A thoracic aortic pseudoaneurysm is a life-threatening complication following thoracic aortic surgery. We describe a surgical strategy for this pseudoaneurysm with a high risk for rupture during median sternotomy. The pseudoaneurysm was distended and widely adherent to the posterior sternum. Elective cardiopulmonary bypass and moderate hypothermia were established, and sternotomy was performed without left ventricle distention or brain ischemia. Total arch replacement was successful and the patient was discharged on post operative day (POD) 18. A key surgical strategy was to avoid ventricular fibrillation before sternotomy. Appropriate sternotomy timing and perfusion strategy are crucial for successful treatment.

**Keywords:** aneurysm, reoperation, aortic arch

**Introduction**

A large thoracic aortic pseudoaneurysm is a rare life-threatening complication following thoracic aortic surgery. Despite advances in endovascular surgery, most treatments remain surgical. In case of a pseudoaneurysm that is distended and adherent to the posterior sternum, a safe redo sternotomy is a key factor for a successful reoperation. Notably, redo sternotomy may injure the aneurysm and cause uncontrollable bleeding. Cardiopulmonary bypass and hypothermic perfusion before redo sternotomy are useful for high-risk cases. Herein, we describe an effective surgical strategy for a large thoracic aortic pseudoaneurysm with a high risk for rupture during median sternotomy in an elderly woman.

**Case Report**

A 72-year-old woman with a large thoracic aortic pseudoaneurysm was referred to us. Her medical history included cigarette smoking, a distal aortic arch aneurysm, and an abdominal aortic aneurysm. Her thoracic aortic aneurysm was treated in another hospital at age 63. The previous procedure involved distal aortic arch replacement with bilateral anterior thoracotomy (clamshell incision). Zone 3 to 4 was replaced with an artificial prosthesis with the proximal suture being a beveled anastomosis. The branches of the cerebral artery were preserved. At age 66, the abdominal aortic aneurysm was replaced with a straight artificial prosthesis. She did not come to hospital on self judgment. So, the pseudoaneurysm was not left unchecked until this time.

On physical examination of the thoracic aorta, a pulsating mass was palpable at the 2nd left parasternal intercostal space. The patient had difficulty in swallowing and her weight decreased by 15 kg in 3 months because of esophagus compression by the pseudoaneurysm. Unfortunately, we could not perform esophagus endoscopic study because we thought there were high risks of rupture in endoscopic study. Computed tomography (CT) revealed an 8.5-cm-diameter pseudoaneurysm with compression of the superior vena cava (SVC), trachea, and esophagus, and a wide adhesion to the posterior sternum. The previous graft was kinked by this large pseudoaneurysm (Fig. 1). Additionally, CT revealed a 7.5-cm-diameter thoracoabdominal aneurysm which spread from the lower descending aorta to the proximal site of the abdominal artificial graft (Fig. 2). There are no pressure differences between upper and lower extremities. Trans-thoracic echocardiography showed a small amount of aortic regurgitation (AR). Carotid echography showed a 72% stenosis of the right common carotid artery and an 85% stenosis of the left common carotid artery. There were high risks for rupture during sternotomy, but endovascular treatment appeared to be difficult because the access arteries were slightly narrow for access of the stent graft. Moreover, the descending aorta or iliac arteries were not suitable for access of the stent graft owing to the large
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was maintained maximally at 3.4 L/min (90 ml/kg/min). Apparent cerebral malperfusion was not indicated by NIRS monitor and there are no signs of peripheral circulatory failure. We planned to preserve own cardiac output as possible in systemic cooling process. We controlled the systemic pressure gradient between systolic and diastolic over 10 mmHg on arterial blood pressure monitor, and the pulmonary artery pressure over 10 mmHg on Swan-Ganz monitor. At 34 min from the start of cooling with a rectal temperature of 28.9°C, the sternum was carefully opened using an oscillating saw and a sternum saw. Full sternotomy was performed without injury to the pseudoaneurysm. At 35 min from the start of cooling with a rectal temperature of 27°C, the heart developed ventricular fibrillation (VF). Because of a sufficient amount of venous drainage and a small amount of AR, the left ventricle was not markedly distended. Tissue adhesions around the right upper pulmonary vein were detached and a left ventricular vent cannula was inserted through the pulmonary vein. Once the rectal temperature reached 24°C, the pump was stopped and circulatory arrest was initiated. After 6 min, selective cerebral perfusion was started smoothly. The perfusion flow was maintained at 4 ml/kg/min in the right carotid artery, and at 2 ml/kg/min in the left carotid and left subclavian arteries. There were no changes in the NIRS-monitored cerebral perfusion during thoracoabdominal aneurysm and adhesion from the previous thoracotomy.

We therefore planned surgical treatment with a median sternotomy. Under general anesthesia, a Swan-Ganz catheter was carefully inserted to the pulmonary artery under X-ray fluoroscopy because the SVC was compressed by the pseudoaneurysm and there were risks for perioperative rupture. A transesophageal echocardiography (TEE) probe was placed at the hypopharynx before sternotomy because of the esophagus compression. After the sternotomy, the probe was carefully advanced to the esophagus. Direct current shock pads were placed on the mid-axillary lines on each side for an external cardioversion. Cerebral perfusion was monitored by near-infrared spectroscopy (NIRS). First, the right axillary artery and left femoral vein were exposed. After systemic heparinization, an arterial cannulation was established on the right axillary artery using a 16-Fr cannula (OptiSite Arterial Cannulae, Edwards Lifesciences, Irvine, CA, USA). A venous cannulation was established using a 24-Fr long cannula (PCKC-V, Toyobo, Osaka, Japan) whose tip was advanced to the right atrium through the femoral vein under X-ray fluoroscopy, because the TEE probe was not advanced to the esophagus at that time. Cardiopulmonary bypass (CPB) was started, and the patient was systemically cooled gradually. The systemic perfusion flow was maintained maximally at 3.4 L/min (90 ml/kg/min). Apparent cerebral malperfusion was not indicated by NIRS monitor and there are no signs of peripheral circulatory failure. We planned to preserve own cardiac output as possible in systemic cooling process. We controlled the systemic pressure gradient between systolic and diastolic over 10 mmHg on arterial blood pressure monitor, and the pulmonary artery pressure over 10 mmHg on Swan-Ganz monitor. At 34 min from the start of cooling with a rectal temperature of 28.9°C, the sternum was carefully opened using an oscillating saw and a sternum saw.

Full sternotomy was performed without injury to the pseudoaneurysm. At 35 min from the start of cooling with a rectal temperature of 27°C, the heart developed ventricular fibrillation (VF). Because of a sufficient amount of venous drainage and a small amount of AR, the left ventricle was not markedly distended. Tissue adhesions around the right upper pulmonary vein were detached and a left ventricular vent cannula was inserted through the pulmonary vein. Once the rectal temperature reached 24°C, the pump was stopped and circulatory arrest was initiated. After 6 min, selective cerebral perfusion was started smoothly. The perfusion flow was maintained at 4 ml/kg/min in the right carotid artery, and at 2 ml/kg/min in the left carotid and left subclavian arteries. There were no changes in the NIRS-monitored cerebral perfusion during

Fig. 1 Preoperative computed tomography showing a large pseudoaneurysm. The previous artificial graft was bended by the aneurysm (A). The pseudoaneurysm was widely adherent to the posterior sternum (B). The pseudoaneurysm was spread out to the 2nd left parasternal intercostal space (C).
the procedures. Actually, the pseudoaneurysm was adherent to the sternum tightly. At least we could not detach the adherent by our fingers. We used electric knife and we detach the tissue carefully. After the pseudoaneurysm resection and tissue adhesion detachment, a 24-mm-diameter fourth branched Dacron graft (J Graft Shield, Japan Lifeline Co., Ltd., Tokyo, Japan) was anastomosed end-to-end to the graft of the previous operation. The previous proximal sutures became loose, and this might have been the major cause of the pseudoaneurysm. The previous kinked graft was very hard and it was difficult to correct the kink. After the distal anastomosis, systemic reperfusion was started. The cerebral arteries and ascending aorta were anastomosed end-to-end to the graft. The patient was re-warmed and weaned from CPB with no complications. The total CPB time was 229 min and the systemic circulatory arrest time was 70 min. Pathologically, no infection or aortitis was evident in the resected aorta. The patient has no hemolytic anemia and the postoperative course was good. The patient was discharged on postoperative day 18 (Fig. 3). After 3 months, replacement of the thoracoabdominal aorta was successfully performed.

**Discussion**

Pseudoaneurysms following thoracic aortic surgery have a high mortality rate in redo surgery.1,2) In particular, there are high risks in pseudoaneurysm cases that have developed anteriorly and adhere to the posterior sternum. If the pseudoaneurysm is ruptured, a serious hemorrhage can make it difficult to enter the mediastinum, and the brain may suffer from ischemia. Shimizu et al. described good result of endovascular repair in patients with pseudoaneurysm after open aortic surgery.3) First we considered thoracic endovascular aortic repair (TEVAR), but in this case endovascular treatment appeared to be difficult due to the narrow access arteries, the large thoracoabdominal aneurysm and adhesion from the previous thoracotomy.

Sternotomy and CPB strategies should be carefully planned in such cases preoperatively. Malvindi et al. described an elective CPB that should be started before redo sternotomy in the presence of less than 2 cm retrosternal space.4) In the present case, the pseudoaneurysm widely adhered to the posterior wall of the sternum, causing serious concern regarding its rupture.
For the sternotomy, the established CPB could decompress the heart and create a space between the mediastinal structures and the sternum. If the pseudoaneurysm was ruptured during the sternotomy, sternotomy should be performed under circulatory arrest. Therefore, systemic cooling was started before the sternotomy. Left ventricular distention was also a concern after developing VF. If an uncontrolled left ventricular distention developed, we planned to initiate circulatory arrest, open the pseudoaneurysm quickly, and commence selective cerebral perfusions.

Cohn and Villavicencio et al. described the use of a venous cannula to vent the left ventricle through the apex. In the present case, the left ventricle could be promptly vented through the right upper pulmonary vein. If she had moderate to severe AR or chronic heart failure due to myocardial ischemia, we might vent from the left ventricle through apex by left thoracotomy before sternotomy. Mohammadi et al. and Bechet et al. described that cannulation of the carotid arteries through the direct cervical approach before sternotomy was an effective method of ensuring cerebral perfusion in high-risk cases of rupture during sternotomy. We did not select this strategy because the patient’s carotid arteries with bilateral moderate stenosis were not suitable for inserting cannulas.

We thought the partial perfusion could prevent from VF because warm blood coming back from the lung would perfuse only the coronary artery and VF is unlikely to be induced. We did not induce total perfusion in systemic cooling process and kept partial perfusion referring to systemic arterial blood pressure and pulmonary artery pressure. We believe that quick cooling by CPB may result in VF before the brain is cooled sufficiently. Thus, we spent more than 30 min for systemic cooling at 28°C.

McCullough et al. reported that the safe duration of hypothermic circulatory arrest is 14 min at 25°C. Even if cerebral perfusion was stopped because of the rupture of the aneurysm during sternotomy or the uncontrolled left ventricular distention after developing VF, there is sufficient time to open the aneurysm and insert selective cerebral cannulas from the aortic lumen under circulatory arrest at 25°C. Sternotomy, opening of the aneurysm, and insertion of selective cerebral cannulas can be smoothly performed only if the brain is cooled sufficiently.

**Conclusion**

We describe an effective surgical strategy for treating a large thoracic aortic pseudoaneurysm with a high risk of rupture during median sternotomy. Elective CPB and moderate hypothermia before sternotomy were smoothly established. Thereafter, the mediastinum could be entered safely and total arch replacement could be performed without complications. Surgical strategies for pseudoaneurysms must be carefully planned and discussed preoperatively with perfusionists and anesthesiologists.

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All the authors have no conflict of interest associated with this study.

**Author Contributions**

Study conception: YI
Data collection: YI
Analysis: YI
Investigation: YI
Writing: YI
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Critical review and revision: all authors
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Accountability for all aspects of the work: all authors

References