2.91	**<0.001**

PASP: Pulmonary Artery Systolic Pressure

In addition, the present study shows that the mean hospital and ICU stay for our patients were about 8.65±1.22 and 2.3±0.6, respectively (Table 3). This is relatively similar to the 10 and 2 days, respectively, reported by Choi et al. in their meta-analysis [12]. The mortality rate reported in our cases was about 24% (4/17 patients); the 4 cases suffered from massive pulmonary embolism. They died after transfer to the ICU. Argyriou et al. performed a retrospective analysis of a large national registry in the UK of 256 patients presented with acute PE and reported a hospital mortality of 25%. The authors added that 5.4%, 16%, and 7.5% suffered post-operative stroke, renal failure, and bleeding, respectively [13].

Similarly, Qimin et al. performed surgical embolectomy for 41 patients; 24 had massive and 17 had submassive PE. The authors reported three mortalities occurred in massive PE patients with no mortalities in the submassive PE group [14]. Choi et al. reported that the main causes of mortality in their meta-analysis were right-sided heart failure, unstable hemodynamics, cardiogenic shock, cardiac arrest, and bleeding. Nevertheless, the authors recommended surgical embolectomy as a primary line of treatment in acute PE [12].

Moreover, Nath et al. reported that induction of anesthesia is a very hazardous period in the presence of massive pulmonary embolism and RV dysfunction, as it can lead to sudden hemodynamic collapse in up to 19% of cases. The authors added that rapid institution of CPB by femoral cannulation percutaneously may be lifesaving in those patients [4].

Study Limitation:

Our study has many limitations, including the small number of patients and the short-term follow-up. However, we are sharing our preliminary experience with surgical embolectomy in the management of acute PE.

Conclusion

Acute PE is still considered one of the major causes of cardiovascular mortality. The decision of treatment is based on the prognosis, location of the embolus, and comorbidities. Thus, the preoperative preparation is very essential. Median sternotomy with cardiopulmonary bypass and surgical embolectomy is a favorable technique with acceptable outcomes.

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