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# Midterm Results of Axilloaxillary Cardiopulmonary Bypass

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## ABSTRACT

**Background:** Total axilloaxillary cardiopulmonary bypass (CPB) is an alternative peripheral cannulation technique that has the advantages of antegrade flow during CPB, monohemispherical brain perfusion in case of circulatory arrest, and achieving excellent decompression of the heart during sternotomy. The results of this strategy, particularly beyond the immediately postoperative period, are not well known.

**Methods:** Eleven patients with huge aortic aneurysms (>80 mm) and/or acute-subacute ascending aorta dissections underwent surgery with totally axilloaxillary CPB. Short- and midterm outcomes, including survival and complications relating to axilloaxillary cannulation, were reported.

**Results:** All attempts at axillary artery cannulation were successful. Ten of the 11 axillary vein cannulation attempts were successful, and the target pump flow was achieved via the axillary vein alone. Postoperatively, clinical examinations revealed no cases of arm ischemia or compartment syndrome. Three patients (27.3%) experienced ipsilateral brachial plexus neuropathy that produced right hand weakness. The neuropathy was transient in 2 patients, and the symptoms resolved completely. Hospital death occurred in 1 (9.1%) of the 11 patients. The mean (±SD) follow-up time was 956 ± 292 days. One of the survivors died on postoperative day 105 from subacute graft infection and sepsis. The right arms of all 9 of the living patients were examined physically and by Doppler ultrasonography. We found a chronic recanalized thrombotic change in the subclavian vein in 1 patient (11.1%), who had no complaints.

**Conclusions:** Axilloaxillary CPB is an alternative technique that can be used under certain conditions. Adding axillary venous cannulation to axillary artery cannulation at least does not increase the risk of a procedure that uses the axillary artery alone, either in the early or mid term.

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## INTRODUCTION

Several peripheral cannulation techniques have been proposed to establish cardiopulmonary bypass (CPB) for patients undergoing complex reoperations, for patients undergoing repair of aortic dissection or aneurysm, and for patients with extensive arteriosclerotic aortic disease in whom direct cannulation would have a high embolic risk. Among these techniques, axillary artery and axillary vein cannulation through a small single subclavicular incision not only achieves excellent decompression of the heart during sternotomy but also has the advantages of antegrade flow during CPB and monohemispherical brain perfusion in case of circulatory arrest. Although axilloaxillary CPB was described more than a decade ago, only a few early experiences have been reported thus far [Bichell 1997; von Segesser 2008; Zattera 2009]. The objective of this study was to describe the short- and midterm results of axilloaxillary CPB in patients who underwent procedures for huge ascending aorta aneurysms or reoperations for type A aortic dissections that required CPB before sternotomy.

## MATERIALS AND METHODS

The ethics commission of the hospital approved the study protocol. Perioperative data were prospectively collected and saved in an electronic database. During the follow-up period, data were collected during outpatient visits, and detailed physical and Doppler ultrasonography (US) examinations were performed.

### *Patients*

Between June 2007 and July 2010, 11 patients with huge ascending aorta aneurysms (>8 cm) or reoperative type A aortic dissections underwent combined axillary vessel cannulation for CPB at the Kartal Koşuyolu Heart and Research Center. The patients ranged in age from 22 to 71 years (mean, 57.0 years). Nine patients (81.1%) were male, and 2 (18.2%) were female (Table 1). The indication for operation was acute type A aortic dissection in 3 (27.3%) of 11 patients, chronic aortic dissection in 1 patient (9.0%), and aneurysm of the arch or the ascending aorta (mean ± SD diameter, 87.9 ± 7.7 mm) in 7 patients (63.7%). Eight

Table 1. Clinical Profile of Patients Undergoing Axilloaxillary Cardiopulmonary Bypass*

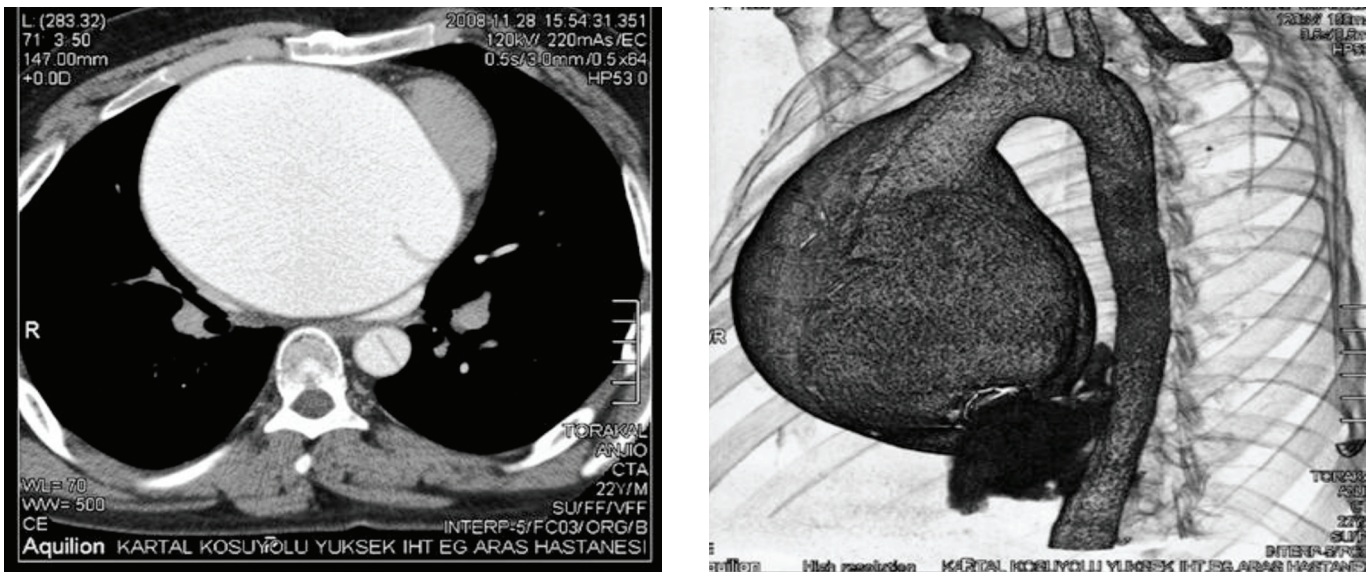
| Sex | Age, y | Previous Operation | Aortic Diameter, mm | Aortic Dissection | Operation | Decompression Indication | ACP Indication |
|---|---|---|---|---|---|---|---|
| M | 55 | AVR | 85 | – | Asc Aort Rep | + | – |
| M | 51 | AVR | 83 | – | Asc + H Arc Aort Rep | + | + |
| M | 48 | AVR | 97 | – | Asc Aort Rep+ | + | + |
| M | 61 | AVR | 82 | – | Asc Aort Rep+ | + | + |
| M | 69 | — | 88 | – | Asc Aort Rep+ | + | + |
| M | 65 | — | 100 | – | Asc + H Arc Aort Rep | + | + |
| M | 50 | CABG | 55 | + | Bentall–De Bono | + | – |
| F | 71 | CABG | 85 | + | Bentall–De Bono | + | + |
| M | 22 | AVR | 80 | – | Asc Aort Rep+ | + | – |
| F | 71 | — | 63 | + | Asc Aort Rep+ | + | – |
| M | 64 | AVR | 53 | + | Asc + H Arc Aort Rep | + | + |

*ACP indicates selective antegrade cerebral perfusion; AVR, aortic valve replacement; Asc Aort Rep, ascending aorta replacement; Asc + H Arc Aort Rep, ascending plus hemiarcus aorta replacement; CABG, coronary artery bypass grafting.

operations were elective, and 3 were emergent. Eight patients (73%) had previously undergone procedures that required sternotomy, 5 patients had undergone aortic valve replacement, and 3 patients had undergone coronary artery bypass grafting. Peripheral CPB was planned for all patients, and axilloaxillary CPB was chosen. Indications for axilloaxillary CPB were decompression of huge aneurysms (Figure) during sternotomy and/or establishing selective antegrade cerebral perfusion (Table 1).

***Surgical Procedure***

In all cases, CPB was established before approaching the sternum. After standard induction of anesthesia, a 6- to 10-cm subclavicular incision was made at a side between the right deltopectoral groove and the mid clavicle, according to a previously described technique [Bichell 1997]. In brief, pectoralis major muscle fibers and the clavipectoral fascia were gently dissected. The brachial plexus was isolated and




Huge aortic aneurysms. Note the close relationship between the aorta and the sternum.

suspended. The axillary artery and vein were then isolated and suspended. Systemic heparin was administered. The artery was clamped at either end of the exposed segment, and a transverse arteriotomy was made. A 6F or 7F flexible arterial cannula was introduced and advanced 2 to 3 cm directly into the artery as the proximal clamp was removed. A proximal tourniquet was secured, and the cannula was secured to the tourniquet and skin after connecting it to the CPB pump's tubing circuit. Arterial patency was verified by backflow, presence of an arterial pulse, and absence of resistance during CPB. Then, the axillary vein, which lies superficial to the artery, was clamped at either end. A longitudinal venotomy was made, and a 26F or 28F venous femoral cannula was advanced to 20 cm as the proximal clamp was removed. The position of the venous cannula within the right atrium was confirmed by transesophageal echocardiogram. A proximal tourniquet was secured, and the cannula was secured to the tourniquet and skin after connecting it to the inflow circuit of the CPB pump.

Once the mediastinal dissections were performed, any other needed venous cannulation was performed through the right atrium. A standard perfusion set with a hollow-fiber membrane oxygenator, a hard-shell venous reservoir with integrated cardiotomy reservoir, and an arterial filter were used in conjunction with a roller pump in a routine fashion, with reliance on gravity drainage alone in all cases.

At the end of CPB, arterial and venous decannulations were performed with reclamping of the vessels. The arteriotomy and the venotomy were then closed with Prolene sutures.

### *Doppler Examination*

The axillary arteries and veins were evaluated by US. US examination was performed with a GE Logiq 9 (GE Healthcare, Piscataway, NJ, USA). A 7-3 MHz multi-hertz probe was used. Arteries were evaluated for flow rate and flow pattern. The caliber of and the existence of turbulent flow in the vein were evaluated in the venous examination.

## RESULTS

### *Short-term Results*

Table 1 lists the operations performed. All axillary artery cannulation attempts were successful without arterial-return resistance. Two of the 11 axillary arteries exhibited arteriosclerotic thickening of the arterial wall that did not interfere with the cannulation or subsequent closure (no need for thrombectomy or reconstruction) of the vessel. Ten of the 11 axillary vein cannulation attempts were successful, and the target pump flow rate of 2.4 L/min per m2 was achieved by the axillary vein alone. In 1 patient who had a 3-week history of coronary artery bypass grafting operation and who was admitted to the clinic with an acute type A aortic dissection, the venous cannula could not pass the angulations between the subclavian vein and the superior vena cava. The tip of the cannula was left at that point. The pump flow achieved in that patient by gravity drainage alone was 1.2 L/min per m2, which was enough to decompress the heart and the ascending aorta during resternotomy. Once the mediastinal dissections were performed, full flow was achieved via additional venous cannulation performed through the right atrium.

No serious cardiac or aortic injury developed during sternal entries or reentries. The mean CPB time was 150 ± 69 minutes (range, 75-317 minutes); the mean aortic cross-clamp time was 67 ± 27 minutes (range, 35-109 minutes). In 7 patients (63.6%), hypothermic circulatory arrest was conducted at moderate hypothermia (at a body temperature of 28C) with antegrade cerebral perfusion (10 mL/kg per minute). The mean selective antegrade cerebral perfusion time was 31 ± 19 minutes (range, 7-59 minutes).

Postoperatively, there were no local wound infections, and clinical examinations revealed no arm ischemia or compartment syndrome. Three patients (27.3%) experienced ipsilateral brachial plexus neuropathy that produced weakness and numbness of the right hand. The neuropathy was transient in 1 patient, with symptoms resolving completely before hospital discharge. Hospital death occurred in 1 (9.1%) of 11 patients. This reoperative patient with type A acute aortic dissection died on postoperative day 17 from renal failure and sepsis.

Table 2. Comparisons of the Physical Examinations*

| | Right Arm | Left Arm | *P* |
|---|---|---|---|
| Wrist Diameter, mm | 18.3 ± 2.7 | 18.1 ± 2.6 | >.05 |
| Systolic blood pressure, mm Hg | 135 ± 25 | 130 ± 25 | >.05 |
| Diastolic blood pressure, mm Hg | 75 ± 15 | 70 ± 20 | >.05 |

*Data are presented as the mean ± SD.

### *Midterm Results*

The mean follow-up time was 956 ± 292 days (2.6 ± 0.8 years). One of the patients died on postoperative day 105 from subacute graft infection and sepsis. All 9 living patients were recently contacted for follow-up. Of these patients, only 1 had undergone subsequent redo aortic surgery, which involved insertion of an endovascular stent graft into his descending thoracic aorta because of massive compression of the true lumen. One of the 2 patients who were discharged with brachial plexus neuropathy reported still having right arm weakness 2.5 years postoperatively, whereas the other patient's symptoms had resolved by 2 months postoperatively. None of the patients reported late scar infections, hypertrophic scar formation, signs of arm ischemia, or venous congestion (arm swelling).

At the follow-up visit, the wrist diameter and the arterial pulse pressure were measured and compared with those of the contralateral arm (Table 2). All patients underwent Doppler US for subclavian arterial and venous stenosis. All of the flow patterns of the subclavian artery were triphasic. We found chronic recanalized thrombotic changes in the subclavian vein of 1 patient. The lumen of the vein had narrowed, the wall was thicker than normal, and there was flow without turbulence in the venous lumen.

The axillary artery has been proposed as an alternative for arterial cannulation in certain surgical procedures, and its use has become increasingly widespread [Strauch 2004; Tiwari 2010; Wong 2010]. It preserves antegrade flow in the

descending aorta, thus reducing retrograde atheromatous embolization from the descending thoracic aorta. It also has the capability of providing selective antegrade cerebral perfusion during circulatory arrest. Despite institutional and surgeon preferences to the contrary, there is some evidence that axillary artery cannulation is superior to other techniques. A recent analysis of 14 studies with respect to which type of cannulation was superior for surgery for acute type A aortic dissection demonstrated a significantly lower complication rate with axillary artery cannulation than for femoral artery cannulation in 1069 of 1829 patients [Tiwari 2010]. These investigators concluded that axillary artery cannulation was proved safe and straightforward, with fewer local and systemic complications, including lower mortality and fewer neurologic complications [Tiwari 2010]. Axillary artery cannulation in conjunction with central right atrial or femoral vein cannulation has been used for CPB in almost all of these studies [Strauch 2004; Tiwari 2010; Wong 2010]. Central venous cannulation does not initiate CPB before sternotomy. Because sternotomy carries an increased risk of injury for major aortic and cardiac structures for certain conditions (such as reoperations for huge aneurysms of the ascending aorta) and because the safest technique for eliminating and managing sternal reentry complications is the establishment of CPB [Garrnet 1989], peripheral venous cannulation can be obligatory.

On the other hand, peripheral cannulation through the femoral or jugular vein, requires an accessory incision and is therefore an additional potential source of postoperative morbidity, especially in severely obese or diabetic patients [Gates 1996]. Axilloaxillary CPB is an alternative that has been proposed as a means of addressing the 2 concerns (CPB before sternotomy and use of a single incision). Although the technique was described more than a decade ago [Bichell 1997], only a few early experiences with it have been reported thus far [Bichell 1997; von Segesser 2008; Zattera 2009], and mid- and long-term results are not known.

Our study describes the early and midterm outcomes of totally axilloaxillary CPB in 11 patients with huge aneurysms of the ascending aorta or reoperative type A aortic dissections. We preferred direct arterial cannulation. Strauch and colleagues showed high rates of technical success for axillary artery cannulation, which was abandoned in only 4% of 284 patients. In addition, 2 patients had brachial plexus injury, and 5 patients had lymphoceles, thus also confirming the infrequency of side-related complications [Strauch 2004]. One other study, which originated from the Texas Heart Institute, showed no intraoperative axillary artery injury or arm ischemia in 83 operations for acute or subacute ascending aorta dissection. At follow-up (mean, 584 ± 474 days), 1 patient reported having right arm weakness for 2.5 years, and 1 patient had right thumb numbness at 120 days after the operation. Five patients (11%) reported having problems with the axillary incision (4 patients with hypertrophic scar formation and 1 with unexplained pectoral atrophy). All of the arterial cannulations that we performed were successful, and we did not experience any ischemic complications in the cannulated extremity, either during the operation or in the postoperative period.

We preferred direct venous cannulation and had only 1 patient in whom cannulation was unsuccessful and the target pump flow was not achieved. We believe that curved catheters and stiff guidewires would be helpful for navigating around the angle formed between the axis of the subclavian vein and the vena cava, but we do not have these catheters or guidewires.

Preliminary experiences with axilloaxillary CPB via the subclavicular [Bichell 1997] and deltoid-pectoralis approaches [Zattera 2009] have previously been described. Bichell and colleagues described 7 patients with severe peripheral vascular disease or aortic disease who underwent direct axillary artery and vein cannulation for CPB. All axillary artery and vein cannulations were successful, and full CPB was achieved without difficulty with flows in excess of 3 L/min. They reported no serious complications referable to the arm and its neurovascular structures; only 2 patients experienced a transient brachial plexus neuropathy, which produced right hand weakness that resolved before discharge [Bichell 1997]. Our study had 3 cases of brachial plexus neuropathy, 2 of which were transient. One patient still has arm weakness 2.5 years after the operation. Zattera and colleagues described the deltoid-pectoralis approach for axilloaxillary CPB in 5 cases of redo surgery on the ascending aorta. They cannulated the axillary artery and vein by the Seldinger technique but needed vacuum-assisted drainage in 2 of the 5 patients to reach the target full flow (2.5 L/min per m2) [Zattera 2009]. On the other hand, von Segesser et al used their original self-expanding subclavian venous cannula and achieved 111% of the calculated target pump flow without any major vascular complications [von Segesser 2008].

We examined all of the patients in the outpatient clinic for any axillary cannulation problems, and we performed Doppler US evaluations. All of the arteries examined were patent with triphasic flow patterns. Doppler US of the axillary vein showed chronic recanalized thrombotic changes in 1 patient who had no symptoms.

There are some limitations of our study. First, this report is for an observational cohort with a limited number of patients from a specific population. The study is purely descriptive because of statistical limitations and the lack of a control group for comparison. The mean follow-up time is not very long, and Doppler analysis was not performed immediately after the operation; thus, comparison with the patients' initial status was not possible.

## CONCLUSION

Our results suggest that adding axillary venous cannulation to axillary artery cannulation at least does not increase the risk of a procedure with the axillary artery alone, in either the early or the mid term. A universal recommendation cannot be made about using axilloaxillary bypass for all patients, but an individualized approach may be the best, especially in reoperative patients with a huge aortic aneurysm or dissection in situations in which antegrade flow is desirable or the patient's wound-healing capacity is depressed.

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