

# Simple and secure thrombectomy involving the peripheral pulmonary arteries for acute pulmonary embolism

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## Abstract

Surgical pulmonary artery thrombectomy is a well-established emergency treatment for massive pulmonary embolism (PE) in which fibrinolysis or thrombolysis cannot happen. However, surgery for massive PE that requires peripheral pulmonary artery thrombus removal remains challenging. We established a simple and secure pulmonary artery thrombectomy method using cardiopulmonary bypass and cardiac arrest. In this procedure, the surgical assistant arm, typically used for coronary artery bypass grafting, is used to obtain a feasible working space during thrombectomy. We present seven consecutive massive PE cases treated with the present surgical method and successfully weaned from cardiopulmonary bypass or extracorporeal membrane oxygenation postoperatively. This procedure can be used to prevent right ventricular failure after surgery as surgeons can remove the thrombus up to the second branch of the pulmonary artery with direct vision.

## Introduction

Pulmonary embolism (PE) is a life-threatening condition that often requires emergency surgery. Surgical pulmonary artery (PA) thrombectomy is an established emergency treatment for massive PE<sup>1,2</sup>. This procedure has facilitated the treatment of most PE cases. However, surgery for severe PE, requiring thrombectomy including peripheral PAs, remains challenging<sup>3</sup>. In such clinical situations, it is difficult to obtain an operative field for direct visualization of the peripheral PA. Recently, we established a simple and secure PA thrombectomy technique utilizing a surgical assistant arm (TERUMO Corporation, Japan), typically used for coronary artery bypass grafting, to obtain a feasible working space. Herein, we report a case series of massive PE treated using our surgical method involving peripheral PA thrombectomy.

## Technique

We applied our technique to seven consecutive patients (one man and six women) between July 2020 and December 2021. The patient characteristics are shown in Table 1. The median patient age was 52 (23–77) years. All patients had massive PE, and two cases required preoperative circulatory extracorporeal membrane oxygenation (ECMO).

A summary of the operative procedure is presented in Video 1. All patients underwent PA thrombectomy using the median sternotomy approach. Cardiopulmonary bypass (CPB) was established with ascending aortic cannulation and bicaval drainage. A left ventricular vent was inserted into the right superior pulmonary vein. After establishing total bypass, the ascending aorta was cross-clamped, and cardiac arrest was achieved via antegrade cardioplegia. The surgical assistant arm was then used to compress the right ventricular outflow tract caudally, leading to a sufficient view of the left PA (Fig. 1a). A longitudinal incision was made in the anterior aspect of the main and left PA, and the thrombus was removed. A tourniquet taping the superior vena cava (SVC) with a cannula was pulled up, and the ascending aorta was compressed to the left with a surgical assistant arm (Fig. 1b). A longitudinal incision was made in the anterior aspect of the left PA, enabling us to directly examine the second branch of the left PA after thrombectomy. In contrast to the left

side, the thrombus on the right side was torn off several times; however, all thrombi up to the second branch were removed step by step. The median operative, CPB, and cardiac ischemic times were 265, 149, and 62 min, respectively.

Five patients who did not require preoperative ECMO were successfully weaned off CPB. Two patients who underwent preoperative veno-arterial ECMO required temporary postoperative veno-arterial ECMO support. One patient developed PE and cardiopulmonary arrest during orthopedic surgery in another hospital and died of multiple organ failure on postoperative day 112. The median postoperative intubation time, ICU stay, and hospital stay were 14 h, 3 days, and 16 days, respectively. Computed tomography at discharge of six living patients showed no thrombus within the PA up to the second branch. The patients provided informed consent for the publication of this case series and the need for approval was waived by our institutional review board.

## Discussion

Our experience highlights the reliability of radical thrombectomy in massive PE cases. Thrombectomy for peripheral PE remains a challenge. Thrombectomy in acute PE surgery has often been performed in beating hearts, as we have previously reported<sup>4</sup>. The concern regarding beating surgery for PE cases is the possibility of residual peripheral PA thrombi. The advantages of pulmonary embolectomy are reduction of PA pressure immediately after surgery<sup>5</sup> and improvement of right ventricular function after surgery<sup>6</sup>, which requires more reliable thrombus removal. Some researchers have recommended gentle thrombectomy with a Fogarty catheter if the thrombus is torn off during thrombectomy to avoid PA injury and the associated pulmonary hemorrhage<sup>7</sup>. However, this approach for peripheral PE is imperfect and can lead to right ventricular failure and/or chronic thromboembolic pulmonary hypertension (CTEPH)<sup>8</sup>. To address this concern, we recently applied the CTEPH technique to treat acute PE. CTEPH surgery aims to reduce postoperative right ventricular pressure by involving a secure endarterectomy of the peripheral PA under circulatory arrest<sup>9,10</sup>. Obtaining a clear view of the right PA is also challenging in acute PE surgery; mobilizing the SVC and compressing the aorta, as described above, can facilitate the task. Furthermore, the right thrombus of the right PA is more prone to tearing than the left PA, owing to anatomical angulation issues. Even if the thrombus breaks off, as explained above, the present method allows for the removal of the thrombus from the peripheral PA. The difference with surgery for CTEPH is that the present procedure does not require circulatory arrest as a fresh thrombus is not strongly adherent to the PA wall. We believe that the cardiac arrest procedure does not adversely affect postoperative cardiac function. All patients without preoperative ECMO support were successfully weaned off CPB. Although one preoperative ECMO case was lost, both preoperative ECMO cases were successfully weaned from ECMO postoperatively. The postoperative course and computed tomography findings indicated that our procedure could accomplish radical thrombectomy of peripheral PE, resulting in low right ventricular pressure and stable hemodynamics postoperatively. Several studies have compared surgical and nonsurgical approaches<sup>5,11</sup>, but few have compared the clinical outcomes of each surgical approach. We believe that our technique can be useful for treating severe PE, and more experience should be accumulated.

**Author contributions:** Concept/design: HS, RK, MM. Article drafting: HS. Critical revision of the article: RK. Approval of the article: all authors.

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### Figure legends

Fig 1a: Caudal compression of the right ventricular outflow tract with the surgical assistant arm provides an adequate view of the left pulmonary artery.

Fig 1b: Pulling up the tourniquet taping the superior vena cava into which the cannula was inserted and compressing the ascending aorta to the left with the arm of the surgical assistant help to obtain a good view of the right pulmonary artery.

Video 1: A summary of our pulmonary artery thrombectomy method.

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