Brachial Artery Perfusion for Redo Ascending and Aortic Arch Cases

Redo Asendan ve Arkus Aorta Olgularında Brakiyal Arter Perfüzyonu

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ABSTRACT Objective: Ascending and/or aortic arch complications identified during the follow-up of previous cardiac surgery dictate urgent reoperation. The role of brachial artery cannulation in such cases was evaluated with regard to its potential benefits. **Material and Methods:** Between January 2000 and December 2007, 50 patients (34 male/16 female; mean age: 50.1 ± 13.5; range: 22-70) underwent repeat cardiac surgery for ascending/aortic arch repair using this technique. The previous surgical procedures were predominantly aortic valve operations. The average interval between the initial cardiac operation and the reoperation was 101 ± 80 months (1- 324 months). The complications leading to repeat cardiac surgery were aneurysm formation and/or rupture in ascending/aortic arch in 28 patients, Stanford type-A dissection in 20 patients and pseudo aneurysm development in 2 patients. **Results:** Hospital mortality was 10% (5 patients), mainly due to uncontrollable bleeding and low cardiac output. The average cardiopulmonary bypass and aortic cross-clamp times were 144 ± 59 (70-335) and 93 ± 25 (53-156) minutes, respectively. The average low flow antegrade cerebral perfusion (via right brachial artery) period was 29 ± 11.6 minutes (range: 16-78 minutes) under moderate (26-30°C) hypothermia. No neurological complication or organ dysfunction was observed in the early or late postoperative periods. Comprehensive neurocognitive function assessments revealed no postoperative deterioration. The average amount of chest tube drainage was 942 ± 133 (550-1300) mL. All survivors (45 patients, 90%) were discharged within 5-16 days postoperatively and were in good condition at their last follow-up visits. **Conclusion:** Perfusion via brachial artery cannulation is a safe and reliable approach in reoperations for ascending and aortic arch complications.

Key Words: Aorta; brain ischemia; brachial artery; reoperation

ÖZET Amaç: Daha önce yapılan kalp cerrahisinden sonra takip sırasında saptanan asendan ve arkus aorta komplikasyonları acil operasyon gerektirir. Böyle olgularda brakiyal arter kanülasyonunun rolü ve potansiyel faydaları değerlendirilmiştir. **Gereç ve Yöntemler:** Ocak 2000 ile Aralık 2007 tarihleri arasında, daha önce açık kalp cerrahisi geçirmiş 50 hastaya (34 erkek/16 kadın; ortalama yaş: 50.1 ± 13.5 yıl; 22-70 arası) bu teknik kullanılarak asendan ve/veya arkus aorta tamiri yapıldı. Hastaların büyük çoğunluğunda daha önceki cerrahi işlem aort kapak operasyonu idi. İlk ve ikinci kalp cerrahisi girişimleri arasındaki ortalama süre 101 ± 80(1- 324) ay idi. İkinci kalp cerrahisini gerektiren patolojiler 28 hastada asendan ve/veya arkus aort anevrizması, 20 hastada Stanford tip A disseksiyon ve 2 hastada psödoanevrizma gelişmesi idi. **Bulgular:** Hastane mortalitesi %10 oldu (5 hasta). Mortalite nedenleri düşük kalp debisi ve kontrol edilemeyen kanama idi. Ortalama kardiyopulmoner bypass ve aortik kros-klemp zamanları sırasıyla 144 ± 59 (70-335) ve 93 ± 25 (53-156) dakika idi. Orta hipotermide (26-30°C) ortalama düşük debili antegrad serebral perfüzyon (sağ brakiyal arterden) süresi 29 ± 11.6 dakika (aralık: 16-78 dakika) oldu. Erken ve geç postoperatif dönemde nörolojik komplikasyon ya da organ disfonksiyonu görülmedi. Kapsamlı nörokognitif fonksiyon değerlendirmelerinde postoperatif kayıp görülmedi. Göğüs tüplerinden ortalama 942 ± 133 (550-1300) mL drenaj oldu. Yaşayan tüm hastalar (45 hasta, %90) postoperatif 5-16 günlerde taburcu oldular. Son yapılan kontrollere kadar kaybedilen hasta olmadı. Hiçbir hastada yeniden cerrahi girişim gerekmedi. **Sonuç:** Asendan ve arkus aorta komplikasyonları için yapılan reoperasyonlarda, brakiyal arter yoluyla perfüzyon emniyetli ve güvenilir bir yöntemdir.

Anahtar Kelimeler: Aorta; beyin iskemisi; brakiyal arter; reoperasyon

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Postoperative ascending and/or aortic arch problems such as aneurysm or dissection development are dreadful complications necessitating a cumbersome reoperation in a precarious location. These complications, although can develop after any type of open heart surgery, are more frequently observed after procedures involving the ascending aorta, mostly aortic valve operations and patients with bicuspid aortic valves are reported to be particularly prone. These complications are rarely encountered during daily practice and although their actual incidence is not known, it is estimated to be on increase, parallel to the cumulative number of patients undergoing aortic valve replacement and ascending aorta operations. Surgical treatment is warranted upon diagnosis; however, available information is limited regarding the underlying mechanism, optimal surgical approach and consequences in these problematic reoperations. For example, sternal re-entry may be quite dangerous due to mediastinal adhesions and close proximity of the dilated and distended ascending aorta to the posterior sternum. Similarly, the present dissection may preclude standard aortic cannulation. Therefore, cannulation technique for cardiopulmonary bypass should vary significantly from the standard procedure. Femoral vessel cannulation is often advised in the classical literature and axillary artery cannulation has gained popularity in the recent years. Others, including us, advocate the use of routine brachial artery cannulation in such cases.

Brachial artery cannulation has many advantages in terms of easy application, low complication rate and good performance.[1] However, its safety and superiority should be reasonably discussed in the light of scientific data. The following is a summary of our experience with the use of brachial artery cannulation in these challenging reoperations.

MATERIAL AND METHODS

Between January 2000 and December 2007, 50 patients (34 male/16 female; mean age: 50.1 ± 13.5, ranging between 22 and 70) underwent reoperation in our institution for aortic aneurysm and/or dissection using selective antegrade cerebral perfusion via proximal right brachial artery cannulation for cerebral protection. The average interval between the initial operation leading to ascending aorta complications and the reoperation for their repair was 101 ± 80 months (range: 1-324 months). Patient demographics were summarized in Table 1. The previous surgical procedures were predominantly aortic valve procedures as described in detail in Table 2. The reoperations were performed for the repair of following complications: aneurysm formation and/or rupture in ascending or arcus aorta in 28 patients (including one with previous aortic valve replacement + ascending aorta wrapping), Stanford type-A aortic dissection in 20 patients, and pseudo aneurysm development in 2 patients. These were described in detail with the other associated pathology in Table 3. The diagnosis was based on data obtained by computed tomography, trans-thoracic echocardiography and angiography.

OPERATIVE TECHNIQUE

We have described our operative technique in detail previously.[1] Briefly, all patients were operated under anesthesia maintained with fentanyl; rectal temperature, electrocardiogram and arterial pressure in the left upper extremity were monitored. The patients were placed in the supine position, with the right upper extremity in slightly more than 90° abduction and slight external rotation.

Dissection and cannulation of the right upper brachial artery was done prior to median sternotomy. A medial longitudinal incision was made along the bicipital groove into the axillary fossa.

TABLE 1: Demographics.

Variable	No. of cases
Sex, male/female	34/16
Hypertension	23 (46%)
Hyperlipidemia	7 (14%)
Smoking	9 (18%)
Chronic Obstructive Pulmonary Disease	7 (14%)
Mean age, years (range)	50,1 ± 13 (22-70)
EF (%)	54,1 ± 10,4 (25-67)

EF: Ejection fraction

TABLE 2: Operative history.

Previous Operations	No. of patients
Aortic valve replacement	22
AVR + Ascending Aorta Wrapping	1
Open aortic valvotomy + subaortic myectomy	1
Supra-coronary ascending aortic graft	7
Coronary artery bypass grafting	14
Aortic valve replacement + coronary artery bypass grafting	1
Modified Bentall procedure	3
Ascending aortic plicate	1

AVR: Aortic valve replacement.

TABLO 3: Reoperation indications.

Aortic Aneurysm	28
Rupture (+)	5
Paravalvular leak	3
Mechanic valve of thrombus	1
Failed biologic valve	2
Coronary artery disease	6
Aortic dissection	20
Without rupture	13
With rupture	7
Coronary artery disease	3
Aortic pseudo-aneurysm development	2
With rupture	1
With coronary artery disease development	1

The incision followed the medial border of the biceps along its groove, which separated the biceps anteriorly from the triceps posteriorly. An incision 6 to 8 cm long is adequate for exposure of artery. The median nerve was exposed and was mobilized laterally, thus exposing the artery after heparin administration. Arterial soft clamps were placed proximal and distal to the cannulation site. Transverse arteriotomy was made by scalpel. The artery was cannulated with a nonwire-reinforced venting catheter (California Medical Laboratories, Irvine, CA), the tip of which was trimmed to 16 to 18 F diameters according to the size of the patient's brachial artery. The catheter was gently inserted into the artery, as its tip was positioned 5 to 7 cm proximal to the arteriotomy (Figure 1). The cannula was then connected to the cardiopulmonary bypass circuit as usual for any arterial return cannula.

Only after these lines were secured, the repeat sternotomy was carefully made, preferably using a pneumatic oscillating blade saw. Any bleeding was quickly controlled and venous cannulation was established via a two-stage venous cannula inserted through the right atrial appendage. Femoral vein was used in eight patients according to the surgeon's preference for venous cannulation, preparing the field before the sternotomy.

Cardiopulmonary bypass was established and the flow was gradually increased to 2.0-2.2 L/min per m^2 body surface area. Core cooling to 26-28^{o}C was started and cardiac arrest was induced by cold antegrade/retrograde cardioplegia solution (Plegisol, Abbot) in conjunction with topical cooling using ice slush or ice-cold saline. After induction of cardiac arrest, the ascending aorta was opened and a Dacron tube graft with or without a prosthetic aortic valve was inserted. Operation could be terminated here as an ascending aorta repair with or without the extension of the procedure as a "hemi-arc repair". If additional aortic arch pathology was to be addressed, the procedure progressed as follows: The flow was decreased to 500–600 mL/min (8–10 mL/kg per min) at 26°C rectal temperature. Then, the three brachiocephalic arteries were clamped. The cross-clamp on the ascending aorta was then released. Early in our experience,

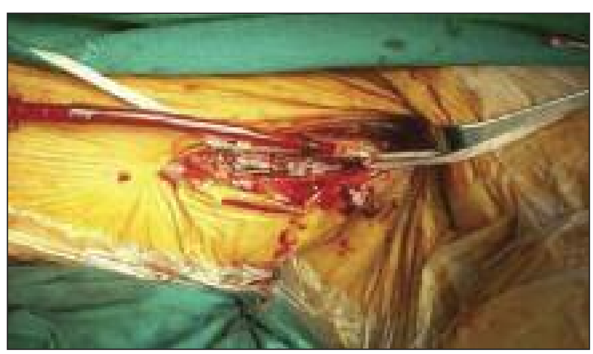

FIGURE 1: Patient is placed in the supine position, with the right upper extremity abducted slightly more than 90° and slightly externally rotated. Following exposure and control of the proximal right brachial artery, the vessel cannula is inserted and is connected to the CPB circuit as the sole arterial return.

we used to monitor the perfusion pressure via an 18-gauge vessel cannula introduced into the brachiocephalic artery just distal to the clamping site, trying to keep this pressure between 40 and 50 mmHg. However, our experience implied that a flow rate of 8-10 mL/kg per min was generally satisfactory to keep the perfusion in safe limits in terms of flow and pressure. Therefore, we left using routine pressure monitoring during antegrade cerebral perfusion. The brachiocephalic vessels were anastomosed onto the roof of the arcus graft as a single aortic patch. After completing distal anastomosis of the arcus graft to the descending aorta (always using "open anastomosis technique"), the clamps on the brachiocephalic vessels were released (first the one on the left subclavian artery and carotid artery, then that on the brachiocephalic trunk) and the flow rate was gradually increased allowing any entrapped air to escape from the proximal end of the graft as its lumen was filled with blood. Then the proximal end of the arcus graft was clamped. Rewarming started at full flow. During rewarming, the anastomosis between the ascending and arcus grafts was completed.

The possible advantages of this approach over femoral cannulation are: 1) The quick restoration of cerebral blood flow in case of an aortic or cardiac injury during sternal re-entry; 2) A less stressful split of adhesions in order to achieve surgical exposure during such an injury, by providing a decompressed heart to work on, and longer safe time periods; 3) Protective effects against bleeding tendency and pulmonary dysfunction by rendering total circulatory arrest unnecessary, therefore avoiding longer perfusion times and deeper levels of hypothermia; 4) Avoidance of a groin incision and its potential morbidity. 5) Using a safer place for cannulation and avoidance of retrograde perfusion of false lumen in the presence of an aortic dissection when compared to femoral artery cannulation.

The patients were closely monitored during their early postoperative recovery for any signs of neurological or distal organ dysfunction. A comparison between the preoperative (a day before the surgery) and postoperative (on postoperative day seven and postoperative month two) neurocognitive functions for each hemisphere was also performed in patients undergoing aortic arch repair by brachial artery perfusion technique. This examination consisted of five tests; namely, the Hospital Anxiety and Depression Scale, Raven's Standard Progressive Matrices Test, Line Orientation Test, Stroop Task, and Rey Auditory Verbal Learning Test. The details of this examination can be found in our institution's previous publications.[2]

STATISTICAL ANALYSIS

Data were analysed using SPSS version 11.5. Comparisons between groups were made by Student's t or Mann-Whitney U tests for continuous variables and Chi-square or Fisher's Exact tests for categorical variables, where applicable. Odds ratio and 95% confidence intervals (CIs) for each risk factor were calculated by univariate analysis. Multiple Logistic Regression analysis–Backward LR procedure-was applied to determine the best indicator on existence of complication and mortality. A p value less than 0.05 was considered statistically significant. All tests of significance were two tailed.

RESULTS

The average cardiopulmonary bypass and aortic cross-clamp times were 144 ± 59 minutes (range: 70-335 minutes) and 93 ± 25 (range 53-156 minutes) minutes, respectively. The average low flow antegrade cerebral perfusion (via right brachial artery) period was 29 ± 11.6 minutes (range: 16-78 minutes). Operative data (principal and associated procedures at reoperation) were summarized in Table 4.

The hospital mortality was 10% (5 patients). Two patients died intra-operatively due to uncontrollable bleeding from anastomotic sites. Three patients died in the early postoperative period due to low cardiac output development. Two patients were re-explored for bleeding. No neurological complication was encountered during the early or late postoperative periods. Three patients had transient right hand paresis, which resolved before discharge. Renal insufficiency was observed in one patient. This patient was operated urgently with the

TABLE 4: Operative data (Principal and Associated Procedures at Reoperation).	
CPB Time (min)	144 ± 59 (70-335)
Xclamp Time (min)	93 ± 25 (53-156)
Low flow antegrade cerebral perfusion time (min)	29 ± 11,6 (16-78)
Hypothermia (ºC)	27.32 ± 1.3 (26-30)
Principal Procedure	
Modified Bentall Procedure	23
Ascending aorta supracoronary graft replacement	12
Ascending aorta supracoronary graft replacement + aortic hemiarch replacement	3
Modified Cabrol	1
Total aortic arch replacement	5
Modified Bentall Procedure + hemiarch replacement	6
Concomitant Procedure	
Aortic hemiarch replacement	3
Coronary artery bypass grafting	6
Aortic valve replacement	5

CPB: Cardiopulmonary bypass, X clamp: Aortic cross-clamp times, min: Minutes

diagnosis of ruptured aortic aneursym and dissection. During the porstoperative period, the patient had low urine output and high blood urea nitrogen and creatinin values as well as high liver enzymes with a diagnosis of hepato-renal insufficiency. Patient underwent hemodialysis and was discharged on postoperative day 16 on routine hemodialysis program. Nineteen patients required positive inotropic agent support. The average amount of postoperative chest tube drainage was 942 ± 133 mL (550-1300), and an average of 4.1 ± 0.4 units of packed red cells were transfused.

A comparison between preoperative (a day before the surgery for all elective patients) and postoperative (on postoperative day seven and postoperative month two) neurocognitive functions in patients undergoing aortic arch repair by brachial artery perfusion technique regarding both right and left hemispheric functions revealed no postoperative regression in any performed test. We measured aspartam amino transferase (AST) and alanine aminotransferase (ALT), blood urea nitrogen (BUN), serum creatinine, amylase, lipase and bilirubine levels preoperatively and on postoperative days one and five (Table 5). These values were high for those patients with high preoperative values. For the rest of the patients, the results were within normal limits and any subtle changes we-

TABLE 5: Renal, hepatic and visseral function tests.

	Preoperative	PO Day 1	PO Day 5	Normal Range
Bun (mg/dL)	35.02±12.48 (23-121)	57.26 ±27.09 (30-162)	51.78 ± 25.1 (26-159)	10-50
Creatinine (mg/dL)	0.9 ± 1.19 (0.4-9.1)	1.3 ± 1.51 (0.6-10.5)	1.24 ± 1.16 (0.6-8.4)	0.5-1.2
AST (U/L)	30 ± 11.75 (11-70)	50.9 ± 58.32 (21-409)	47.16 ± 57.32 (17-381)	0-38
ALT (U/L)	26.5 ± 8.4 (10-47)	35.27 ± 19.4 (7-129)	29.5 ± 12.4 (11-67)	0-41
Amylase (U/L)	66.4 ± 26.3 (12-152)	106 ± 106.1 (32-559)	92.57 ± 37-239)	28-100
Lipase (U/L)	36.2 ± 15.3 (13-65)	40.4 ± 26.9 (6-126)	48.4 ± 27.1 (11-101)	13-60
Direct Bilirubine (mg/dL)	0.2 ± 0.1 (0.02-0.9)	0.5 ± 0.54 (0.08-2.2)	0.4 ± 0.5 (0.09-3.3)	0.00-0.30
Total Bilirubine (mg/dL)	0.9 ±0.29 (0.3-1.8)	1.3 ± 1.02 (0.3-4.4)	1.13 ± 0.7 (0.19-4.7)	0.00-1.10

PO: Postoperative, AST: Aspartic amino transferase, ALT: Alanine aminotransferase, BUN: Blood urea nitrogen.

re similar to those of patients undergoing routine open cardiac operations. All survivors (45 patients, 90%) were discharged on postoperative days 5-16 (average discharge time: 7.2 ± 3.9 days) were in good condition on their last follow-up visits. The mean follow-up time was 47.6 ± 20.5 months (range: 3-76 months). Postoperative data were summarized in Table 6.

DISCUSSION

Recurrent aortic aneurysms, persistent or newly developed dissection, new onset of valvular and coronary artery disease, graft infection, and prosthetic endocarditis are not rare after aortic operations.[3-7] As the number of aging population undergoing cardiac surgery increases, those under risk for aortic complications necessitating future reoperations exhibit a parallel increase.[8] Crawford et al. acknowledged technical problems and other conditions leading to reoperation in such a population.[9] These often include insufficient or incomplete treatment attempts such as the localized aortoplasty technique, replacement of only a small segment of the diseased ascending aorta, graft wrapping to dilate ascending aorta, supravalvar graft insertion without addressing to Valsalva sinus dilation, development of false aneurysms at anastomotic sites and intimal dissections at the cannulation site. Dougenis et al demonstrated that many such patients had some dilation of the aorta present at the initial operation that was not addressed appropriately.[4] Some others developed dissections or false aneurysms formed during or early after the previous operation. According to von Kodolitsch et al an aortic dissection occurred in 0.6% of cases after aortic valve operations.[10] They found that aortic wall fragility and thinning were risk factors for aortic dissection. Mortality rates ranging from 6% to 19% after reoperations on the ascending aorta and the aortic root have been reported.[9,11,12] Our results are in accordance with these previous reports.

TABLE 6: Postoperative data.

Extubation (hour)	11.7 ± 3.9 (8-31)
Discharge from hospital (day)	7.2 ± 1.9 (5-16)
Drainage (ml)	942 ± 133 (550-1300)
Positive inotrope (dopamine and/or dobutamine)	19 (38%)
Discharge from ICU (day)	2.34 ± 1.02 (1-5)
Neurological dysfunction	
Local	1 (2%)
Transient	3 (6%)
Hepatorenal failure	1 (2%)
Transfusion	5.3 ± 0.9 (3-8)
Revision	3 (6%)
Bleeding	2 (4%)
Brachial artery repair	1 (2%)
Follow up (months)	47.6 ± 20.15 (3-76)
Excitus	5 (10%)

ICU: Intensive care unit.

We mostly performed modified Bentall technique for redo root replacements, if coronary ostia could be brought easily to the graft for end to side anastomosis. This was not possible in one case and Cabrol technique was used for tension free button anasthomosis.

The hazards of sternal re-entry are well known. When done on emergency cases, the mortality somehow related to accidental injury during resternotomy dramatically increased as Goodwin et al. indicated. In their series of emergency reoperations, the mortality was 43%, with half of these occurring intraoperatively.[13] Preoperative lateral chest X-rays may help delineate the close anatomical relatonship of the great vessels or heart with the posterior sternum.

The choice of the arterial cannulation site is equally important. The femoral artery is not a preferred side for arterial cannulation in the presence of a thoracoabdominal aortic or iliofemoral vascular disease, aortic dissection or in vascular conditions associated with a risk of retrograde thrombi or atherosclerotic debris embolization.[14] Atheroembolism is a major source of morbidity and mortality during aortic operations and retrograde arterial perfusion through an atherosclerotic aorta has been shown to be associated with stroke and visceral organ injury. Heavy ascending aortic atherosclerosis was shown to be frequently associated with severe abdominal atherosclerosis.[15] On the other hand, during surgical treatment of acute type-A dissection, cannulation of the femoral artery and retrograde aortic perfusion may result in pressurization of the false lumen and subsequent brain and visceral malperfusion, with devastating consequences.[7] Recently, the axillary artery has gained popularity as a potential cannulation site, especially for complex aortic procedures.[7,16] However, axillary artery cannulation requires an extensive, more complicated dissection and a side-graft anastomosis. Axillary artery is in close proximity to the aortic arch, carotid arteries and major nerves. Iatrogenic injuries to these stuructures are possible during axillary artery cannulation.[17] To avoid such complications, recently special cannulas have become commercially available; however, we use right brachial artery for cannulation before sternal reentry in reoperations for aortic repairs because this approach offers a less extensive dissection, less potential for collateral damage and hematoma, easy set up and take-down, surprisingly good hemodynamic performance, easy healing and low complication rate. In addition, it decreases the risk of embolization and provides better surgical exposure by not cluttering the field with cannulas and lines. Antegrade brain perfusion is never interrupted, providing whatever necessary time to the surgeon for arch repair or repair of any potential injury inadvertently done during sternal re-entry. This technique renders deep levels of hypothermia unnecessary and moderate hypothermia around 26-28°C is often adequate. A previous study of ours revealed excellent neurologic outcome in patients operated using this approach.[2,18] Use of this unilateral cerebral perfusion technique raises concerns about the adequacy of perfusion to the contralateral hemisphere. This issue was discussed in detail in our previous publication.[19] We do perform bilateral carotid artery duplex scan for elective patients but not transcranial Doppler preoperatively. In our experience, at the initiation of antegrade perfusion, visual assessment of the returning blood through left common carotid and subclavian arteries has been the most valuable proof of contralateral hemispheric perfusion, and its amount was always satisfactory.

Clamp duration for right arm was about 6 to 8 hours in our cases and we did not observe right upper limb ischemia in any patient, probably due to rich anatomic collateral flow of the upper arm region. Arterial cannula may be switched to the aortic graft following the termination of the distal anastomosis, if rewarming is too slow, but this was not necessary for this cohort.

We conclude that, right brachial artery cannulation for the repair of postoperative aortic complications provides excellent results, technical simplicity, good neurologic outcome and allows for optimal repair without time restraints and decreases the risk of cerebral embolization, causes less bleeding and pulmonary complications by avoiding the necessity for deep hypothermia and decreases cardiopulmonary bypass and operative time periods.

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