Clinical outcome of thoracoabdominal aortic aneurysm surgical repair: preoperative predictors, intraoperative challenges, and postoperative sequelae

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Background

Thoracoabdominal aortic aneurysm (TAAA) represents 10% of thoracic aneurysms and 5% of all aortic aneurysms. TAAA open surgical repair has been a challenging operation since decades, as it conjugates the pathological comorbidities of AAA and surgical challenges of TAA.

Patients and methods

A prospective cohort nonrandomized study was carried out on 20 patients with TAAA of different Crawford extents. A bad outcome was considered when mortality or irreversible morbidity that affects the patient's lifestyle occurred. Different preoperative and intraoperative factors were correlated reciprocally with the bad outcome cases to line out the possible risk factors.

Results

The total studied cases were 20. The postoperative morbidities among the cases were chest complications (35%), cardiac morbidities (30%), renal impairment (25%), superficial surgical site infection (SSI) (25%), multiorgan system failure (10%), and paraplegia (10%). Early mortality was seen in 35% of the studied cases. The direct cause of mortality was cardiac insults (43%), chest complications (28.5%), and multiorgan system failure (28.5%). Reciprocal correlation between both preoperative predictors and intraoperative events and bad outcome group revealed a strong association between age +65 years (75% of bad outcome group), preoperative ischemic heart disease (IHD) (50%), preoperative renal impairment (37.5%), aneurysmal Crawford extent II (37.5%), ruptured aneurysm (37.5%), aneurysmal size greater than 7 cm (25%), total operative time greater than 4 h (75%), and bleeding greater than 2500 ml (50%) and bad outcome.

Conclusion

Age +65 years, preoperative cardiac and renal comorbidities, and aneurysmal extent II are the most important predictors of bad outcome. Prolonged total operative time and massive intraoperative bleeding are the most important operative challenges.

Keywords:
aortic aneurysm, surgical repair, thoracoabdominal

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Introduction

Thoracoabdominal aortic aneurysm (TAAA) is by far less common than isolated abdominal aortic aneurysm (AAA), and it represents ~5% of the aortic aneurysmal disease cases [1]. The estimated incidence in the USA is 5.9 cases per 100 000 person per year. A study by Clouse *et al.* [2] suggested that this incidence is increasing and is closer to 10 cases per 100 000 person per year.

Although TAAA is anatomically and surgically classified with TAA, it is pathologically and epidemiologically more related to AAA, because TAAA and AAA share the same pathogenesis, risk factors, and affected population [3]. On the contrary, this surgical classification with the TAAs is owing to the need of thoracotomy and supraceliac clamping as a common approach for surgical treatment of thoracic aneurysms.

Open surgical repair of the TAA and TAAA has been a big challenge facing the vascular surgeons through all the successive eras, as it is associated with a big catabolic burden on the patient, especially the heart, beside the local effect of the operation, and thus high morbidity and mortality. Thoracotomy, diaphragmatic division, and supraceliac clamping are the major operative differences between TAAA and AAA surgical

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repair, and they are responsible for the poor outcome and the high morbidity and mortality of this major operation. The occurrence of paraplegia and renal impairment postoperatively is usually associated with high mortality and poor life quality if the patient survives; they are taken as an indicator of bad outcome. In most experienced centers in the USA, the rate of mortality is 4.8% and that of postoperative paraplegia is 4.6%. In some studies, the incidence of paraplegia is much higher, reaching 30% mainly in less experienced centers [4]. This local effect of the operation is not the only sequela, as the operation carries a big catabolic burden on the patient, which can affect all body systems and on the top of them, the heart.

In the era of endovascular surgery and interventional radiology, the role of open surgery in the vascular field has regressed markedly. Endovascular treatment of the aortic aneurysmal disease (EVAR) is a rapidly growing field with promising results regarding overcoming the high morbidity and mortality and reducing the long hospital stay and convalescence period associated with the open surgical repair [5]. However, some limitations and facts (related to visceral segment endografting) make FEVAR and BEVAR not feasible treatments for all TAAAs and mandate surgical repair [6].

The study aims to correlate the sequelae of this major surgery with certain preoperative predictors and intraoperative adverse events to line out the most possible risk factors for bad outcome.

Patients and methods

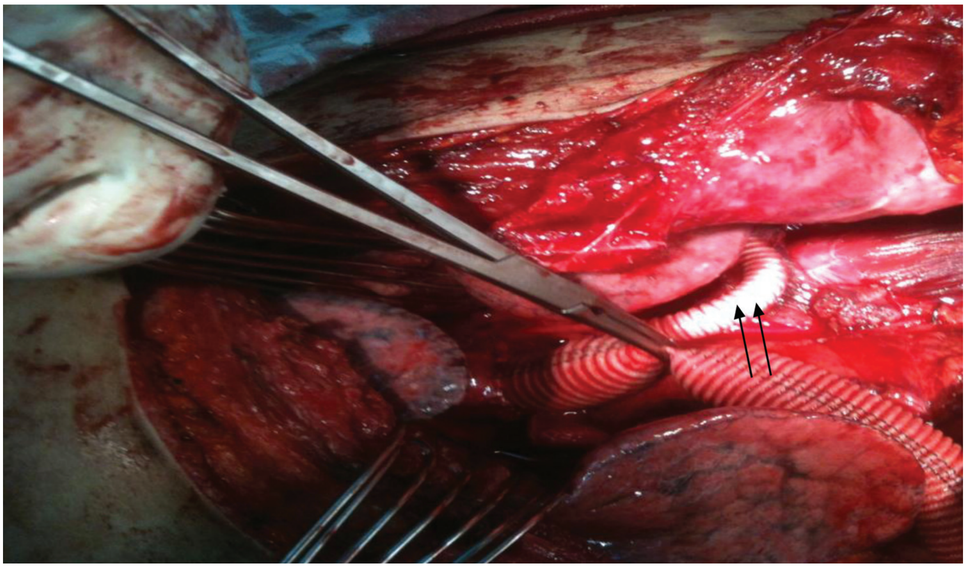
A prospective cohort nonrandomized study was carried out in Kasr Elaini Hospital between October 2014 and November 2017. A total of 20 patients with TAAA indicated to undergo surgical repair were included in the study. The study was approved by the Ethical Committee of the General Surgery Department of Kasr Elaini Faculty of Medicine. Our objectives were identifying the operative sequelae, morbidities, and mortality in the first 3 months postoperatively, and correlating this outcome with different preoperative and intraoperative factors: patient related factors, aneurysmal related factors, and operative adverse events.

The indications to undergo open repair among the studied population (patients with TAAA, any Crawford extent, both sex, and any age) included ruptured aneurysm, maximum aneurysmal transverse diameters of 5.5 cm in abdomen and/or 6.5 cm in chest or more (these were the threshold diameters considered for indication in patients with atherosclerotic aneurysmal etiology), maximum aneurysmal transverse diameters of 5 cm in abdomen and\or 6 cm in chest or more (these were the threshold diameters considered for indication in patients with congenital weak mesenchyme; Marfan's syndrome, and dissection aneurysmal etiology), all with limitations to perform FEVAR or BEVAR. Confirmation of diagnosis and criteria of indication to undergo surgical repair was carried out by doing computed tomography chest and abdomen with intravenous contrast, plus 2D computed tomography angiography or 3D computed tomography angiography in different projections or views. This imaging modality gave us information about the maximal aneurysmal transverse diameter in the chest and abdomen, anatomical extent of the aneurysm, presence or absence of rupture, and relation of the aneurysm with the major branches, that is, celiac artery, superior mesenteric artery (SMA), and renal arteries, all of which helped us in confirming indication and putting a preliminary plan for the operation regarding extension of the thoracoabdominal incision and the used technique (Fig. 1).

The unfit patients (those with intractable cardiac, chest, or renal insults), cases with difficult anatomical criteria (as those with difficult proximal clamping encroaching on the origin of left subclavian artery), and secondary cases (visceral patch aneurysmal dilatation) were excluded from the study because they were expected to have a bad outcome from the start.

All data about the patient (name, age, sex, special habits as smoking, medical history, other comorbidities, and physical fitness) and aneurysmal disease (duration of illness, presenting manifestations, the cause of aneurysmal dilatation, whether the aneurysm is intact or ruptured, and anatomical extent) were obtained and documented through a questionnaire, physical examination (specially chest auscultation, blood pressure measurement, and abdominal palpation), and doing the routine investigations, including complete blood count, random blood sugar, aspartate aminotransferase, alanine aminotransferase, blood urea, serum creatinine, prothrombin time and concentration, international normalized ratio, arterial blood gas, ECG, echocardiogram, plain chest radiography, and pulmonary function tests. Cardiac enzymes were assessed in suspected cases to exclude unstable angina. The patients' residence and telephone number were documented also for easy accessing

Figure 1



Intraoperative picture after fashioning the proximal anastomosis of the synthetic graft. The clamp is shifted on the graft distal to the origin of side arm conduit (arrows) to allow distal perfusion.

them after hospital discharge. The documented data of each patient were saved in a separate file for easy retrieving.

The operation was done using general inhalation anesthesia with auxiliary epidural analgesia. A single lung ventilation is used for cases with extents I and II to avoid unnecessary overtraction of the left lung during reaching the left subclavian artery and the pulmonary veins as they enter the left atrium. A fiber-optic laryngoscope and a guide wire were used to push the endotracheal tube into the right main bronchus.

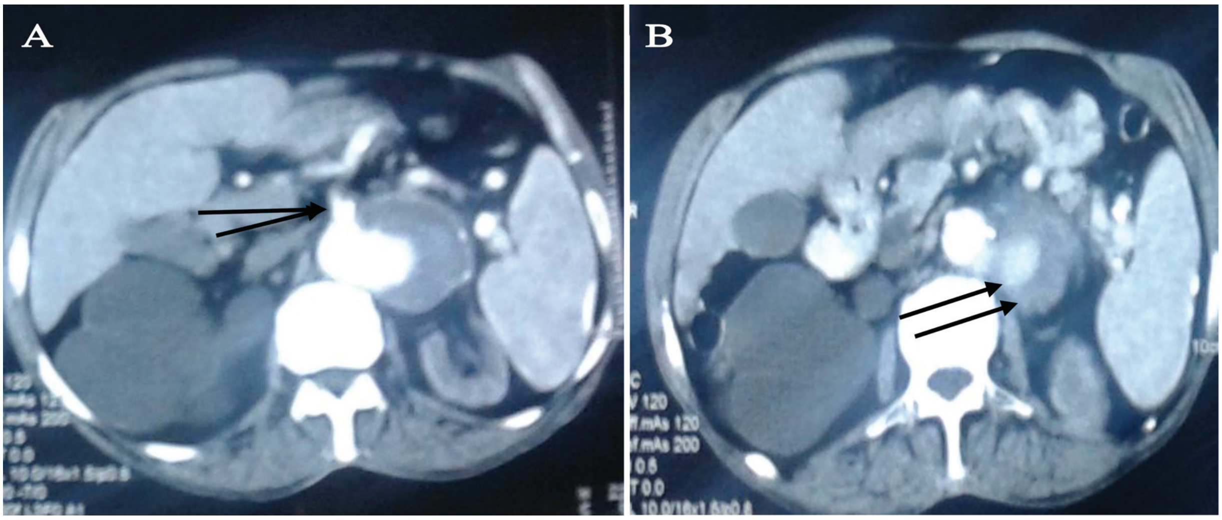
An intrathecal (in the subarachnoid space) 6-french spinal catheter was inserted in cases with aneurysmal extents I and II to achieve cerebrospinal fluid (CSF) drainage and guard against early paraplegia. The catheter is tunneled subcutaneously in the back as it was planned to be left for 3 days postoperatively. The CSF was drained passively and intermittently to reach an intrathecal pressure of 4 mm water. Intrathecal pressure was measured either manually [the same way of measuring the central venous pressure (CVP)] or by connecting the catheter to a pressure transducer and then to a special monitor.

The used technique was aortoiliac side arm bypass conduit. This technique is considered a modification to clamp and sew technique by adding an integrated passive (pump off) assisted bypass circulation. In this technique, a tube ringed Dacron graft (8 mm×16 cm) is sewed end to left side of the main aortic graft few centimetres from its proximal end, to act as a side arm bypass conduit. The distal end of the conduit is then sewed to the side of the left iliac artery to allow distal perfusion to the pelvis and lower limbs during fashioning the visceral and distal anastomoses. This technique was feasible for aneurysmal extents III, IV, and V. Fashioning aortoiliac side arm conduit takes about 10–15 min (Fig. 2). For aneurysmal extents I and II the classic sequential segmental clamping technique plus left partial heart bypass was done with the help of cardiothoracic surgeons.

In either technique, the aneurysm was exposed through continuous thoracoabdominal incision plus diaphragmatic division through the left copula and extraperitoneal abdominal approach. The level of thoracotomy depends on the thoracic extent of the aneurysm: eight intercostal space for extent IV, sixth intercostal space for extents III and V, and fourth intercostal space for extent I and II. The aortic graft (Dacron ringed silver coated measuring 20 mm×16 cm) was inserted using the usual inlay isolation technique. Implantation of visceral and intercostal branches was done using Carrel's patch technique as a routine. The separate implantation technique was done only when the branches are widely separated mandating patch of size more than 6 cm. Intercostal arteries reimplantation was done only for aneurysmal extents I and II to guard against delayed paraplegia.

The perfusion of important organs was achieved immediately after finishing visceral anastomosis by shifting the proximal clamp downward the prosthetic graft distal to the Carrel's patch.

Figure 2



Computed tomography axial cuts of ruptured type IV thoracoabdominal aortic aneurysm: (a) at the level of SMA (arrows) and (b) at a lower level, showing the extravasated blood (arrows). SMA, superior mesenteric artery.

All data about the operation was collected and documented. They included total operative and actual aortic clamping time, time of pelvic and lower limb ischemia, time of visceral ischemia, volume of blood loss, vital parameters [mean arterial pressure (MAP), pSO_2, pH, CVP, urine output, and body temperature], and technique of visceral branches implantation.

All patients are nursed in the ICU postoperatively where they were put on mechanical ventilation machine for at least 48 h. A broad-spectrum antibiotic was given routinely for all patients for at least 5 days as a prophylaxis against infection. Reperfusion injury was diagnosed by the ICU physician when unexplained rapid deterioration occurred in the general condition of the patient early postoperative period, within 24 h. Further occurrence of multiorgan system failure (MOSF) without other obvious cause was taken as a retrospective confirmation of this diagnosis. MOSF was suspected when clinical stigmata of failure of at least two systems supervened, and confirmed by doing the organ-specific laboratory tests. DIC was a strong parameter for the diagnosis of this condition. Visceral and lower limb ischemia are also ruled out.

The discharged patients were followed regularly every week and for 3 months postoperatively in the outpatient clinic. In this stage, surgical site infection (SSI), delayed paraplegia, and delayed graft related hematomas were specially excluded. The patient was checked for abnormal chest or abdominal pain and fever, and the whole wound was thoroughly examined for tenderness, signs of seroma formation, infection, or disruption. Neurological examination of both lower limbs was done to exclude delayed paraplegia.

The surgical outcome included the operative-related morbidities and mortality, as the primary outcome parameter. A bad outcome was considered when mortality or irreversible morbidity that affects patient's lifestyle occurred. Different preoperative and intraoperative factors were correlated reciprocally with the bad outcome cases to line out the possible risk factors, as the secondary outcome parameters.

Results

The total studied cases was 20 case, comprising 16 (80%) male patients and four (20%) female patients, with age ranging from 25 to 75 years, with mean equal 47, median equal 50, and SD equal 19.6. Overall, 14 (70%) cases had significant preoperative comorbidities, 13 (65%) patients had hypertension, seven (35%) patients had chronic obstructive lung disease (COLD), five (25%) patients had ischemic heart disease (IHD), five (25%) patients had renal insufficiency (with creatinine level 2 or higher), two (10%) patients had restrictive lung disease, and only one (5%) patient was on regular hemodialysis.

Overall, 11 (55%) cases were Crawford extent IV, three (15%) cases were extent V, three (15%) cases were extent II, two (10%) cases were extent I, and one (5%) case was extent III. The mean aneurysmal size ranged from 5.5 to 9 cm, with a median of 7.25 cm, mean of 6.8 cm, and standard deviation equal 1.35. In 17 (85%)

Table 1 Distribution of operative-related morbidities and mortality

Morbidity	*N*=20 [*n* (%)]
Chest complications	7 (35)
Infection	5 (25)
Respiratory failure	2 (10)
Pleural effusion (within infection cases)	1 (5)
Cardiac complications	6 (30)
Stable angina	2 (10)
Unstable angina	1 (5)
Acute MI and heart failure	2 (10)
Arrhythmias	2 (10)
Renal complications	5 (25)
Renal impairment	3 (15)
Acute renal failure	2 (10)
Superficial wound infection	5 (25)
MOSF	2 (10)
Paraplegia: early	2 (10%)
Early mortality: within 3 weeks	7 (35)
Cardiac cause	3 (of 7) (43%)
Chest cause	2 (of 7) (28.5%)
MOSF	2 (of 7) (28.5%)

MI, myocardial infarction; MOSF, multiorgan system failure.

cases, the aneurysm was intact, whereas in three (15%) cases, the aneurysm was ruptured.

Total operative time ranged from about 3 h and 40 min to 5 h, with mean equals 4 h and 33 min, median equals 4 h and 20 min, and standard deviation equals 1.45. The amount of bleeding ranged from 1700 to 2900 ml, with mean equals 2275 ml, median equals 2300 ml, and SD equals 1.4.

Overall, seven (35%) patients developed chest complications, five (25%) cases in the form of chest infection and two (10%) cases in the form of well-established respiratory failure. One (5%) case of chest infection developed right pleural effusion. Moreover, six (30%) patients developed cardiac complications: two (10%) cases developed stable angina, one (5%) case developed unstable angina, two (10%) cases developed arrhythmias, and two (10%) cases developed acute myocardial infarction. The two cases of acute myocardial infarction eventually developed acute heart failure. In addition, five (25%) patients developed renal insufficiency: three (15%) of them in the form of impairment and the other two (10%) in the form of hemodialysis-dependent acute renal failure. Additionally, five (25%) patients developed SSI, all of them were superficial wound infection; two (10%) patients developed MOSF; and two (10%) patients developed early paraplegia. Overall, seven (35%) patients died within the first 3 months postoperative. The direct cause of death was cardiac insult in three (43%) cases, chest complications in two (28.5%) cases, and MOSF in two (28.5%) cases. A total of eight (40%) patients were considered to have bad outcome, including seven mortality cases plus a survived acute renal failure case. This survived acute renal failure case was included within the bad outcome group because this insult is permanent and affected the patient lifestyle (Tables 1 and 2).

Discussion

The study showed that chest morbidities were the most frequent postoperative complications, representing 35% of the studied cases, followed by cardiac morbidities, affecting 30%, renal complications, affecting 25%, mild superficial SSI, affecting 25%, then MOSF, affecting 10%, and paraplegia affecting, 10% of cases. Early mortality that occurred within the first 3 weeks postoperatively represented 35% of the studied cases. The direct cause of mortality was cardiac insults in 43% of mortality cases, chest complications in 28.5%, and MOSF in 28.5% of them.

Coseli *et al.* [7] reported that the most frequent postoperative morbidity was pulmonary complications accounting for 35.8% of studied cases, followed by cardiac complications for 26%, renal complications for 19.8%, spinal cord deficits for 9.6%, brain stroke for 3%, and MOSF for 2.3% of total cases. They also stated that MOSF was the most frequent cause of early operative mortality, which occurred during the 30 days postoperative, and represented 14.7% of all studied cases.

Reciprocal correlation between preoperative predictors, intraoperative events, and bad outcome group revealed a strong association between age +65 years (75% of bad outcome group), preoperative IHD (50%), preoperative renal impairment (37.5%), aneurysmal Crawford extent II (37.5%), ruptured aneurysm (37.5%), aneurysmal size greater than 7 cm (25%), total operative time greater than 4 h (75%), and bleeding greater than 2500 ml (50%) and bad outcome.

Many factors interact together in a synergistic manner to produce coagulopathy and MOSF. These factors included hypothermia, intractable acidosis, severe bleeding and shock, and total operative time more than 4 h. Prolonged operative time makes the patients exposed to overdose of general anesthesia and makes them more prone to hypothermia, all of which augmented the catabolic stress of the surgery.

Johns *et al.* [8] talked about the factors that influence the overall outcome of TAAA open surgical repair and

Table 2 Preoperative predictors, intraoperative events distribution, and their correlation with bad outcome group

Variable: preoperative predictors and intraoperative adverse events	Distribution within all studied cases (20 case) [*n* (%)]	No/percentage which had a bad outcome; relative morbidity and mortality risk [*n* (%)]	Distribution within bad outcome group (total 8 cases) [*n* (%)]
Age group (years)			
25–35	7 (35)	**2/7 (28.5)**	2 (25)
+35–45	**1 (5)**	**0/1 (0)**	0
+45–55	2 (10)	**0/2 (0)**	0
+55–65	2 (10)	**0/2 (0)**	0
+65	8 (40)	**6/8 (75)**	**6 (75)**
Comorbidities			
HTN	13/20 (65)	6/13 (46)	6/8 (75)
COLD	7/20 (35)	2/7 (28)	2/8 (25)
IHD	5/20 (25)	4/5 (80)	4/8 (50)
Renal impairment	5/20 (25)	3/5 (60)	3/8 (37.5)
Restrictive lung disease	2/20 (10)	0/2 (0)	0/8 (0)
CRF	1/20 (5)	1/1 (100)	1/8 (12.5)
Aneurysmal factors			
Anatomical extent			
IV	11/20 (55)	3/11 (27)	3/8 (37.5)
V	3/20 (15)	0/3 (0)	0/8 (0)
II	3/20 (15)	3/3 (100)	3/8 (37.5)
I	2/20 (10)	1/2 (50)	1/8 (12.5)
III	1/20 (5)	1/1 (100)	1/8 (12.5)
Size (diameter in cm)			
5.5–6.5	11/20 (55)	0/11 (0)	0/8 (0)
6.5+-7	6/20 (30)	0/6 (0)	0/8 (0)
7+	3/20 (15)	2/3 (66)	2/8 (25)
all condition			
Intact wall	17/20 (85)	5/17 (29)	5/8 (62.5)
Ruptured wall	3/20 (15)	3/3 (100)	3/8 (37.5)
Operative events			
Total time			
3 h 40 min	3/20 (15)	0/3 (0)	0/8 (0)
3 h 40 min to 4 h	7/20 (35)	2/7 (28.5)	2/8 (25)
4 h+ to 4 h 30 min	5/20 (25)	3/5 (60)	3/8 (37.5)
4 h 30 min+ to 5 h	5/20 (25)	3/5 (60)	3/8 (37.5)
Bleeding (ml)			
1700	2/20 (10)	0/2 (0)	0/8 (0)
1700+ to 2000	6/20 (30)	0/6 (0)	0/8 (0)
2000+ to 2500	8/20 (40)	4/8 (50)	4/8 (50)
2500+ to 2900	4/20 (20)	4/4 (100)	4/8 (50)

COLD, chronic obstructive lung disease; CRF, chronic renal failure; IHD, ischemic heart disease; HTN, hypertension.

stated that patients with age below 60 years and dissection etiology for their aneurysms had a better prognosis. The explanation was that those patients had less preoperative atherosclerotic comorbidities, which are usually found in elderly patients with atherosclerotic aneurysmal etiology.

Hypothermia starts to exert adverse effects when it drop below 32°C, when it causes hypothermic coagulopathy, acidosis, or more seriously, MOSF. This is owing to the widespread cellular metabolic dysfunctions [9]. Splanchnic ischemia during supraceliac aortic clamping can produce coagulopathy by causing acute hepatic affection, which in turn may be owing to direct hepatic ischemia or toxic hepatitis from bacterial translocation owing to intestinal ischemia-reperfusion injury [10]. Another important hidden cause for bleeding is the systemically used heparin at the time of aortic clamping.Safi [11] stated that the presence of chronic renal insufficiency preoperatively is the second strongest predictor for occurrence of postoperative acute renal failure and mortality, coming only after aneurysmal rupture.

Coseli and colleagues added the aneurysmal extent as an important factor, beside patient age and aneurysmal pathology, in determining the outcome of the operation.

There is controversy in literature about the best operative technique and protective adjuncts to improve the overall outcome, either clamp and sew technique alone (cross-clamping), or with adjuncts. Some surgeons have strongly held opinions about the best method, but as the data state, equivalent results are attainable with each approach if experimentally supported principles are followed. However, patient physiology or anatomy may dictate the technique, such as assisted circulation if the patient cannot tolerate one-lung anesthesia and the cardiac strain of proximal cross-clamping or hypothermic circulatory arrest if there is no place for a proximal aortic clamp. Each of the different techniques has pros and cons.

Kouchoukos *et al*. [12] conducted a study that compared between different surgical techniques for cases with TAAA. The study revealed that although assisted circulation plus spinal fluid drainage was the most prevalent technique, cross-clamping plus spinal fluid drainage had the lowest total morbidity.

The aortoiliac side arm bypass conduit technique for repair of TAAA (extents III, IV, and V), actually conjoined the advantages of the clamp and sew technique plus most advantages of the assisted bypass circulation without the need to sophisticated cardiac, femoral, or extracorporeal connections. The fashioned aortoiliac side arm conduit acts as an *in situ* (intracorporeal) short bypass circuit without the need to pump. Tracing the time of actual aortic cross-clamping would be 10–15 min only, which is the time of fashioning the proximal aortic anastomosis, after which the distal perfusion is established through the bypass conduit. Early establishment of this distal perfusion decreases markedly the hemodynamic risk of thoracic aortic cross-clamping, which represents a strain over the heart owing to upper body arterial hypertension. Moreover, the risk of declamping hypotension decreased markedly as a big part of the circulatory vascular bed is already perfused. Anesthesia team was grateful to such technique and reported easy hemodynamic control during the whole procedure.

Conclusion

Age above 65 year, preoperative cardiac and renal comorbidities, and aneurysmal extent II are the most important predictors of bad outcome. Moreover, prolonged total operative time greater than 4 h and intraoperative massive bleeding greater than 2500 ml are the most important operative challenges that associate with bad outcome. Clamp and sew technique with meticulous tissue dissection, lessening total operative and aortic clamping time, minimizing bleeding, and applying efficient supportive measures by the anesthesiologist and ICU physician is still the backbone of the operative success. However, if CSF drainage and the left partial heart bypass are a standard operative adjuncts for aneurysmal extents I and II, a simple passive (pump off) assisted circulation (aortoiliac side arm bypass conduit) is better applied for aneurysmal extents III, IV, and V to decrease the heart strain and hemodynamic changes related to thoracic aortic clamping.

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Conflicts of interest
There are no conflicts of interest.

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