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Article

Arterial Cannulation Through Aneurysm and Aortic Anastomosis During Proximal Thoracic Aortic Aneurysm Surgery

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Abstract

Background: Proximal aortic aneurysm surgery involving the aortic root and ascending aorta represents a specific surgical intervention in terms of the number of surgical incisions, arterial cannulation methods as well as anastomosis technique and cerebral protection. This study aims to present a case series of a new surgical technique for proximal aortic aneurysm surgery exclusively through midsternal approach and consisting of arterial cannulation from the aneurysmatic segment and through aortic anastomosis. **Methods**: This retrospective study included 90 patients who were operated for proximal thoracic aortic aneurysm using a new surgical technique mainly consisting of single standard midsternal approach without extension of the incision, arterial cannulation through the aneurysmatic segment and aortic anastomosis, deep hypothermic circulatory arrest, and open distal anastomosis without cerebral perfusion. **Results**: Ascending aorta replacement (replacement) and ascending aorta replacement plus aortic root replacement (ARR) was performed in 60 (66.7%) and 30 (33.3%) patients, respectively. Intraoperative courses were uneventful. The mean durations for deep hypothermic circulatory arrest (DHCA), cross-clamp, and cardiopulmonary bypass were 24.9 ± 3.2 min, 169.7 ± 52.8 min, and 235.3 ± 57.6 min, respectively. Most common postoperative complication was atrial fibrillation (18.9%) followed by inotropic need (10%) and wound infection (7.8%). Three patients died (3.3%) during hospitalization. **Conclusions**: This new method for the treatment of proximal aortic aneurysms offers a viable and safe alternative with only midsternal surgical incision, without damaging any segment of the healthy aortic tree for arterial cannulation, without prolonging the operation time, and avoiding complications related to additional incisions and cannulation of the healthy aortic tree.

Keywords

proximal aortic surgery; aneurysm; cannulation; anastomosis; cerebral protection

Introduction

Proximal aortic aneurysm surgery involving the aortic root (ARA)and ascending aorta (AAA) is a specific surgical intervention in terms of the number of surgical incisions, arterial cannulation methods, anastomosis technique, and cerebral protection [1]. The aim of this surgery should be to use the least number of surgical incisions, not to damage the healthy aortic tree for arterial cannulation, to resect the entire aneurysm, to use a safe aortic anastomosis technique and a simple and safe cerebral protection method.

Previous studies reported distant cannulation methods for proximal aortic aneurysm surgery such as axillary and femoral artery (directly or indirectly with graft) cannulations or cannulations of the healthy innominate artery or right subclavian artery with the extension of the midsternal incision right and upwards [2,3]. Conventional arterial cannulation methods require an additional incision, use a healthy aortic tree for cannulation purposes, and leave aneurysmal tissue in cases where an open distal anastomosis is not performed.

In this study, we aimed to present a case series of our surgical technique for proximal aortic aneurysm surgery exclusively through midsternal approach and consisting of arterial cannulation from the aneurysmatic segment, open distal aortic anastomosis under deep hypothermic circulatory arrest (DHCA) without cerebral perfusion, and arterial cannulation through the aortic anastomosis. The anastomosis cannulation method was first described as a case report in 2019 [4].

With this method, proximal aortic aneurysms can be managed using only a sternotomy incision and aneurysm cannulation, allowing cannulation without causing damage to the healthy aortic tree and graft integrity.

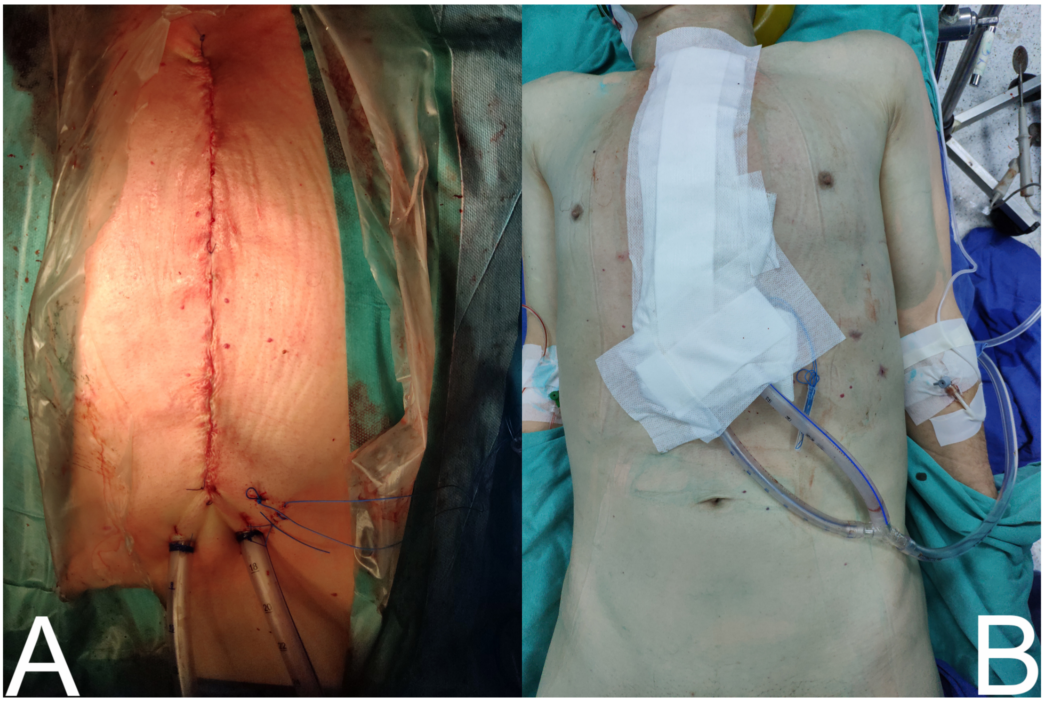

Fig. 1. Median sternotomy incision, the only surgical access used in the technique. (A) Median sternotomy incision, the only surgical access used in the technique; (B) Median sternotomy incision, the only surgical access used in the technique.

Methods

The study included 90 patients who were operated in our institution between October 2018 and July 2024 for proximal thoracic aortic aneurysm by a single surgical team using a new surgical technique mainly consisting of single standard midsternal approach without extension of the incision, arterial cannulation through the aneurysmatic segment (at the beginning of the operation) and aortic anastomosis (after DHCA), deep hypothermic circulatory arrest, and open distal anastomosis without cerebral perfusion.

Surgical Technique

Only standard midsternal incision is used in all patients, without extension (Fig. 1A,B). Arterial cannulation is initially done from the aneurysmatic segment (Fig. 2). The mean ascending aortic diameter and aortic root diameter of the cases was 53.3 ± 6.7 mm (range, 45–70) and 52 ± 6.3 mm (range, 45–73), respectively. For venous cannulation, either right atrial two-stage venous cannulation or bicaval cannulation is used depending on the operation. A vent cannula is placed in the right upper pulmonary vein and a root cannula is placed in the ascending aorta. Aneurysm cross-clamp is placed to distal ascending aorta and the patient is cooled to 28 degrees centigrade first. Meanwhile, coronary distal anastomoses, mitral and aortic valve replacements (MVR and AVR) are performed. During these procedures, the patient is gradually cooled down to 18 degrees centigrade. DHCA is established and cross clamp is removed when the blood volume level in the venous reservoir is 1500–1700 cc.

After open distal anastomosis, the technique consisting of arterial cannulation through the aortic anastomosis was first described in 2019 and was used to re-initiate cardiopulmonary bypass [4]. In this technique, firstly, graft and proximal aortic tissue of the arcus aorta are sutured from the middle of the inner curvature to the middle of the outer curvature using 3/0–25 prolene sutures supported by teflon strip. Three or four 4/0–25 pledgeted sutures are placed to the posterior of the anastomosis from inside, to prevent bleeding from the posterior.

Main anastomosis line suture is advanced to 11 o'clock position at the outer curvature of aorta. A separate 3/0–25 pledgeted prolene safety suture is placed at 11 o'clock position and tied. This suture is also tied with the main anastomosis line suture. Then, the main anastomosis line suture is advanced up to 1 o'clock position at the inner curvature of the aorta. A separate 3/0–25 pledgeted suture is placed at 1 o'clock position and tied (safety suture). This suture is also tied with the main anastomosis line suture. Thus, most parts of the anastomosis are secured against the risk of bleeding, except for the area that will be used for arterial cannulation, which is located at the 12 o'clock position at the top of the anastomosis (Fig. 3A).

For the aortic cannula to be safely placed at the apex of the anastomosis (at 12 o'clock position), two 3/0–25 pledgeted cannula fixing sutures are placed (from the graft to the arcus aorta and from the arcus aorta to the graft). The main

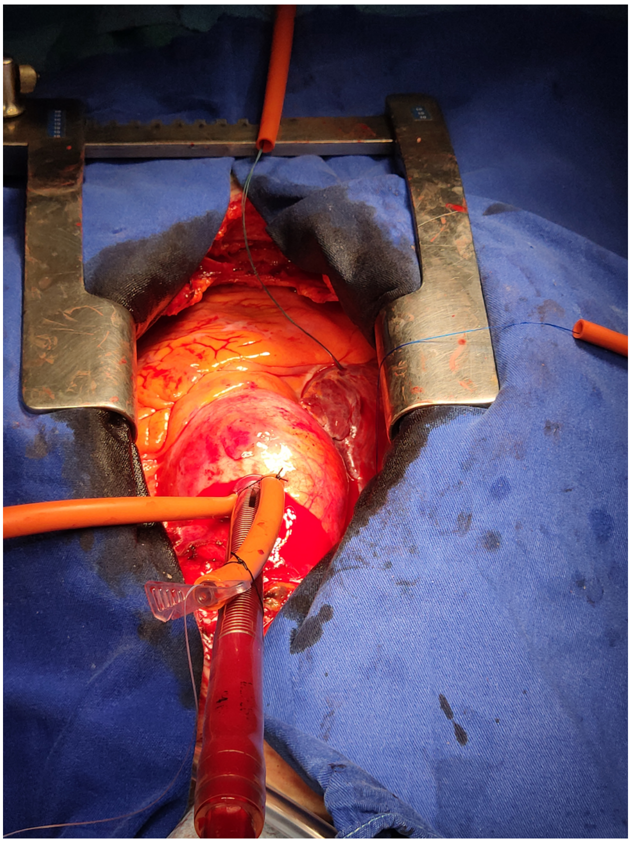

Fig. 2. Arterial cannulation through the aneurysm. The entire aneurysmatic aortic segment is resected up to the brachiocephalic artery. To be able to evaluate the aortic arch from inside and for a safe anastomosis, open distal aortic anastomosis is preferred. All patients are operated under deep hypothermic circulatory arrest (DHCA) (18 degrees centigrade), cerebral perfusion is not used, and near-infrared spectroscopy (NIRS) monitoring was done throughout the operation.

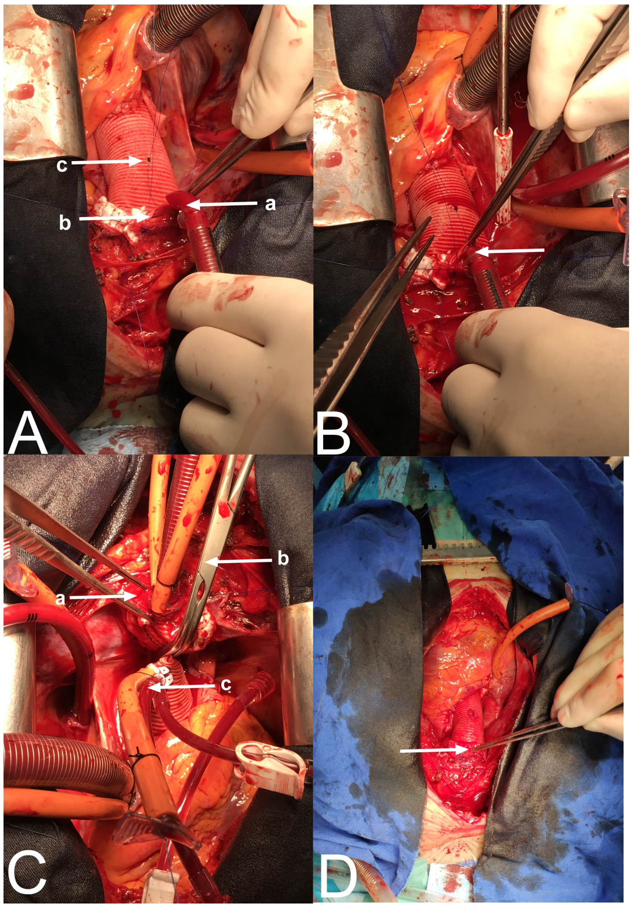

Fig. 3. Arterial cannulation through the aortic anastomosis. (A) (a) arterial cannula before insertion; (b) anastomosis opening at 12 o'clock position; (c) opening for aortic root cannula; (B) arrow, insertion of the arterial cannula into the aortic anastomosis; (C) (a) arterial cannula placed through aortic anastomosis; (b) cross-clamp; (c) aortic root cannula; (D) arrow, appearance after decannulation.

anastomosis line suture at 1 o'clock position is advanced to 11 o'clock position, but the suture is not continued down to the anastomosis line before placing the cannula into the anastomosis.

The perfusionist initiates flow from the arterial cannula and the aortic cannula is inserted into the opening between the graft and the aortic tissue at the apex of the anastomosis (Fig. 3B).

Then, each of the aortic cannula fixation sutures is tied once, and they are passed through the notches of the aortic cannula, sutures are separately fixed using snairs down to the base of the cannula, and snairs are tied to the cannula (Fig. 3C). In addition, the main anastomosis line suture, which was advanced from 1 o'clock position to 11 o'clock position, is advanced over the anastomosis.

Meanwhile, before placing aortic cross-clamp, air is extracted from the proximal end of the graft in cases of ascending aortic replacement (AAR), and through the root cannula placed through the small opening on the graft made by cautery in cases of aortic root replacement (ARR). After removing enough air, a cross clamp is placed on the graft in order to perform the remaining surgical procedures. Then, proximal aortic anastomosis is performed in cases of ascending aortic replacement. In cases where coronary bypass surgery is also performed, the proximal end of the saphenous vein grafts is anastomosed onto the graft and cross-clamp is removed following removing the air again. If Bentall operation is performed and there is no other surgical procedure to be performed, the cross-clamp is not placed again after termination of DHCA.

A gradual warm-up strategy is used to avoid postoperative neurological problems. After establishing cardiopulmonary bypass after DHCA, the warm-up process is not started for five minutes. After five minutes, warning is started so that the temperature difference between the blood and the heater is kept at 3 degrees centigrade up to 24 degrees centigrade, at 5 degrees centigrade from 24 degrees centigrade to 32 degrees centigrade, and at most 8 degrees centigrade from 32 degrees centigrade to 37.6 degrees centigrade.

After warming the patient, the right upper pulmonary vein cannula and root cannula are removed, cardiopulmonary bypass is terminated, and venous cannula is removed. After giving the blood in the venous reservoir to the patient, while taking the aortic cannula from the anastomosis, the assistant surgeon holds the anastomosis area including the distal part of the graft and proximal part of the aortic arch and removes the aortic cannula, the surgeon ties both cannula fixation sutures. Then the assistant surgeon releases the anastomosis area, the surgeon ties the arms of the main anastomosis line sutures together and brings the safety sutures at 11 and 1 o'clock positions closer and ties by suturing the anastomosis site (Fig. 3D). After the bleeding control, drains are placed before the operation is completed. **Supplementary video 1** shows the summary of the procedure.

Statistical Analysis

Number Cruncher Statistical System (NCSS) 2020 Statistical Software (East Kaysville, UT, USA) was used for the analysis of data. Descriptive data are presented as mean ± standard deviation, median and range, number, and percentage, where appropriate. Normality was tested using Shapiro Wilk test and graphical methods. Intergroup comparisons of continuous variables were done using student *t* test or Mann Whitney U test, depending on the normality of the distribution. Categorical data were compared using Pearson's chi-square test or Fisher's exact test. A p value < 0.05 was indication of statistical significance.

Results

Table 1 shows demographical and preoperative clinical characteristics of the patients. The mean age was 58 ± 14.4 years, majority of the patients were male (76.7%), and the most common cardiac pathologies were aortic root aneurysm plus ascending aortic aneurysm plus aortic valve insufficiency (AI) (22.2%) and ascending aortic aneurysm plus aortic valve insufficiency (14.4%).

Ascending aorta replacement (AAR) and ascending aorta replacement plus aortic root replacement (ARR) was performed in 60 (66.7%) and 30 (33.3%) patients, respectively. Table 2 shows the details of the operations.

Table 1. Demographical and preoperative clinical characteristics of the patients.

Characteristics	n = 90
Demographics	
Age, years	58 ± 14.4 (61, 21–82)
Sex	
Male	69 (76.7%)
Female	21 (23.3%)
Co-morbid conditions	
Hypertension	38 (42.2%)
Diabetes	30 (33.3%)
COPD	11 (12.2%)
ECAD	6 (6.7%)
Ejection fraction, %	52.25 ± 11.9 (60, 30–65)
Logistic Euroscore, %	6.9 ± 4.1 (5, 1.1–22.3)
Creatinine, mg/dL	1.0 ± 0.3 (0.9, 0.5–1.9)
Cardiac pathology	n = 90
AAA	8 (8.9%)
AAA+AI	13 (14.4%)
AAA+AS	11 (12.2%)
AAA+AI+AS	4 (4.4%)
AAA+MI+TI	1 (1.1%)
Operated AV+AAA+AS	1 (1.1%)
AAA+CAD	9 (10%)
AAA+AI+CAD	7 (7.8%)
AAA+AS+CAD	3 (3.3%)
AAA+AI+AS+CAD	2 (2.2%)
AAA+AI+MI	1 (1.1%)
AAA+AI+MI+CAD	2 (2.2%)
ARA+AAA+CAD	1 (1.1%)
ARA+AAA+AI	20 (22.2%)
ARA+AAA+AI+CAD	1 (1.1%)
ARA+AAA+AS+CAD	1 (1.1%)
ARA+AAA+CAD	1 (1.1%)
ARA+AAA+AS+AI+SAA	1 (1.1%)
ARA+AAA+AI+AS+SAA	1 (1.1%)
ARA+AAA+AI+MI	1 (1.1%)
ARA+AAA+AI+MI+TI	1 (1.1%)

Continuous data and categorical data are presented as mean ± standard deviation (median, range) and number (percentage), respectively.

Abbreviations: AAA, ascending aortic aneurysm; AI, aortic valve insufficiency; ARA, aortic root aneurysm; AS, aortic valve stenosis; AV, aortic valvotomy; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; ECAD, extracardiac arterial disease; MI, mitral valve insufficiency; SAA, small aortic annulus; TI, tricuspid valve insufficiency.

Intraoperative Course

All operations were uneventful. No incision other than standard median sternotomy incision was required. Healthy aortic tree was not used for cannulation in any of the cases and no cannulation-related complication such as perfusion problem, bleeding around the cannula or dislocation, or complication during decannulation was seen. Reestablishment of cardiopulmonary bypass was not required in any of the patients. The mean durations for DHCA, cross-clamp, and cardiopulmonary bypass was 24.9 ± 3.2

Table 2. Details of the surgical interventions.

Operations	n = 90
AAR	6 (6.7%)
AAR+AVR	26 (28.9%)
AAR+Redo AVR	1 (1.1%)
AAR+AVR+ARE (Nunez)+MVR	1 (1.1%)
AAR+CABG	8 (8.9%)
AAR+AVR+CABG	13 (14.4%)
AAR+AVR+MVR+CABG	2 (2.2%)
AAR+HAR+CABG	2 (2.2%)
AAR+MVR+Tricuspid de Vega annuloplasty	1 (1.1%)
Bentall	21 (23.3%)
Bentall+CABG	3 (3.3%)
Bentall+CABG+MVR	1 (1.1%)
Bentall+ARE (Nunez)	2 (2.2%)
Bentall+ARE (Nunez)+CABG	1 (1.1%)
Bentall+MVR+Tricuspid de Vega annuloplasty	1 (1.1%)
David + CABG	1 (1.1%)

AAR, ascending aorta replacement; ARE, aortic root enlargement; AVR, aortic valve replacement; CABG, coronary artery bypass graft; HAR, hemi-arcus replacement; MVR, mitral valve replacement.

min (median 26, range: 19–36), 169.7 ± 52.8 min (median 161, range: 59–321), and 235.3 ± 57.6 min (median 227, range: 134–447), respectively.

Postoperative Course and Complications

Mean awakening time and extubation time was 3.7 ± 2.4 h (median 3, range: 2–12) and 11.7 ± 31.8 h (median 11, range: 5–168), respectively. Patients stayed at the intensive care unit for a mean duration of 37.4 ± 37.2 h (median 22, range: 18–188). Mean postoperative bleeding was 575.2 ± 234.6 mL (median 500, range: 150–1400).

Patients were hospitalized for a mean duration of 9.7 ± 1.2 days (median 11, range: 4–60). Table 3 shows complications developed during hospitalization. Most common postoperative complication was atrial fibrillation (18.9%) followed by inotropic need (10%) and wound infection (7.8%). Three patients died (3.3%) during hospitalization.

AAR versus AAR plus ARR Cases

Durations of cross-clamp (196.3 ± 58.1 vs. 158.9 ± 42.9 min, $p = 0.003$) and cardiopulmonary bypass (271.5 ± 62.7 vs. 214.1 ± 44.6 min, $p = 0.001$) were significantly longer, frequency of preoperative hypertension was significantly more common (55.2% vs. 30%, $p = 0.041$), frequencies of postoperative inotropic need (31% vs. 6.7%, $p = 0.004$) and wound infection (20.6% vs. 6.7%, $p = 0.032$) were significantly more common, and frequency of postoperative atrial fibrillation was significantly less common (5.2% vs. 30%, $p = 0.011$) among patients that received

Table 3. Postoperative complications.

Complications	n	%
Pleural effusion	2	2.2%
Pericardial effusion	4	4.4%
Revision due to bleeding	3	3.3%
Transient neurological dysfunction	4	4.4%
Re-intubation with tracheostomy	1	1.1%
Re-operation	1	1.1%
Transient renal dysfunction	1	1.1%
Inotropic need	9	10%
Atrial fibrillation	17	18.9%
Wound infection	7	7.8%
In-hospital mortality	3	3.3%

AAR plus ARR when compared to the patients that received AAR. The two groups did not differ in terms of other perioperative parameters (Table 4).

There was no significant difference found in the age and gender distribution of cases based on operation types ($p > 0.05$). Ejection fraction, preoperative creatinine measurements, total circulatory arrest (TCA) time, and Logistic EuroSCORE measurements also did not show significant differences between two operation types ($p > 0.05$); however, cross-clamp time (CC) and cardiopulmonary bypass (CPB) time were significantly longer in operations where ascending aorta and aortic root replacements were performed compared to those where only ascending aorta replacement was done ($p < 0.01$).

The rate of hypertension (HT) was found to be significantly higher in operations involving ascending aorta and aortic root replacements ($p < 0.05$). There were no significant differences in the rates of diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), extracardiac arterial disease, postoperative pleural effusion, bleeding revision, postoperative neurological morbidity, reintubation, reoperation, blood usage, or postoperative renal morbidity based on operation types ($p > 0.05$).

The rates of inotropic drug usage and wound infection were significantly higher in operations involving ascending aorta and aortic root replacements ($p < 0.01$). Atrial fibrillation (AF) was significantly higher in cases with ascending aorta replacement ($p < 0.05$). There were no significant differences in terms of mortality between the groups ($p > 0.05$). Awakening time, extubation time, intensive care unit (ICU) stay time, postoperative bleeding amount, hospital stay, and follow-up periods also did not show statistically significant differences based on operation types ($p > 0.05$).

Follow-up

Eighty-seven patients were followed for a mean duration of 36.5 ± 21.4 months (median 34, range: 1–69). Five patients required re-hospitalization during follow-up: pericardial effusion (n = 3), aortic root endocarditis (n = 1), and

Table 4. Peroperative parameters by operation type.

	Ascending aorta replacement (AAR) Mean ± SD (Median)	Bentall (AAR+ARR) Mean ± SD (Median)	p
Age (year)	59.27 ± 14.31 (65)	53.17 ± 16.49 (58)	[a]0.114
Ejection fraction	55.73 ± 5.92 (55)	55.65 ± 7.58 (60)	[b]0.508
Preop Creatinine (mg/dL)	0.94 ± 0.27 (0.9)	1.01 ± 0.23 (1)	[b]0.095
TCA (Total circulatory arrest) (min)	25.54 ± 3.24 (26)	25.35 ± 3.38 (25)	[b]0.775
CC (Cross clamping) (min)	159.04 ± 43.08 (157)	196.48 ± 58.41 (175)	[a]0.003**
CPB (Cardiopulmonary Bypass) (min)	214.29 ± 44.83 (215)	271.70 ± 62.91 (260)	[b]0.001**
Logistic Euroscore	6.27 ± 4.43 (5.27)	6.41 ± 4.91 (4.01)	[b]0.995
	n (%)	n (%)	
Sex			[c]0.286
Female	15 (25)	6 (20)	
Male	45 (75)	24 (80)	
HT	15 (25)	13 (43.3)	[c]0.041*
DM	15 (25)	5 (16.7)	[c]0.404
COPD	3 (5)	3 (10)	[d]0.381
Extracardiac Arterial Dissease	2 (3.3)	2 (6.7)	[d]0.591
Postop Pleural Effusion	2 (3.3)	0 (0)	[d]1.000
Postop Pericardial Effusionn	3 (5)	1 (3.3)	[d]1.000
Revision for Bleeding	2 (3.3)	1 (3.3)	[d]1.000
Postop Neurological Morbidity	4 (6.7)	0 (0)	[d]0.297
Re-intubation	0 (0)	1 (3.3)	[d]0.324
Re-operation	1 (1.7)	0 (0)	[d]1.000
Blood transfusion	16 (26.7)	9 (30.0)	[c]0.632
Postop Renal Morbidity	0 (0.0)	1 (3.3)	[c]0.324
Inotropic use	2 (3.3)	7 (23.3)	[d]0.004**
AF	15 (25.0)	2(6.7)	[c]0.011*
Wound infection	2 (3.3)	5 (16.7)	[d]0.032*
Mortality	2 (3.3)	1 (3.3)	[d]0.546
	Mean ± SD (Median)	Mean ± SD (Median)	
Awakening time (h)	5.75 ± 4.18 (5)	5.30 ± 3.24 (4)	[b]0.649
Extubation time (h)	19.43 ± 32.54 (10,8)	12.83 ± 7.96 (11)	[b]0.883
Duration of ICU Stay (h)	37.33 ± 36.55 (22)	39.18 ± 40.45 (22)	[b]0.969
Postop bleeding amount (cc)	582.29 ± 233.5 (550)	556.52 ± 252.85 (500)	[b]0.562
Duration of hospitalization (days)	12.02 ± 5.53 (11)	13.22 ± 11.45 (10)	[b]0.800
Duration of follow-up (months)	30.28 ± 16.07 (34)	32.78 ± 14.93 (30)	[a]0.532

[a]Student t test.
[b]Mann Whitney U test.
[c]Pearson Chi Square test.
[d]Fisher Exact test.
*$p < 0.05$, **$p < 0.01$.
AF, atrial fibrillation; CC, cross clamping; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; DM, diabetes mellitus; HT, hypertension; ICU, intensive care unit; TCA, total circulatory arrest.

pulmonary embolism (n = 1). Patients re-hospitalized for endocarditis and pulmonary embolism died, both at three months.

Discussion

The surgical technique for the treatment of proximal aortic aneurysms described in this study, in which the approach is limited to midsternal incision and arterial cannulation is performed over the aneurysm segmentand at the anastomosis site, provided encouraging results. Traditionally, in the surgery of proximal aortic aneurysms, an axillary or femoral incision is made in addition to the sternotomy incision for distant arterial cannulation, or innominate artery cannulation is preferred by extending the midsternal skin incision [1–3]. This case series consists of ascending and aortic root aneurysm cases that were operated using the technique described. In addition, aortic root enlargement (ARE) and Bentall operation were performed in two patients with aortic root aneurysm and small aortic annulus [5].

Different techniques are used by experienced aortic surgery groups for optimal arterial cannulation in proximal thoracic aortic aneurysm surgery and different complication rates have been reported. One of these is the use of the innominate artery for arterial cannulation. Jassar *et al.* [3] reported one death and one postoperative permanent stroke case, seven reoperations due to bleeding, 12 cases requiring ventilation more than 24 hours, and three permanent pacemaker morbidity cases among 100 cases of elective ascending aortic andhemiarch reconstructions for proximal aortic aneurysms operated with direct innominate artery cannulation. Di Eusanio *et al.* [6] reported 3.6% in-hospital mortality and 1.8% transient neurological dysfunction in a series of 55 patients operated with innominate artery cannulation using graft. Preventza *et al.* [7], in their series of 68 patients in which they performed innominate artery cannulation using graft, the 30-day mortality, stroke, and postoperative confusion rates were 1.5%, 4.4%, 10.3%, respectively. In their larger series (n = 263) with the same technique, they reported perioperative mortality and permanent stroke rates of 4.9% and 1.9%, respectively. Garg *et al.* [8], in a series of 50 elective ascending aorta and arch replacement cases in which they performed direct innominate artery cannulation with the Seldinger technique, stroke rate was 2%, and cannulation could not be performed in two cases due to the tortuous course of the artery. In the series of Preventza *et al.* [9], in which innominate artery cannulation was used, complication rates were as follows: 30-day mortality, 1.5%; stroke, 4.4%; temporary postoperative neurological confusion, 10.3%; tracheostomy need, 11.8%; acute renal failure, 7.4%; reoperation due to bleeding, 7.4%; poor wound healing, 4.4%; and pericardial effusion, 2.9%.

Distant arterial cannulation approaches such as through axillary, subclavian, and femoral arteries are also used. Schachner *et al.* [10] reported 14% complication rate in a series of 65 patients who underwent axillary artery cannulation for aortic surgery. According to Sabik *et al.* [3], in a series of 399 patients in which axillary artery cannulation was performed with side graft, complication rates were as follows: cannulation related brachial plexus injury, 1.8%; axillary artery damage, 1.8%; aortic dissection, 0.8%; arm ischemia, 0.8%; in-hospital mortality, 8%; postoperative respiratory failure, 24%; and sepsis, 9%. In that study, reported complication rate for direct axillary artery cannulation was 5%, the most common complications being brachial plexus injury (1.8%) and axillary artery injury (1.8%); and the mortality rate was 7.6%. In the study by Regesta *et al.* [11], direct proximal subclavian artery cannulation was performed in 44 cases with 6.8% in-hospital mortality rate, and 6.8% permanent neurological deficit, 9% temporary neurological dysfunction, 4.5% tracheostomy, 4.5% permanent hemodialysis, and 6.8% re-exploration due to surgical bleeding rates. Kamiya *et al.* [12] performed 153 femoral artery cannulations for aortic surgery and reported 12.4% in-hospital mortality, 4.6% stroke, 20.3% transient neurological dysfunction, 11.8% renal failure, and 8.5% respiratory failure rates.

In the present study where we used the aneurysmatic segment and the aortic anastomosis site for arterial cannulation, we obtained relatively low and acceptable rates of complications: postoperative pericardial effusion, 4.4%; revision due to bleeding, 3.3%; reintubation need, 1.1%; re-operation, 1.1%; postoperative temporary renal dysfunction, 1.1%; and 30-day hospital mortality, 3.3%. In addition, no additional cannulation or re-cannulation after decannulation was required. On the other hand, for example, Schachner *et al.* [10] reported a 10% need for conversion to femoral cannulation or aortic perfusion in their case series where they used axillary cannulation.

Rather than distant arterial sites, the aneurysm segment that will already be removed from the body is used for cannulation at the beginning of the operation in the present technique. Preservation of the healthy aortic tree would provide advantages. By not using a femoral incision, risks of femoral wound healing problems, and complications due to retrograde flow such as atheroembolism related stroke and visceral organ damage are avoided [1,2]. By not using an axillary incision, complications such as axillary artery, vein, and brachial plexus injury in the subclavicular region, localized dissection, local wound infection, insufficient arterial flow for cardiopulmonary bypass, and extremity malperfusion (ischemia, compartment syndrome) are avoided [1,4,9,10]. By not extending the sternal incision upwards and to the right side and not cannulating parts of the healthy aortic tree such as the innominate artery and the right subclavian artery, we exclude the complications related to these and nearby structures. Obviating the use of a second surgical incision would shorten the operation time [10]. When the anatomy of the innominate artery is considered, cannulations and manipulations would not be free from risks. Particularly, the phrenic nerve and sympathetic chain may be prone to trauma [9,11,13]. Every additional incision would pose some risks for potential complications.

If distal ascending aorta rather than aneurysm itself is preferred for cannulation, aneurysmatic tissue remains in the distal segment of the ascending aorta after aortic replacement, since it is necessary to leave aortic tissue for anastomosis apart from the cannulation site and the cross-clamp site. When cannulation is performed from the aneurysm and aortic anastomosis site this is avoided and the cannulation sites remain within the surgeon's field of view throughout the operation. Thus, problems such as blood loss in other incision sites and kinking of the cannula are also avoided. In addition, in hemodynamically unstable patients, cardiopulmonary bypass conditions can be achieved in a short time with direct aneurysm cannulation. No side graft is needed in cannulations through the aneurysm or through the aortic anastomosis. However, arterial cannulation from the aneurysmatic segment should be done with caution. There may theoretically be risks such as dissection, bleeding, and rupture during cannulation. However, we did not experience any such problems in our case series.

For arterial flow after DHCA,remote arterial cannulation sites may be prepared at the beginning of the operation [1], or the opening created with cautery on the graft or side branch of the branched graft may be used for this purpose.The present technique obviates the cost related with a branched graft or allows the preservation of the integrity of a non-branched graft.

During open aortic distal anastomosis, cerebral protection can be achieved by hypothermia alone or antegrade or retrograde cerebral perfusion can be used with hypothermia. We apply only deep hypothermia, which is consistent with previous studies. We protect the brain with only DHCA of less than 36 minutes and use open aortic distal anastomosis, without cerebral perfusion; thus, avoiding the risks of antegrade cerebral perfusion, debris mobilization/embolization, and hyperperfusion and edema due to cerebral perfusion. It has been demonstrated that retrograde cerebral perfusion does not provide sufficient oxygen to the cerebral tissue [14].

Limitations

The main limitation of this study is its observational and non-comparative nature, although it describes an alternative approach for proximal aortic surgery.

Conclusion

This newly developed method for the treatment of proximal aortic aneurysms offers a viable and safe alternative with only midsternal surgical incision, without damaging any segment of the healthy aortic tree for arterial cannulation, without prolonging the operation time, and avoiding complications related to additional incisions and cannulation of the healthy aortic tree. This method offers a safe and comparable alternative when the results of other techniques are reviewed. The technique needs to be evaluated in large patient groups in comparison with other techniques.

Abbreviations

AAR, ascending aorta replacement; AF, Atrial fibrillation; ARR, aortic root replacement; AAA, ascending aortic aneurysm; ARA, aortic root aneurysm; ARE, aortic root enlargement; AS, aortic valve stenosis; AV, aortic valvotomy; AI, aortic valve insufficiency; AVR, aortic valve replacement; CABG, coronary artery bypass graft; CAD, coronary artery disease; CC, cross clamping; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; DHCA, deep hypothermic circulatory arrest; DM, diabetes mellitus; ECAD, extracardiac arterial disease; HAR, hemi-arcus replacement; HT, hypertension; MI, mitral valve insufficiency; MVR, mitral valve replacement; NCSS, number cruncher statistical system; NIRS, near-infrared spectroscopy; SAA, small aortic annulus; TCA, total circulatory arrest; TI, tricuspid valve insufficiency.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

All authors contributed to the study conception and design. Statistical analysis was designed and performed by MK. Material preparation and data collection were performed by all authors. The first draft of the manuscript was written by MK, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study protocol of this retrospective study was approved by the local ethics committee and the study was conducted in accordance with the Declaration of Helsinki (Ethical Committee for Clinical Research, Haydarpasa Numune Research and Training Hospital, Istanbul, Turkey, date, August 28, 2023; no, HNEAH-KAEK 2023/154/4269). All patients gave informed consent for the surgical procedure before the operation.

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Conflict of Interest

The authors declares no conflict of interest. Mehmet Kaplan serves as editorial board member of this journal. Mehmet Kaplan declares that he was not involved in the processing of this article and has no access to information regarding its processing.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.8003.

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