# Early Outcomes of Total Arch Replacement in the Treatment of Aortic Dissection

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**ABSTRACT:**

**Overview:** Aortic dissection are severe pathologies with high mortality and complication rates post-surgery despite significant advancements in both diagnosis and surgical treatment. Aortic arch replacement surgery is a classic and highly effective treatment method at Cho Ray Hospital.

**Objectives:** Describe clinical, paraclinical characteristics, postoperative results, general complications and early hospital mortality.

**Methods:** Descriptive cross sectional study.

**Results:** 102 patients underwent aortic arch replacement surgery due to aortic dissection. Males predominated at 72.5%. The male:female ratio was 2.5:1. The average age was 56.45 ± 11.79 years. A history of hypertension was present in 81.4% of cases. Most patients with aortic dissection were admitted in an acute condition, accounting for 95%. Patients with type A aortic dissection accounted for 87.3%, with the entry tear in the ascending aorta at 27.5%. Isolated aortic arch replacement was performed in 46.1% of patients, while 53.9% underwent aortic arch replacement with frozen elephant trunk technique. 7 patients required aortic root replacement, 7 needed aortic valve surgery, and 10 required CABG. Most patients were cooled to 25 degrees C with cerebral perfusion to three branches. Ascending aorta cannulation was established in 45.2% of cases. The average cardiopulmonary bypass time was 257.7 minutes, with selective cerebral perfusion time at 115.9 minutes and lower body circulatory arrest time averaging 57.2 minutes. Postoperative neurological complications occurred in 10.8%, and the rate of renal failure requiring dialysis was 17.8%. The mortality rate was 9.6%. Longer cardiopulmonary bypass times and body temperatures above 25 degrees significantly increased the rate of postoperative renal failure requiring dialysis. Patients with postoperative renal failure requiring dialysis had a statistically significant increase in postoperative mortality rates. Aortic root intervention surgery combined with arch replacement did not affect the rate of postoperative complications. Aortic arch replacement with frozen elephant trunk technique did not affect cardiopulmonary bypass time, clamping time, or the rate of postoperative complications.

**Conclusions:** Total arch replacement at Cho Ray Hospital initially showed a safe and effective with acceptable mortality rate.

***Keywords:*** *Total arch replacement, frozen elephant trunk, aortic dissection.*

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## BACKGROUND

The aortic arch (AA) is an arch-shaped segment of the vessel, normally limited from in front of the origin of the brachiocephalic artery to behind the origin of the left subclavian artery. As the aortic arch has a very deep anatomical position which is the origin of the arteries that feed the brain and upper limbs with many complex anatomical components around, surgery or intervention to treat pathology in the AA area always remains a huge challenge.

Among acquired pathologies of the aortic arch related to the arch region, aortic arch dissection (also known as aortic dissection or separation of the wall) is the most commonly encountered. The term "aortic dissection" was proposed by Jean Pierre Maunoir in 1802 (1). The prevalence of aortic arch dissection has increased due to rising human life expectancy, which is accompanied by an increased risk of cardiovascular and metabolic diseases. In the United States, the incidence of aortic arch dissection is approximately 2,000 patients per year, with a high mortality rate (2). Despite advances in understanding and various conservative treatment modalities, aortic arch dissection still carries a high mortality rate of 56%-58% with medical treatment alone (2). Surgery remains an effective and common treatment option, especially for Type A aortic arch dissection. Recently, advancements in extracorporeal circulation have enabled the performance of various complex surgeries on the aortic arch region, with a mortality rate ranging from 15% to 23%. Aortic arch replacement surgery is the most severe type, involving significant risks related to brain protection, bleeding, and multiple organ failure (3).

Cho Ray Hospital has routinely performed this surgery since 2010, with a significant number of patients. Therefore, it is essential to conduct a study to evaluate the outcomes of aortic arch replacement surgery in the treatment of aortic dissection at Cho Ray Hospital. This study aims to provide a comprehensive summary, allowing for an analysis of the advantages and disadvantages of different strategies for establishing cannulation in extracorporeal circulation, as well as techniques for brain and organ protection. The goal is to develop surgical procedures that achieve higher treatment efficacy, thereby reducing mortality and complications, and approaching the surgical outcomes observed internationally.

## RESEARCH SUBJECTS AND METHODS

### Research subjects

All patients indicated for and undergoing aortic arch replacement surgery for the treatment of aortic dissection from January 2020 to January 2023 at Cho Ray Hospital.

### Sample selection criteria

- Patients diagnosed with aortic arch dissection based on clinical and imaging findings.

- Patients indicated for and undergoing aortic arch replacement surgery according to the 2021 AATS consensus and the 2019 consensus of the European Association for Cardio-Thoracic Surgery and the European Society for Vascular Surgery.

- Patients who consent to participate in the study.

### Research methodology

#### *Experimental design*

Prospective descriptive study, longitudinal follow-up without a control group.

***Surgical procedure for aortic arch replacement***

- The patient is positioned supine, and endotracheal anaesthesia is administered.

A median sternotomy is performed, either full or upper half (in cases of aortic arch rupture and unstable patient haemodynamics, a groin incision is made to expose and establish femoral artery cannulation prior to thoracotomy). Intravenous Heparin is administered at a dose of 300 IU/kg.

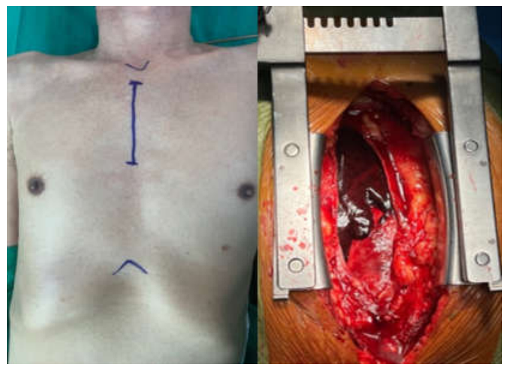

**Figure 1. Upper half sternotomy and full sternotomy in patients with medical record numbers 2220055216 and 2220050351**

- Arterial cannulation: Direct cannulation of the aortic arch, femoral artery, axillary artery, or brachiocephalic trunk.

- Venous cannulation: Typically, the superior vena cava (24Fr – 28Fr) and inferior vena cava (32Fr – 34Fr) are selected, or a dual-stage venous cannula through the right atrium.

- Initiate cardiopulmonary bypass (CPB), maintaining hypothermia between 25°C and 28°C.

- Clamp the aortic arch. Administer cardioplegia solution indirectly or transect the ascending aorta and administer cardioplegia solution directly into the coronary ostia using HTK or Delnido solution.

- Evaluate the ascending aorta and aortic root to determine if preservation or replacement of the aortic root is feasible.

- Management of the aortic arch and descending thoracic aorta:

▪ Dissect the region for the distal anastomosis on the aortic arch, prepare a branched artificial vascular graft (if a branched graft is unavailable, use two straight vascular grafts and suture them together to form a branched graft). If aortic arch replacement with Frozen Elephant Trunk (FET) is indicated, prepare a combined vascular graft: Thoraflex by Terumo or Evita by Jotec.

▪ Stop circulation, and perform antegrade cerebral perfusion directly into the 2 or 3 branches of the aortic arch at a flow rate of 8-12 ml/kg/min using a separate centrifugal pump, monitoring cerebral oxygenation with an Invos 5100C device.

▪ Resect the aortic arch, inspect for damage and any entry tear in the arch, and assess for cerebral artery dissection. Depending on the extent and severity of the damage, the preoperative evaluation, and the direct observation of the lesions during surgery, decide whether to perform a complete arch replacement alone or use the FET technique.

▪ Select the site for the distal anastomosis based on the location of the entry tear and the quality of the vessel wall. Suture the roots of the aortic arch branches if necessary.

▪ Perform the distal anastomosis to the branched artificial vascular graft using 3-0 or 4-0 prolene suture with an external vascular pledget.

▪ If using the FET, introduce the combined graft device with the stent graft portion into the true lumen of the descending aorta. Deploy the stent graft. Anastomose the aortic arch to the skirted edge of the combined vascular graft.

- Clamp the artificial vascular graft transversely, restore distal circulation through a cannula placed into a branch of the artificial graft, and address any accompanying structural heart defects if present (aortic root, aortic valve, mitral valve, tricuspid valve, coronary artery bypass grafting, etc.).

- If the aortic root is replaced, perform an end-to-end anastomosis of the two ends of the artificial vascular graft using 3-0 prolene suture. If the aortic root is not replaced, anastomose the artificial graft to the proximal end at the sinotubular junction using 3-0 or 4-0 prolene suture with continuous or interrupted stitches and an external vascular pledget.

- Release the clamp to allow the heart to resume beating and raise the temperature. Sequentially restore each branch of the aortic arch by end-to-end anastomosis to the branches of the artificial vascular graft.

- Expel air, continue raising the temperature, and wean from the CPB system. If weaning from CPB is not possible, transition to ECMO support.

- Ensure meticulous hemostasis. Place drainage systems and electrodes.

Close the sternum. Transfer to the intensive care unit.

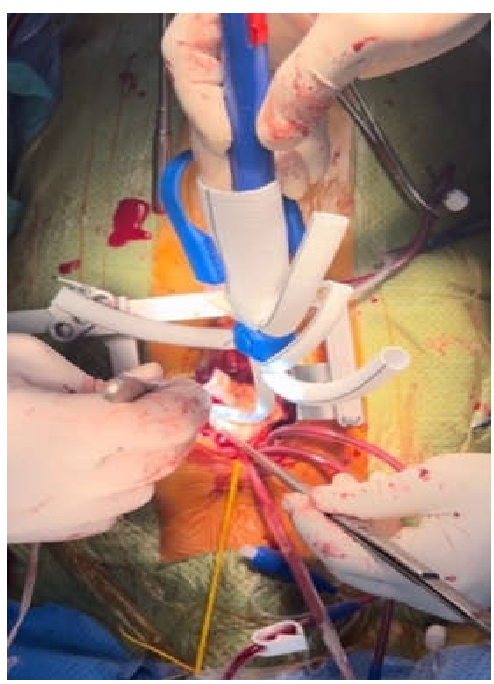

**Figure 2. Selective antegrade cerebral perfusion via three routes and placement of the Thoraflex device in the aortic arch replacement for patient 2220055216**

***Statistical methods***

- Data was entered into a computer based on digitized medical records and processed using statistical methods in medicine, with the application of SPSS 20.0 software.

- Continuous variables were described as mean ± standard deviation. Discrete variables were presented as percentages. The results for continuous variables were compared using the Student's t-test for two independent groups, the paired t-test for two related groups, and ANOVA for three or more groups. The results for discrete variables were compared using the $\chi^2$ test. A p-value of less than 0.05 was considered statistically significant.

***Ethics in research***

The study was conducted with the approval of the Ethics Committee. The families of the patients participating in the study were informed and explained about the disease condition and severity, the treatment solutions and options available to the patients, advised about the prognosis and treatment possibilities, and signed consent forms prior to surgery.

**RESULT**

Over the study period from January 2020 to January 2023, we enrolled 102 patients who underwent aortic arch replacement surgery for aortic dissection. The study group had the following characteristics: **Table 1.**

**Table 1. Patient Characteristics**

| Characteristic | Value (n=102) |
|---|---|
| Age | 56,45 ± 11,79 years |
| Male | 74 (72,5%) |
| Hypertension | 83 (81,4%) |
| Smoking | 48 (47,1%) |
| Stroke | 1 (1,0%) |
| Diabetes mellitus | 8 (7,8%) |
| Dyslipidemia | 3 (2,9%) |
| Acute condition | 97 (95%) |
| Chest pain | 91 (89,2%) |
| Shortness of breath | 8 (7,8%) |
| Syncope | 3 (2,9%) |
| Mesenteric ischemia | 1 (1,0%) |
| Limb ischemia | 1 (1,0%) |
| Bilateral leg weakness | 2 (2,0%) |
| Neurological symptoms | 3 (2,9%) |

**Table 2. Preoperative Clinical Characteristics**

| Characteristic | Value (n=102) |
|---|---|
| Type A dissection | 89 (87,3%) |
| Pericardial effusion rate (%) | 37,3% |
| Pericardial effusion thickness (mm) | 11,3 ± 6,5 |
| Aortic annulus (mm) | 25,5 ± 5,2 |
| Valsalva sinus diameter (mm) | 38,6 ± 7,8 |
| Ascending aorta diameter (mm) | 44,6 ± 7,3 |
| Aortic arch diameter (mm) | 33,2 ± 8,5 |
| EF (%) | 64,5 ± 8,4 % |
| Ascending aortic aneurysm with severe aortic regurgitation (grade 3 & 4) | 7 (6,8%) |
| Estimated Glomerular Filtration Rate (eGFR) | 71,47 ± 27,88 mL/min/1.73m2 |

CT imaging recorded that 87.3% of patients had Type A aortic dissection. In cases of Type B dissection, retrograde dissection to the aortic arch through the left subclavian artery was observed. Contrast-enhanced CT imaging detected an entry tear in 44.1% of cases. Most entry tears were located in the ascending aorta, accounting for 27.5%. Entry tears in the arch segment accounted for 12.7%. Dissection involving the brachiocephalic artery was observed in 35.6% of patients, and dissection extending to the celiac trunk was seen in 23.5%.

**Table 3. Surgical Characteristics**

| Characteristic | | Value (n=102) | Percentage (%) |
|---|---|---|---|
| Surgical methods for the aortic arch | Isolated aortic arch replacement | 47 | 46,1% |
| | Aortic arch replacement with FET | 55 | 53,9% |
| Associated surgeries | Bentall procedure | 3 | 2,9 |
| | Tirone David procedure | 4 | 3,9 |
| | Aortic valve replacement | 7 | 6,9 |
| | Coronary artery bypass grafting | 10 | 9,9 |
| Hypothermia | < 25 degrees | 9 | 8,9 |
| | 25 degrees | 91 | 89,2 |
| | 28 degrees | 2 | 1,9 |
| Arterial cannulation site for CPB | Ascending aorta | 46 | 45,2 |
| | Right axillary artery | 20 | 19,6 |
| | Femoral artery | 36 | 35,3 |
| Number of cerebral perfusion arteries | 2 branches | 21 | 20,6 |
| | 3 branches | 81 | 79,4 |
| CPB time (minutes) | | 257,7 ± 73,2 | |
| Aortic cross-clamp time (minutes) | | 148,8 ± 55,6 | |
| Selective cerebral perfusion time (minutes) | | 115,9 ± 69,8 | |
| Lower body circulatory arrest time (minutes) | | 57,2 ± 25,8 | |

**Table 4. Postoperative Outcomes**

| Characteristic | | Value (n=102) | Percentage (%) |
|---|---|---|---|
| Postoperative sedation usage | Yes | 12 | 11,8 |
| | No | 90 | 89,2 |
| Postoperative awakening time | < 12 hours | 58 | 64,4 |
| | 12 – 24 hours | 23 | 25,6 |
| | >24 hours | 9 | 10,0 |
| Extubation time | Not extubated | 10 | 9,8 |
| | Tracheostomy | 14 | 13,7 |
| | Extubation < 24 hours | 37 | 36,3 |
| | Extubation > 24 hours | 39 | 40,2 |
| Postoperative neurological complications | Altered consciousness | 6 | 5,9 |
| | Cerebral infarction | 11 | 10,8 |
| | Cerebral hemorrhage | 1 | 0,9 |
| Postoperative organ ischemia complications | Renal failure requiring haemodialysis | 18 | 17,8 |
| | Elevated liver enzymes | 42 | 42,0 |
| Postoperative infection complications | Pneumonia | 44 | 42,6 |
| | Sepsis | 20 | 19,8 |
| Post-op aortic regurgitation (4 cases of Tirone David procedure) | | grade 1,5/4 : 2<br>grade ¼: 2 | |
| Mortality | | 10 | 9,8 |

Postoperative outcomes recorded that there were 4 cases (accounting for 3.9%) of reoperation for haemostasis. These cases experienced bleeding from the sternum. There was 1 recorded case of surgical site infection. This infection had not spread through the sternum into the mediastinum. The patient underwent wound debridement, dressing changes, antibiotic therapy, and secondary skin closure.

Most patients were discharged within 30 days postoperatively. The success rate of the surgeries, with patients being discharged in stable condition, was 90.2%. It was recorded that 9.6% of patients either died or were discharged at their request; among these, 2 cases involved in-hospital deaths due to postoperative ventricular fibrillation, with failed defibrillation and intensive medical treatment, and 8 severe cases were discharged at their request due to sepsis and multiple organ failure. (Table 4)

**DISCUSSION**

The average age of the patients in our study was 56.74 ± 11.84 years, with the most common age group being 50-69 years. This result is similar to the study by Vu Ngoc Tu (4), where the average age of patients with Type A aortic dissection was 51.7 ± 11.4 (range 20-73), and Phung Duy Hong Son (5), with an average age of 57 ± 12 (range 29-80). Most studies indicate that aortic dissection is more common in males, with an average age range of 50-65 years; however, it can also occur in younger individuals, especially those with Marfan syndrome. Therefore, the typical age for aortic arch pathology requiring arch replacement is in older adults. Most patients were 60 years or older.

In our study, a history of hypertension was predominant among the patients, accounting for 82.1%. The study by Vu Ngoc Tu (4) reported 46.9% hypertension, and Phung Duy Hong Son (5) reported 72.1% hypertension. We noted that more than half of the patients with aortic dissection were admitted within 24 hours of symptom onset. Most entry tears for aortic dissection were located in the ascending aorta, accounting for 27.5%, and in the arch segment, accounting for 12.7%. More than one-third of patients had dissection involving the brachiocephalic artery. One-quarter of patients had dissection extending to the celiac trunk on contrast-enhanced CT imaging. In the CT scans from Vu Ngoc Tu (4), most patients were classified as having DeBakey type I aortic dissection, meaning the dissection spanned the entire length of the aorta. Only 4.9% had DeBakey type II, with the dissection confined to the ascending aorta. CT imaging not only helps confirm the diagnosis of Type A aortic dissection but also assesses complications, the extent of the dissection, the condition of the aortic branches, and the corresponding organs supplied. This information is crucial for planning surgery and predicting postoperative outcomes. Following the established guidelines set forth by the European Association for Cardiothoracic Surgery (EACTS) and the Society of Thoracic Surgeons (STS), surgical intervention for aortic root dilation in conjunction with aortic valve replacement becomes a strong recommendation when the combined diameter of the root and ascending aorta exceeds 45mm (class IIa). Our experience includes four successful cases of aortic valve-sparing root replacement utilizing the Tirone David procedure. This approach has demonstrated exceptional safety with minimal risk of complications and mortality during the perioperative period, applicable to both elective surgeries and urgent interventions for acute type A aortic dissection.

We primarily established arterial cannulation for CPB through the ascending aorta in 46 (45.2%) cases and the femoral artery in 36 (35.3%) cases, with only 8.8% using axillary artery cannulation. Vu Ngoc Tu (4) found that femoral artery cannulation is quicker and simpler, suitable for emergency cases, but does not provide antegrade perfusion and may exacerbate retrograde aortic dissection. The rate of femoral artery cannulation (either alone or combined with axillary artery) was 13.6%, mainly in the early phase of the study, during emergencies, and when the perfusion flow through the axillary artery was limited. In Okita's study (6), the selected cannulation sites included the aortic arch/ascending aorta (331; 75.1%), femoral artery (71; 16.2%), axillary artery (1; 0.2%), femoral artery + axillary artery (8; 1.8%), and ascending aorta + femoral artery (25; 5.7%).

Similar to Okita, we predominantly chose the ascending aorta for cannulation. Although this technique is challenging, we found that when successfully performed, it is the most physiological cannulation site, overcoming the limitations of other cannulation sites, and requires only one median sternotomy. However, an important consideration when performing this technique is the constant use of ultrasound to assess the aorta to accurately identify the true lumen. Clinically, we observed that transesophageal echocardiography (TEE) is optimal but not always feasible. Conversely, using a surface ultrasound probe directly on the aortic wall through the surgical field, we found that placing the ultrasound probe directly on the aortic wall and inserting the needle under direct ultrasound guidance allows for precise visualization of the needle entering the true lumen. This method facilitates the introduction of the guidewire and subsequent arterial cannulation using the Seldinger technique.

Additionally, we found that the needle insertion site for cannulation should be in the middle of the ascending aorta, shifted towards the lesser curvature near the pulmonary artery. Avoid placing the cannula too high towards the arch, as this may easily create a tear in the distal part of the aortic arch, and avoid placing it too close to the aortic root, as there will not be enough space to clamp the aorta during cardioplegia. At Cho Ray Hospital, all surgeons in our center can perform this technique easily and are familiar with it. Femoral artery cannulation is mostly used in extreme emergency cases, such as aortic rupture and unstable haemodynamics preoperatively. We rarely use axillary artery cannulation. Apart from the inconvenience of an additional incision and the time required for exposure, we observed that in some cases of dissection extending to the brachiocephalic artery, the true lumen is very small or has a thrombus in the false lumen. Thus, perfusion via the right axillary artery may sometimes be insufficient to deliver adequate blood flow to the aortic arch and descending aorta, while potentially over-perfusing the brain.

Most of our cases were also operated on through a full median sternotomy. Preoperative identification of the entry tear location is crucial for proactively planning the surgical approach. In our study, 27.5% of cases had entry tears in the ascending aorta, 12.7% in the arch, and 3.9% in the descending aorta. Therefore, the primary surgical method was ascending aorta and arch replacement. Seven cases in our study required concurrent aortic valve surgery, including three cases requiring aortic valve replacement with a 23 mm biological valve and four cases undergoing the Tirone David procedure. The coronary artery bypass grafting rate was 10%, with 8 out of 10 cases needing only single-vessel grafting.

In our study, all cases used branched artificial vascular grafts to separately anastomose the branches of the aortic arch. This approach facilitates haemostasis, simplifies the anastomosis of each branch, and prevents anastomotic dilatation.

Out of 102 cases of aortic dissection undergoing aortic arch replacement in our study, 55 cases (53.9%) were combined with distal endovascular stent graft placement (Frozen Elephant Trunk).

In our study, we found that the Frozen Elephant Trunk (FET) technique is optimal in aortic arch replacement surgery to minimize the risk of late reintervention in the distal aorta. If the patient has good financial resources, new generation hybrid grafts such as Thoraflex or Evita Neo are the optimal choices. For patients with limited financial means, the FET using supplementary endovascular grafts directly sutured to the artificial vascular graft and the aortic wall during the distal anastomosis can significantly reduce costs. Additionally, aligning with the perspectives of other authors and our experience, we found that moving the distal anastomosis closer to the heart (Zone 0) facilitates the anastomosis, limits bleeding, and makes haemostasis easier. The first step is to clamp, transect, and reimplant the branches of the aortic arch, and close the roots of the arch branches before circulatory arrest (7). The second step, during circulatory arrest, involves placing the FET device from Zone 0 into the aortic arch and descending aorta, followed by a distal anastomosis at Zone 0 without resecting the aortic arch vessels, which helps save circulatory arrest time (8).

A recent meta-analysis by Preventza suggests that targeting the FET stent-graft at T8 or higher, or using a stent-graft length of ≥15 cm, are significant risk factors for the development of spinal cord injury (9). Particularly in Vietnam, it is not always possible to have FET devices of the desired length (less than 150 cm). Therefore, when only longer devices are available, moving the distal anastomosis to Zone 0 can help shorten the stent deployment position in the descending aorta, typically above T8, to reduce the risk of spinal cord ischemia.

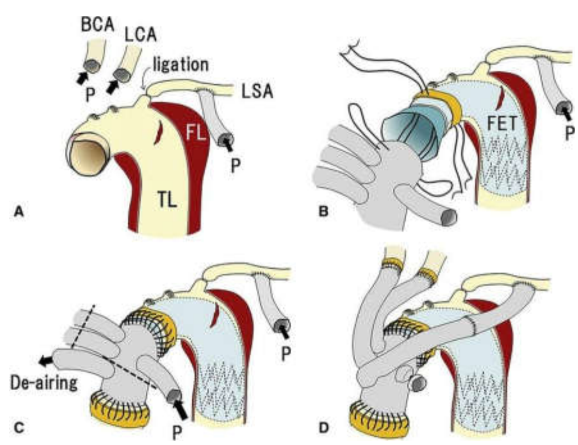


**Figure 3. Illustration of Z-0-FET**

*Source: Yamamoto H, (2020) (7)*

In our study, most patients were cooled to a temperature of 25°C. It was noted that 8.9% of patients in the aortic dissection group underwent deep hypothermia; these cases had dissection involving the cerebral arteries and established two arterial branches for cerebral perfusion. Most patients were perfused through three arterial branches during surgery. As neural tissue is the most sensitive to ischemia, the level of hypothermia in aortic surgery was chosen to be sufficiently deep to protect the brain. Vu Ngoc Tu (4) found that hypothermia and circulatory arrest combined with selective cerebral perfusion are commonly used organ protection techniques in acute Type A aortic dissection surgery. One-third of patients used this technique during interventions on the aortic arch or for complete replacement of the dissected ascending aorta segment using the open distal anastomosis technique (without clamping the ascending aorta). To minimize the risk of cerebral and abdominal organ ischemia while reducing systemic complications from excessive hypothermia, mild to moderate hypothermia was applied in 74.0% of cases, with only 10% undergoing deep hypothermia.

Our results indicate that longer CPB times and maintaining body temperatures at 25°C or higher significantly increased the incidence of postoperative renal failure requiring haemodialysis ($P<0.001$). Furthermore, postoperative renal failure requiring haemodialysis significantly increased the postoperative mortality rate ($P<0.001$). Therefore, in our study, we support cooling to 25°C during circulatory arrest.

Postoperative complications recorded in our study included: 4 cases of postoperative bleeding requiring reoperation, 44 cases (43.6%) of postoperative pneumonia, 20 cases (19.8%) of postoperative sepsis, 18 cases (17.8%) of renal failure requiring haemodialysis, and 42 cases (42.0%) of liver failure. We did not find a correlation between the characteristics of the surgical methods and the postoperative complications. However, one significant factor was noted: longer CPB times and body temperatures of 25°C or higher significantly increased the rate of postoperative renal failure requiring haemodialysis. There were 9.4% of patients who either died or were discharged at their request. Our mortality rate is similar to that reported by Phung Duy Hong Son (5), with 12.5% (ascending aorta replacement + classic total arch replacement) and 9.1% (arch replacement with FET).

The study by Uchida (10) reported a mortality rate of 7.1% in the group undergoing total ascending aorta replacement and 6.0% in the group undergoing total aortic arch replacement. Evaldas Girdauskas et al. (11) (n=276) found that the bleeding rate was 17.9%, the stroke rate was 13.3%, renal failure occurred in 29%, and respiratory failure in 13.8%. A meta-analysis of several single-centre studies reported surgical outcomes for total arch replacement in Type A aortic dissection, showing a combined in-hospital mortality rate of 8.6% (95% CI: 7.2–10) (12). The rates of stroke and spinal cord ischemia were 5.7% (95% CI: 3.6–8.2) and 2% (95% CI: 1.2–3), respectively (13).

## CONCLUSION

The results of aortic arch replacement surgery for the treatment of aortic dissection at Cho Ray Hospital demonstrate safety and efficacy, with an acceptable mortality rate compared to international studies.

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