Axillary artery cannulation in ascending aortic pathologies

Çıkan aort patolojilerinde aksiller arter kanülasyonu

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Background: We analyzed the results of axillary cannulation for cardiopulmonary bypass (CPB) and the factors affecting mortality and morbidity.

Methods: Eighty-four patients (58 males, 26 females; mean age 53.8±13.2 years; range 20 to 77 years) were operated on for ascending aortic pathologies with axillary arterial cannulation between November 2006 and January 2009. Overall, 124 procedures were performed in 84 patients, and the most commonly performed procedure was the replacement of the ascending aorta which was employed in 64 patients (76.2%). The most common indication for operation was ascending aortic aneurysm that was present in 51 patients (60.7%). Three (3.6%) patients had previously undergone open heart surgery. Hypothermic circulatory arrest was used in 51 (60.7%) patients, and the axillary artery was cannulated directly in 75 (89.3%) patients and via a side graft in nine (10.7%) patients.

Results: Postoperatively, three patients (3.6%) had in-hospital mortality because of sepsis, intraoperative bleeding, and low cardiac output syndrome. Neurological complications were seen in 10 (11.9%) patients (8 had transient neurological dysfunction and 2 had stroke). The mean duration of hospital stay was 5.1±5.6 (range 1 to 46) days. Postoperative follow-up was 10.3±5.5 (range 1 to 15.5) months on average (total of 68.5 patient/years). There was no mortality during the follow-up after discharge. No relationship was found between the method of cannulation and mortality or, neurological complications.

Conclusion: The axillary artery is a safe route for arterial cannulation, and the axillary route does not cause an increase in postoperative mortality and morbidity.

Key words: Ascending aorta; axillary artery cannulation; selective antegrade cerebroplegia.

Amaç: Bu çalışmada kardiyopulmoner bypass (KPB) için aksiller kanülasyonun sonuçları ve mortalite ve morbiditeye etki eden faktörler incelendi.

Çalışma planı: Kasım 2006 - Ocak 2009 tarihleri arasında çıkan aort patolojileri nedeniyle ameliyata alınan 84 hasta (58 erkek, 26 kadın; ort. yaş 53.8±13.2 yıl; dağılım 20-77 yıl) aksiller kanülasyonla ameliyat edildi. Toplamda 84 hastaya 124 işlem uygulandı ve en sık uygulanan işlem 64 hastaya (%76.2) yapılan çıkan aort replasmanıydı. En sık ameliyat endikasyonu 51 hastada (%60.7) bulunan çıkan aort anevrizmasıydı. Üç hasta (%3.6) daha önce açık kalp ameliyatı geçirmişti. Hipotermik dolaşım arresti 51 hastada (%60.7) kullanıldı ve aksiller arter 75 hastada (%89.3) doğrudan, dokuz hastada (%10.7) ise bir yan greft aracılığıyla kanüle edildi.

Bulgular: Ameliyat sonrasında hastaların üçünde (%3.6) sepsis, ameliyat sırası kanama ve düşük kardiyak debi sendromu nedeniyle hastane mortalitesi meydana geldi. Hastaların 10'unda (%11.9) nörolojik komplikasyonlar görüldü (8'inde geçici nörolojik disfonksiyon ve 2'sinde inme). Ortalama hastanede kalma süresi 5.1±5.6 (dağılım 1-46) gündü. Ameliyat sonrası ortalama takip süresi 10.3±5.5 (dağılım 1-15.5) aydı (toplam 68.5 hasta/yıl). Taburcu sonrası takip sürecinde mortalite görülmedi. Kanülasyon yöntemi ile mortalite ya da nörolojik komplikasyonlar arasında herhangi bir ilişki saptanmadı.

Sonuç: Aksiller arter arteriyel kanülasyon için güvenli bir yoldur ve aksiller yol ameliyat sonrası mortalite ve morbiditede artışa neden olmaz.

Anahtar sözcükler: Çıkan aort; aksiller arter kanülasyonu; selektif antegrad serebropleji.

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Alternative arterial cannulation sites to the ascending aorta in cardiopulmonary bypass (CPB) are the transverse arch of the aorta, descending aorta, femoral artery, iliac artery along with the axillary, subclavian, and high brachial arteries.[1,2] The early utilization of the axillary artery was reported by Dias et al.[3] in 1976. The axillary artery has been especially proposed for operations on the ascending aorta and arch.[4] This route of cannulation also enables selective antegrade cerebral perfusion.[4]

There is about a 1 to 3% incidence of stroke in all cardiac procedures.[5] Among the many strategies proposed for protection,[6] axillary arterial cannulation has become increasingly popular since Sabik et al.[7] introduced this concept for use in CPB. We started to cannulate the axillary artery for ascending aortic pathologies, for example, dissections and atherosclerotic aortas. This has necessitated the need for alternative cannulation sites since November 2006. In this paper, we analyze the results of axillary cannulation for CPB and the factors affecting mortality and morbidity.

PATIENTS AND METHODS

We operated on 84 patients (58 males, 26 females; mean age 53.8±13.2 years; range 20 to 77 years) with ascending aortic pathologies on CPB with axillary arterial cannulation between November 2006 and January 2009. Three patients (3.6%) had previously undergone open heart surgery. The preoperative NYHA functional status of the patients is as follows: 19 patients (22.6%) class 1, 33 (39.3%) class 2, 26 (31.0%) class 3, and six (7.1%) class 4. Preoperatively, 63 patients (75%) had hypertension, seven (8.3%) had coronary artery disease (CAD), five (6%) had diabetes mellitus and chronic obstructive pulmonary disease, and three patients (3.6%) had renal dysfunction and previous cardiac surgery. Eighteen patients had none of the risk factors. Of the seven patients (8.3%) with CAD, two had previously undergone percutaneous transcoronary angioplasty with stent (PTCA). Thirty-five patients (41.7%) had emergency surgery. The most common indication for surgery was an ascending aortic aneurysm in 51 patients (60.7%). The indications for operations are listed in table 1. We performed 124 procedures on 84 patients with axillary arterial cannulation, and the most commonly performed procedure was replacement of the ascending aorta in 66 patients (78.6%). The list of procedures is given in tables 2 and 3. The nine hemiarch replacement procedures were performed on the patients with aortic dissection. All patients were followed up routinely at our hospital outpatient clinic.

Postoperative morbidity was divided into three categories. Renal morbidity described patients having significant (>50%), progressive increases in blood urea nitrogen (BUN) and creatinine values or those having the need for dialysis. Pulmonary morbidity was defined as those who had prolonged ventilation (over 24 hours postoperatively), re-intubation, pleural effusion, and

Table 1. Indications for surgery

	Frequency (n)	Patient (%)
Type A dissection	35	41.7
AAA		
Isolated	23	27.4
+ AR	7	8.3
+ Type A dissection	4	4.8
+ AS	3	3.6
+ AR + CAD	3	3.6
+ AR + MR	2	2.4
+ Annuloaortic ectasia	1	1.2
+ CAD	4	4.8
+ Intramural hematoma	1	1.2
+ Type B dissection	1	1.2
+ Ar Ao aneurysm	1	1.2
Aneurysm in the arcus aorta	1	1.2
AAAA + AR	2	2.4
Total	84	

AAA: Ascending aortic aneurysm; AR: Aortic regurgitation; Ar Ao: Arcus aorta; AS: Aortic stenosis; CAD: Coronary artery disease; MR: Mitral regurgitation; AAAA: Aneurysm in the arcus and the ascending aorta.

Table 2. Operations performed individually

Procedures	Patient	
	(n)	(%)
SGIAA	34	40.5
Modified Bentall de bono	15	17.8
SGIAA + AVR	10	12.0
RAHA	8	9.5
SGIAA + CABG	4	4.8
SGIAA + AVR + MVR	2	2.4
SGIAA + AVR + ET procedure	1	1.2
SGIAA + AVR + ET procedure + CABG	1	1.2
SGIAA + ET procedure	1	1.2
Modified Bentall de bono + CABG	1	1.2
RAHA + CABG	1	1.2
RAAA	1	1.2
RAAA + ET procedure	1	1.2
RAAA + AVR	1	1.2
Replacement of arcus aorta	1	1.2
SGIAA + aortic valve repair	1	1.2

SGIAA: Separated graft interposition in the ascending aorta; AVR: Aortic valve replacement; ET: Elephant trunk; CABG: Coronary artery bypass graft; RAHA: Replacement of ascending and hemiarcus aorta; RAAA: Replacement of ascending and arcus aorta.

Table 3. Procedures performed at total

Procedures	Patient	
	(n)	(%)
Aortic root replacement	16	19.0
Aortic segment replacement		
Ascending aorta	66	78.6
Hemiarcus	9	10.7
Arcus	4	4.8
Elephant trunk	4	4.8
Aortic valvular procedures		
Aortic valve replacement	15	17.9
Reconstruction	1	1.2
Coronary artery bypass grafting	7	8.3
Mitral valve replacement	2	2.4

pneumothorax while neurologic morbidity was defined according to the report of Ergin et al.[8] as patients with permanent and transient dysfunction.

Surgical method

The axillary artery exposure for cannulation is obtained through a 6 to 10 cm incision just below the lateral two thirds of the clavicle. The fibers of the pectoralis major muscle are split. The clavipectoral fascia is then incised, exposing the pectoralis minor muscle, which is divided or retracted laterally. In the dissection, the axillary vein is usually encountered first. The axillary artery lies in a superior position, is deeply situated, and is readily palpated. If approached directly following the thoracoacromial trunk, the artery is easily exposed and encircled by umbilical tape. Proximal and distal control of the axillary artery is gained, and the umbilical tape is passed through a tourniquet. In case of direct axillary arterial cannulation, Satinsky clamps are placed proximal and distal to the cannulation site after heparin is administered. A transverse incision is made, and the axillary artery is cannulated with either an 18- or 21-French straight arterial cannula. The tourniquet is tightened, and the cannula is tied to the tourniquet. Flow is evaluated through the cannula by back bleeding, and, if adequate, the cannula is connected to the arterial line and secured to the skin. In direct cannulation of the axillary artery, the distal clamp on the axillary artery is left in place until the end of perfusion. In case of a side-graft cannulation, an 8 mm Dacron graft is anastomosed to the axillary artery in an end-to-side fashion. The distal axillary clamp is not used in these cases, and arterial blood pressure monitoring via the right radial artery is possible throughout the operation. After median sternotomy, cannulation of the caval veins, insertion of the venting cannula via the right superior pulmonary vein, and insertion of the retrograde cardioplegia cannula via the coronary sinus are completed in that order. Next, the brachiocephalic artery is explored and encircled with umbilical tape. After the cross-clamp is placed and cardioplegia is delivered, the operation is performed. In cases with hypothermic circulatory arrest (HCA), the cross-clamp is removed after the proximal anastomosis is done and the brachiocephalic artery has been clamped. The flow rates during the operations are maintained according to the right arterial blood pressure readings in case a side graft is used. Antegrade cerebral perfusion is maintained with a 500 cc/minute flow rate and is increased to 750 to 1000 cc/minute when necessary. Cerebral protection is monitored by evaluation of back bleeding from the left carotid artery, and a pH-stat strategy is used in all cases. Warming is made via the axillary artery cannula unless a problem with the arterial flow is encountered. At the end of the operation, the axillary artery is decannulated and repaired. In cases with a side graft, the graft is excised just above the anastomosis and is repaired with 6/0 prolene sutures. In direct cannulation of the axillary artery, 6/0 continuous prolene sutures are used to repair the artery.

Statistical methods

The definition of complications and methods of analysis were consistent with the guidelines issued by Edmunds et al.[9] Results were presented as mean ± standard deviation. Side-graft cannulation and direct cannulation of the axillary artery were compared for the cross-clamp, perfusion and hypothermic circulatory arrest (HCA) durations, time to extubation, and postoperative drainage along with intensive care unit (ICU) and hospital stays with a t-test for independent samples with $p<0.005$ being accepted as significant. Perioperative risk factors were analyzed with logistic regression. The transient neurologic dysfunction (TND) and stroke (cerebrovascular event, CVE) rates between the direct and side-graft cannulated patients were compared with Fisher's exact test. A p value less than or equal to 0.05 was considered statistically significant for all comparisons. A commercial statistical software package SPSS for Windows, version 16.0, (SPSS Inc, Chicago, IL, USA) was used for data analysis.

RESULTS

Axillary arterial cannulations were made via a side graft in nine patients (10.7%) and directly on the artery in 75 patients (89.3%). The mean aortic cross-clamp and perfusion times were 80.6±39.8 (range 34-189) and 144.3±58.6 (range 70-254) minutes, respectively. Hypothermic circulatory arrest was used in 51 (60.7%) patients with antegrade cerebral perfusion. The mean

temperature was 26.4±3.0 °C (range 18 to 33). In the patients who had HCA in the operation, the mean degree of hypothermia was 25.0±2.5 °C (range 18 to 32 °C).

Postoperatively, three patients (3.6%) had in-hospital mortality. In all of the cases, the axillary artery was directly cannulated. Two patients died intraoperatively. One of the patients could not be weaned from the CPB, in spite of inotropic and intra-aortic balloon pump (IABP) support. This patient was operated on for ascending aorta replacement with a separated graft interposition for type A aortic dissection and had undergone an aortic valve replacement (AVR) previously. He was admitted to our hospital with type A dissection involving the left coronary ostium with thrombus. On preoperative echocardiography (ECG), the ST segments were elevated. Coronary artery bypass graft (CABG) surgery was performed concomitantly with graft interposition. The cross-clamping duration was extended, and the patient could not be weaned from CPB. The other patient was also operated for type A dissection. He presented with paraplegia, and his ascending aorta and arch were replaced at the same time with an elephant trunk procedure. Hypothermic circulatory arrest was used (77 minutes). He died because of uncontrolled bleeding intraoperatively.

Postoperative course and follow-up

None of the patients had axillary artery injury. There was a single (1.2%) patient who had brachial emboli postoperatively, and an embolectomy was performed. He did not have peripheral arterial disease, but he did have a previous PTCA of the left anterior descending branch of the left coronary artery. He was operated on for ascending and hemiarch aortic replacement for type A dissection by direct cannulation of the axillary artery. Twenty-three minutes of HCA was used in this patient. He was the only patient who had wound infection at the subclavicular incision site postoperatively. At his 13-month follow-up, he did not have any problems. Neurological complications were seen in 10 (11.9%) patients (eight had temporary neurological dysfunction (TND) and two had a stroke). All of the neurological complications were seen in the direct cannulation groups, but the statistical analysis did not show a significant difference between these groups (TND: 8/75 for direct cannulation and 0/9 in side-graft group, p=0.382; CVE: 2/75 for direct cannulation and 0/9 in side-graft group, p=0.793) in terms of neurological complications. A total of 24 patients had postoperative complications. These are listed in table 4, and it can be seen that 14 patients had pulmonary morbidity. Of the four patients with chronic obstructive pulmonary disease (COPD), only one of them had pulmonary complications (prolonged ventilation). Also, of the three patients who had chronic renal failure preoperatively, only one required dialysis. Among these three cases, she was the only patient on whom HCA was used. The other two cases had uneventful postoperative courses.

The mean duration of hospital stay was 12.6±5.9 (range 1 to 46) days, and the mean intensive care unit stay was 5.4±5.6 (range 1 to 46) days. Postoperative follow-up was 10.3±5.5 (range 1 to 15.5) months on average (total of 68.5 patient/years). There was no mortality during follow-up.

The method of axillary cannulation was analyzed according to the intraoperative and postoperative variables in order to find out if there were any differences. The cross-clamp (direct vs. side-graft cannulation 77.3±37.1 vs. 102.0±42.8 on average; p=0.007) and perfusion (direct vs. side-graft cannulation 137.5±48.9 vs. 180.5±54.1 on average; p=0.0001) durations were significantly less in the direct cannulation group. The duration of ICU stay was less in the side-graft group (direct vs. side-graft cannulation 5.0±5.6 vs. 4.8±3.7 on average; p=0.009). There were no significant differences between the two methods of cannulation (direct vs. side-graft) in terms of mortality, stroke, or TND.

DISCUSSION

Axillary artery cannulation offers several advantages:[6] *(i)* the axillary artery is generally free from atherosclerosis; *(ii)* it eliminates the risk of retrograde embolization; *(iii)* it provides antegrade perfusion of the true lumen in aortic dissection; *(iv)* antegrade cerebral perfusion is never interrupted; and *(v)* bihemispheric perfusion is assured. Watanabe et al.[10] report that axillary arterial cannulation is useful, especially in the following conditions: *(i)* coexistence of abdominal or iliac

Table 4. Postoperative morbidity

	(n)	(%)
Pulmonary	14	16.7
Arrhythmia	11	13.1
Neurologic	10	11.9
Transient neurologic dysfunction	8	9.5
Cerebrovascular event	2	2.4
Renal	8	9.5
Revision operation for any cause	6	7.1
Postoperative bleeding	4	4.8
Infection	4	4.8
Pericardial effusion	4	4.8
Low cardiac output	2	2.4
Need for IABP support	1	1.2
Local complications	1	1.2

IABP: Intra-aortic balloon pump.

aneurysm; *(ii)* coexistence of chronic peripheral arterial occlusive disease; *(iii)* extension of aortic dissection to the femoral artery; and *(iv)* considerably narrow true lumen compressed by the false lumen in aortic dissection. In the 392-patient series of Sabik et al.,[11] the indications for axillary cannulation were a calcified ascending aorta in 32%, an ascending aortic aneurysm in 29%, type 1 aortic dissection in 21%, cardiac reoperation in 18%, and a calcified femoral artery in 6%.

We prefer the right axillary artery for cannulation. However, the left axillary artery has also been proposed since it is isolated from the carotid system and debris, meaning microbubble embolization can be avoided at the beginning of perfusion. Another reason it has been proposed is because the left subclavian artery is less prone to obstruction or dissection than the right.[10,12] Schachner et al.[13] report that in 14% of their series, they had to switch the cannulation site to the ascending aorta or the femoral artery, but we did not face that kind of complication.

Sinclair et al.[1] discussed the safeguards and pitfalls of the axillary route for CPB. They state that a side graft ensures adequate perfusion and may be useful in case compartment syndrome ensues during CPB. The extra time for anastomosis and weeping around the graft are the main drawbacks of this technique.[1,14] Although both cannulation-related and perfusion-related (inadequate flow) problems have been encountered with the direct cannulation technique, Schachner et al.[15] also report malperfusion problems in aortic dissections with the use of a side graft. Another potential problem is the difficulty in the evacuation of air with the side-graft technique.[16] One of the most important series which documented reduced morbidity with the side-graft technique[11] showed that the principal advantage of the side graft is avoidance of iatrogenic dissection that could occur with direct cannulation. This has also been reported by others.[17] Yılık et al.[18] report lower transient neurologic dysfunction rates with the use of a side graft, and this could be related to pressure-controlled perfusion. Although the actual rates were high in the direct cannulation group, the difference was not significant. There were 10 patients with neurologic complications in our studies. Two had stroke (2.4%) and eight had TND (9.5%). Our results are compatible with the other studies.[18,19]

Hypothermic circulatory arrest was used in 60.7% of our patients, which is similar to other axillary cannulation series like that of Neri et al.[12] Touati et al.[20] demonstrated that in aortic arch cases, axillary arterial cannulation may help the surgeon avoid the use of HCA. Although HCA exceeding 25 minutes has previously been associated with mortality,[21] we did not find a similar association in the logistic regression analysis. Of the three mortalities, HCA was only used in one patient for 77 minutes. We used moderate hypothermia in the operations with HCA. There was a single patient that was cooled to 18 °C. His total duration of HCA was 21 minutes, and the total cross-clamp duration was 45 minutes. He had no morbidity postoperatively and was discharged on the 11th postoperative day. Besides this patient, the lowest degree of applied hypothermia was 21 °C. The avoidance of deep hypothermia may be one of the reasons why HCA was not a significant risk factor for mortality and morbidity. As Kazui et al.[22] have reported, antegrade cerebral perfusion ensures a safe operation at temperatures of 22 °C.

In a study of 106 patients with type A dissection, Moizumi et al.[23] report 7.2% hospital mortality, and the absence of axillary arterial cannulation was an independent predictor of hospital death with an odds ratio of 8.2. The hospital mortality in our series was comparable at 4.8%. The mortality rate in patients who suffer from stroke has been reported with an incidence of 20 to 38%.[24] In our study, two patients suffered from stroke, and one of them died. Despite success in axillary cannulation, mortality as high as 15% has been reported,[1] but adverse events such as death and stroke occur reportedly at less than 7% in centers experienced in this procedure.[25]

There was a single patient who required a brachial embolectomy. The axillary artery, unlike the femoral artery, is rich in collaterals, especially from the thyrocervical trunk to the suprascapular and transverse cervical arteries. This makes the distal circulation less prone to ischemic events.[12] Although our rate of local complications was low, the high rate of these complications reported by Strauch et al.,[4] caused Sabik et al.[7] to argue for the use of a side graft for axillary artery cannulation. Furthermore, Schachner et al.[15] report that axillary injuries are less frequent (they had none) in cases of cannulation via a side graft. Contraindications for the use of the axillary artery are scarce and include atherosclerosis or extension of the dissection into the axillary artery.[17]

The axillary artery is a safe route for arterial cannulation for CPB. Both direct and side-graft cannulation give favorable clinical results. The prolonged durations of cross-clamp and perfusion in side-graft cannulation do not lead to adverse outcomes; however, direct cannulation may be preferred for ease in technique.

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