The Heart Surgery Forum #2015-1284
18 (4), 2015 [Epub August 2015]
doi: 10.1532/hsf.1284

Online address: http://journal.hsforum.com

Open Distal Anastomosis Technique for Ascending Aortic Aneurysm Repair without Cerebral Perfusion

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ABSTRACT

Background: This study aimed to report the outcomes of patients who underwent proximal thoracic aortic aneurysm surgery with open distal anastomosis technique but without cerebral perfusion, instead under deep hypothermic circulatory arrest.

Methods: Thirty patients (21 male, 9 female) who underwent ascending aortic aneurysm repair with open distal anastomosis technique were included. The average age was 60.2 ± 11.7 years. Operations were performed under deep hypothermic circulatory arrest and the cannulation for cardiopulmonary bypass was first done over the aneurysmatic segment and then moved over the graft. Intraoperative and early postoperative mortality and morbidity outcomes were reported.

Results: Average duration of cardiopulmonary bypass and cross-clamps were 210.8 ± 43 and 154.9 ± 35.4 minutes, respectively. Average duration of total circulatory arrest was 25.2 ± 2.4 minutes. There was one hospital death (3.3%) due to chronic obstructive pulmonary disease at postoperative day 22. No neurological dysfunction was observed during the postoperative period.

Conclusion: These results demonstrate that open distal anastomosis under less than 30 minutes of deep hypothermic circulatory arrest without antegrade or retrograde cerebral perfusion and cannulation of the aneurysmatic segment is a safe and reliable procedure in patients undergoing proximal thoracic aortic aneurysm surgery.

INTRODUCTION

Traditional proximal thoracic aortic aneurysm surgery involves the use of the distal part of the ascending aorta, axillary artery, or femoral artery as the preferred cannulation site. However, such an approach is associated with a number of challenges and risks due to cross-clamp including difficulties in aneurysmatic aortic tissue resection and performing distal anastomosis, and the risk of tissue injury caused by the sutures. An alternative strategy utilized to circumvent these disadvantages is to operate on the ascending aorta using the deep hypothermic circulatory arrest (DHCA) technique without the use of cross-clamp. In the latter approach, the main strategies for providing cerebral protection include straight DHCA, retrograde cerebral perfusion (RCP), and antegrade cerebral perfusion (ACP), without clearly demonstrated benefits of one over the others [Elefteriades 2010; Bachet 2010; Ueda 2010].

Therefore, in this study we analyzed a group of patients who underwent proximal thoracic aortic aneurysm surgery with open distal anastomosis technique but without cerebral perfusion, where cardiopulmonary bypass (CPB) was initiated through the cannulation of the aneurysmal aortic segment, followed by continuation of CPB through cannulation over single-branch graft, or tube graft, or valved conduit.

MATERIALS AND METHODS

Study Population

Between June 2009 and March 2015, 30 patients (21 male, 9 female) underwent proximal thoracic aortic aneurysm surgery with open distal anastomosis technique under total circulatory arrest (TCA), without cerebral perfusion. The average age was 60.2 ± 11.7 years (range, 30-74 years). Written informed consent was obtained from all patients and the study protocol was approved by the institutional ethics committee.

The outcome of straight TCA was analyzed. The following set of preoperative data were collected for all patients: age, sex, diagnosis, left ventricle ejection fraction (LVEF), type of surgery, history of coexistent conditions such as diabetes mellitus, hypertension, peripheral vascular disease, and neurological and renal dysfunction. Characteristics of the study population are shown in Table 1.

The diagnoses were established with echocardiography, computed tomography, and coronary angiography/cardiac catheterization. Patients had ascending aorta aneurysm associated with aortic valvular disease, coronary artery disease, or mitral valve disease (Table 2). None of the patients had significant carotid artery lesion or neurologic dysfunction.

Surgical Technique

All procedures were performed under general anesthesia with routine monitoring, and nasopharyngeal heat probes were used. Following median sternotomy and heparinization, cardiopulmonary bypass was established using an ascending aortic cannula (California Medical Laboratories, 8 mm, 24 Fr, Aortic Arch Cannula, Curved Tip; California Medical

Received May 21, 2015; accepted June 29, 2015.

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Table 1. Preoperative Data of the Patients*

	n	%
Female sex	9	30
Male sex	21	70
Hypertension	18	60
Diabetes	14	46.7
Renal dysfunction	1	3.3
COPD	12	40
Peripheral vascular disease (non-critical)	1	3.3
Euroscore II	1.8-15.8 (3.8 ± 2.9)	
EF, %	30-65 (53.3 ± 10.6)	

*Data are presented as the mean ± SD where indicated. COPD indicates chronic obstructive pulmonary disease; EF, ejection fraction; SD, standard deviation.

Table 2. Preoperative Diagnoses of the Patients

	n (%)
Ascending aortic aneurysm	2 (6.7)
Ascending aortic aneurysm + aortic insufficiency	10 (33.3)
Ascending aortic aneurysm + aortic stenosis	9 (30)
Ascending aortic aneurysm + coronary artery disease	3 (10)
Ascending aortic aneurysm + aortic insufficiency + coronary artery disease	3 (10)
Ascending aortic aneurysm + aortic stenosis + coronary artery disease	2 (6.7)
Ascending aortic aneurysm + aortic stenosis + mitral insufficiency	1 (3.3)

Laboratories, CA, USA) and a right atrial two-staged venous cannula (Dual Stage Venous Return Catheter, 34/46 Fr; California Medical Laboratories, CA, USA). Double venous cannulation (Venous return catheter, Straight, 32 Fr; California Medical Laboratories, CA, USA) was done in one patient who underwent mitral repair. The axillary, femoral, or innominate artery was not used for cannulation in any of the patients.

Initial Surgical Correction

During core cooling, the innominate artery and vein were dissociated and exposed as long as possible. After cardiopulmonary bypass commenced, cardiac arrest was achieved under cross-clamp by antegrade blood cardioplegia. Coronary artery bypass, aortic valve replacement, or aortic root surgery was performed at 28°C. Only the patients undergoing aortic replacement alone were directly cooled to 18°C. Cross-clamp was placed and blood cardioplegia was administered when cardiac fibrillation or arrest developed during cooling.

Open Distal Anastomosis with TCA

Cross-clamp was removed at 18°C and the distal anastomosis was performed under TCA using the open anastomosis technique without cerebral perfusion. After completion of distal anastomosis, cardiopulmonary bypass was reinitiated through the single branch in patients (n = 10) where a single-branch graft was used (Gelweave Gelatin Impregnated Woven Vascular Prosthesis, Vascutek Terumo, Vascomed Medikal, Istanbul, Turkey); through the distal part of the tube graft (n = 12) (Polythese IC/ICT, Collagen-coated woven polyester vascular prosthesis, Perouse Medical, Route Du Manoir, Ivbry Le Temole, France); and through the distal part of the valved conduit (n = 8) in the remaining cases (Sorin, Carbomedics Carbo-Seal ascending aortic prosthesis, Sorin Group Italia, Saluggia [VC], Italy).

Following deaeration, the cross clamp was moved to the distal part of the graft and the patient was warmed. In order to prevent potential bleeding into the posterior part of the anastomosis from the distal or proximal aortic anastomosis, single pledget sutures in triplets were placed within the aorta. The transected proximal and distal parts of the ascending aorta were reconstructed by outer Teflon felts. In addition, Bioglue (Surgical Adhesive, 2 mL, CryoLife, Kennesaw, GA, USA) was applied to distal and proximal aorta anastomoses.

Post-TCA Procedures

During the warming phase, proximal anastomoses were performed in patients undergoing proximal tube graft anastomosis as well as coronary bypass. The air was evacuated from the tube graft and the lungs were aerated. After target temperature and pressure levels were achieved, cardiopulmonary bypass was terminated. During CPB, hematocrit levels were maintained between 20% and 24% and mean arterial pressure above 60 mmHg. Procedures performed in the study participants are shown in Table 3.

Deep Hypothermic Circulatory Arrest Management

For cerebral protection, patients were kept in the Trendelenburg position and hypocapneic ventilation (arterial PCO_2, 23-32 mmHg) was used. In all patients, the body temperature was gradually lowered for DHCA down to 18°C and systemic hypothermia was attained. In order to obtain homogenous and complete cooling, care was practiced to maintain a temperature gradient of 4-6°C between the perfusate temperature of the CPB and nasopharynx. Topical cooling of the cranium was also performed in addition to systemic hypothermia using ice packs around the head.

The same method was followed during the termination of DHCA with approximately 1°C increments every 3 minutes and no more than 10°C of temperature difference between the perfusate temperature and nasopharynx. Prior to DHCA, thiopental at a dose of 3-10 mg/kg (500 mg to 1 g) was administered to lower the intracranial pressure by decreasing the cerebral metabolic rate and cerebral blood flow. In addition, after the removal of aortic cross clamp and before reperfusion, methylprednisolone at a dose of 2 × 250 mg was given. Before DHCA was initiated, mannitol (0.5 g/kg) was also given to preserve renal function and to decrease cerebral edema and intracranial pressure.

Table 3. Perioperative Data of the Patients*

Duration of CPB, min	152-283 (210.8 ± 43)
Duration of CC, min	107-233 (154.9 ± 35.4)
Duration of TCA, min	20-29 (25.2 ± 2.4)
Graft type	n (%)
Tube graft	12 (40)
Single-branch graft	10 (33.3)
Valved conduit	8 (26.7)
Operation type	
Supracoronary AR	2 (6.7)
Supracoronary AR + AVR	12 (40)
Bentall	6 (20)
Bentall + CABG	2 (6.7)
Supracoronary AR + CABG	3 (10)
Supracoronary AR + AVR + CABG	4 (13.3)
Supracoronary AR + AVR + Mitral repair	1 (3.3)

*Data are presented as the mean ± SD where indicated. AR indicates aortic replacement; AVR, aortic valve replacement; CABG, coronary artery bypass graft; CC, cross-clamp; CPB, cardiopulmonary bypass; TCA, total circulatory arrest; SD, standard deviation.

Statistical Analysis

Data were collected and managed with Microsoft Access database. For statistical analysis of the study data, IBM SPSS Statistics 22 (IBM SPSS, Turkey) software was used. In addition to descriptive statistical methods (mean, standard deviation, and frequency), Kruskal-Wallis test and Mann Whitney U test were used to compare the parameters between groups and to determine the group responsible for the differences. Statistical significance was assumed if $P < .05$.

RESULTS

TCA, CPB, and CC Times

The average duration of TCA was less than 30 minutes. The mean TCA time, CPB time, and cross-clamp (CC) time were 25, 211, and 155 minutes, respectively. Average duration of stay in the intensive care unit and at the hospital was less than 3 and 10 days, respectively. Time to awake and duration of intubation were also within normal ranges (Table 4).

There was a significant difference in CBP time between surgery types (P: .024; $P < .05$). Mann Whitney U test showed a significantly higher CPB time for Bentall procedure, as compared to supracoronary aortic replacement + aortic valve replacement (AVR) and supracoronary aortic replacement + coronary artery bypass graft (CABG) (P_1: .013; P_2: .034; $P < .05$). In this regard, there were no significant differences between other procedure types.

CC time was similar across different types of procedures ($P > .05$). Again, TCA was similar for different surgical procedures ($P > .05$) (Table 5).

Table 4. Postoperative Data of the Patients*

Time to awakening, h	4-17 (10.1 ± 3.5)
Duration of intubation, h	7-19 (12.9 ± 3.5)
ICU stay, d	1-23 (2.5 ± 4.3)
Hospital stay, d	7-37 (9.5 ± 5.9)

*Data are presented as the mean ± SD where indicated. ICU indicates intensive care unit; SD, standard deviation.

Table 5. Durations of CPB, CC, and TCA by Operation Type*

Operation type	CPB duration (median, min)	CC duration (median, min)	TCA duration (median, min)
Supracoronary AR + AVR	191 (192.5 ± 31.1)	143 (142.1 ± 22.3)	25 (25 ± 2.6)
Bentall	256 (255.8 ± 14.6)	175 (173.5 ± 27.3)	27 (27.2 ± 0.4)
Supracoronary AR + CABG	175 (179.3 ± 19.9)	141 (137 ± 19.3)	25 (25.7 ± 3.1)
P	.024**	.146	.258

*Data are presented as the mean ± SD where indicated. AR indicates aortic replacement; AVR, aortic valve replacement; CABG, coronary artery bypass graft; CC, cross-clamp; CPB, cardiopulmonary bypass; TCA, total circulatory arrest; SD, standard deviation.
**Kruskal-Wallis test: $P < .05$.

Postoperative Period

No patients had neurological complications. One patient (3.3%) who had chronic obstructive pulmonary disease (COPD) died due to postoperative respiratory failure on the 22nd postoperative day. Another patient with COPD also developed respiratory failure requiring re-intubation; however, she responded to treatment and was discharged with full recovery after renormalization of respiratory parameters on the 37th postoperative day.

Nine patients required low dose inotropics at the termination of CPB and during early periods of intensive care unit care. But no patients needed intra-aortic balloon pump (IABP).

Ultrafiltration and/or renal dose dopamine perfusion was used in patients with preoperative renal dysfunction (n = 1) and in those who had low intraoperative urinary output (n = 2). Postoperative renal failure developed in one patient (3.3%), which responded to medical treatment and fluid management.

Average amount of bleeding was 591.3 ± 222.9 mL (range, 200-1150) during the first 24 hours. Revision was required in 3 patients due to bleeding (10%) and wound side revision was required in another 2 (6.6%). Four patients had postoperative atrial fibrillation (13.3%) and sinus rhythm was reestablished with medical treatment in all patients.

Whole blood or packed red blood cells were transfused for patients whose hematocrit value was less than 24%.

Follow-Up

The duration of follow up ranged between 1 and 70 months. Currently, all discharged patients are alive with Class I functional capacity.

DISCUSSION

The technique described herein for ascending aorta surgery does not involve exposure of the axillary or femoral artery, as arterial cannulation is done through the aneurysmatic aorta. With this technique, the amount of tissue to be resected under cross-clamp is not limited because cannulation is not done from the distal part of the ascending aorta. In addition, laceration of the ascending aorta due to cannulation is avoided. The open distal anastomosis technique allowed us to examine the aortic arch and its branches and the status of the endothelium in terms of atherosclerosis, regional dissection, and ulcerated or soft plaque formation.

The optimum site of arterial cannulation in ascending aorta aneurysms is controversial. Femoral artery cannulation is an independent predictor of in-hospital mortality [Khaladj 2008] and neurological dysfunction [Westaby 1999] due to the risk of retrograde cerebral embolization. In our patients, the ascending aorta was used as the site of arterial cannulation, obviating the need for axillary, femoral, or innominate artery cannulation [Preventza 2015]. After termination of TCA, the arterial cannula was transferred to the single branch of the single-branch graft or onto the tube graft or valved conduit.

Cerebral protection is an essential component of successful aortic surgery. In ascending aorta aneurysms extending up to the beginning of the aortic arch, open distal anastomosis without cross-clamp under deep hypothermia and total circulatory arrest has a direct effect on the success of surgery [Dumfarth 2013]. Following open distal anastomosis, the transfer of the arterial cannula to the single branch of the graft or onto the tube graft or valved conduit allowed us adequate resection of the aortic aneurysmatic segment up to the level of the innominate artery, leaving no residual aneurysmal tissue. Thus, the tissue integrity was maintained in the native distal aorta and in the innominate artery, as no cannulation was performed.

Deep hypothermic circulatory arrest was initially described by Griepp et al [Griepp 1975]. While it is possible to achieve antegrade or retrograde cerebral perfusion during TCA and aortic surgery under deep hypothermia at 18°C, it is also possible to perform surgery without cerebral perfusion up to a maximum duration of 30 minutes [Dumfarth 2013; Ziganshin 2014]. Deep hypothermia minimizes the brain metabolism and allows full neurological recovery after the operation.

Hypothermia is of utmost importance in organ protection. Hypothermia and general anesthesia protect the brain against ischemia. Cerebral metabolic rate for oxygen is related to brain temperature. Cellular function (electrical activity of neuronal transmission of impulses) and cellular integrity (maintenance of cellular homeostasis) are both supported by cerebral metabolism. Temperature affects both function and integrity; general anesthetics on the other hand affect primarily the functional component.

In clinical practice, there is a combined effect, but temperature seems to be more important in terms of cerebral protection from anoxia [Kouchoukos 2003]. Due to low risk of postoperative neurological dysfunctions at 18°C in durations less than 30 minutes, we preferred not to implement cerebral perfusion in our patients.

Absence of antegrade cerebral perfusion allowed simplification of the surgical exposure area. Additional tubing and cannula used for antegrade cerebral perfusion is associated with the risk of intimal injury and embolization. During distal anastomosis, the surgical site should be providing a good mechanical exposure and be dry as not to cause distraction for the surgeon. During the perfusion, a flow rate may lead to hypoperfusion, while the opposite may end up with hyperperfusion [Dumfarth 2013].

In a 10-year analysis of 400 patients undergoing deep hypothermic arrest alone, excellent clinical results have been reported. The average duration of DHCA was 31 minutes, with a stroke rate of 13.1% in DHCA exceeding 40 minutes [Gega 2007]. The reported rates of mortality and stroke in the surgical interventions involving the ascending aorta and aortic arch are 2% and 1.9%, respectively. Mortality and stroke rates in ACP or RCP were not better [Ziganshin 2013].

In a logistic-regression analysis by Svensson et al [Svensson 1994] involving 656 patients undergoing aorta surgery with deep hypothermia and circulatory arrest, 44 patients (7%) had transient or permanent stroke, with increased risk of stroke or death in circulatory arrest duration exceeding 40 and 65 minutes, respectively.

In a 394-patient series reported by Gega and associates in 2007 [Gega 2007], the question whether or not antegrade cerebral perfusion should be added to DHCA was addressed, and a straight DHCA duration of less than 40 minutes was suggested to be adequate. In addition, there was a low rate of postoperative neurological complications, most of which were due to embolism. In the histopathological examination of 8 specimens from patients who died following DHCA, no cell death or signs of ischemia were detected, particularly in the ischemia-sensitive areas such as the hippocampus. Similarly in our study, DHCA alone was utilized with an average TCA duration of 25.2 ± 2.4 minutes, with all patients having a TCA of less than 30 minutes. The time to awakening ranged between 4 and 17 hours (mean: 10.1 ± 3.5 h) in our patients. The duration of intubation was between 7 and 19 hours (mean: 12.9 ± 3.5 h). Postoperative neurological assessments revealed no transient or persistent neurological dysfunction in any of our patients. In addition, there were no problems of cognitive functions, balance, and fine hand movements.

Misfeld et al [Misfeld 2012] reported that the current surgical techniques utilized for aortic surgery in their unit consisted of moderate hypothermia, antegrade unilateral or bilateral cerebral perfusion, with a permanent neurological deficit rate of 11%.

Literature data suggest that permanent neurological deficits occurring after aorta surgery are mainly due to strokes caused by embolism rather than the direct effect of the cerebral protection method used. In the study by Amarenco et al [Amarenco 1992], the prevalence of ulcerated plaques of the aortic arch was 28% among 183 patients with cerebral infarction, as opposed to 20% in 56 patients with cranial bleeding. Blauth et al showed the presence of a direct association between age, severe atherosclerosis of the ascending aorta, and atheroembolism [Blauth 1992].

Similarly, age emerged as a significant risk factor for stroke in the univariate analysis, and partial perfusion techniques involving the descending aorta were strongly predictive of postoperative stroke, as shown by Okita et al [Okita 2001], who also found that the use of aortic clamping for anastomosis instead of open anastomosis was the strongest risk factor for stroke. Furthermore, these authors also concluded that clamping of the relevant segment of the aorta was associated with a sharp increase in the risk of cerebral embolism due to the mobilization of loose atheroma plaques or mural thrombi. These observations support our open anastomotic technique.

The major limitation of our study is the small sample size (n = 30). Following initial positive results and similar supportive literature reports, the number of patients undergoing surgery with this technique in our unit is now expanding.

Conclusion

Accomplishing such a major surgical procedure without cerebral perfusion and additional incisions other than sternotomy, in association with the absence of neurological deficits and very low mortality (only 1 patient), is an encouraging factor in expanding the number of our patients to be operated using the currently described technique. This technique allows adequate aneurysmatic tissue resection, obviates the need for axillary or femoral artery cannulation, and leaves no cannula-related lesions on the proximal thoracic aorta thanks to the transportation of the arterial cannula to the single-branch graft or onto the tube graft or valved conduit after distal anastomosis, and allows the examination of the inner surface of arch and its branches. Surgical treatment of the aneurysms of the ascending aorta may be performed safely with open distal anastomosis and TCA of less than 30 minutes.

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