# Open repair of suprarenal and thoracoabdominal type IV aneurysms using the "roof top" approach. A single center early experience

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**Abstract:**

**Introduction:** The open repair of suprarenal (SR) and thoracoabdominal (TAAA) type IV aneurysms remains a difficult challenge with relatively high morbidity and mortality. The aim of this study was to report and analyze the initial experience of the "roof top" approach for the treatment of suprarenal (SR) and thoracoabdominal (TAAA) type IV aneurysms in our center

**Patients and methods:** From February 2016 till September 2019 we treated seven patients for SR and TAAA type IV aneurysms using the "roof top" approach, which is a total abdominal procedure and consists of a bilateral sub-costal incision and left sided medial visceral rotation. All patients presented with hypertension and most of them with coronary artery disease and/or smoking. The beveled proximal anastomosis in our series incorporated the origins of the visceral vessels and right renal artery, with the proximal end cephalad to the celiac artery and the distal end just below the right renal artery. The site of the distal anastomosis depended on the extent of the disease and was either the bifurcation of the aorta (5 patients) or the common / external iliac arteries, when bilateral iliac aneurysms co- existed (2 patients).

**Results:** There was one death in the 30 days postoperative period and another in hospital death 58 days postoperatively. The most common complications were due to respiratory problems, whereas two patients presented one - renal artery thrombosis, but without need for dialysis. The mean time of splachnic ischemia was 25 min and 21 min extra time was needed for the left kidney revascularization.

**Conclusion:** The 'roof top' approach with left sided medial visceral rotation, is a feasible method offering certain advantages for the treatment of complex aortic aneurysms involving the splachnic vessels.

**Keywords:** abdominal aortic aneurysm; suprarenal aneurysm; thoracoabdominal aneurysm; roof top

## INTRODUCTION

The operative management of suprarenal (SR) abdominal aortic aneurysms (AAA) and those affecting the proximal abdominal aorta and its major branches is considered a difficult challenge to the surgeon. The difficulty of exposing those sections of the aorta and the relatively high morbidity and mortality of such operations has led to the progress of various endovascular[1,2] or hybrid techniques[3,4]. Although endovascular techniques offer a less invasive alternate to open surgery, the total endovascular repair remains challenging and the long- term durability of the stent grafts is yet unknown, concerning mainly the younger patients. Even more, there is at least 6 weeks delay of the order of the complex patient-tailored endografts, which makes impossible the endovascular treatment in emergency cases. Finally, there are cases like mycotic aneurysms or redo operations in infected aortic grafts, when open surgery is mandatory.

The most common thoracoretroperitoneal approach allows unrestricted access to the distal thoracic and proximal abdominal aorta but the "two body-cavity" exposure adds significant perioperative morbidity.

We report the initial results of our single center experience of open repair of suprarenal and thoracoabominal Type IV aneurysms using the roof-top approach (bilateral subcostal incision) and a left sided medial visceral rotation. As Thoracoabdominal (TAAA) type IV (also known as total AAA) is considered the aneurysm that involves the entire visceral aortic segment, so that the repair needs a graft replacement cephalad to the celiac axis.

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## PATIENTS AND METHODS

A retrospective single-institute clinical study was undertaken and although it includes a small number of patients, the aim of the study is to report and analyze the outcomes of this specific technique at a single tertiary vascular center**.** From February 2016 till September 2019 we performed seven open repairs of SR and TAAA IV. The initial decision between open and endovascular repair was based on anatomic suitability, the age of the patient and type of the disease. We chose the open repair when more than one branches (fenestrated or chimney) were needed for endovascular repair, preferably in patients younger than 75 years old and in a case of aorto-enteric fistula with infected endograft. The mean max aneurysm diameter was 66 mm (50- 91mm). The mean diameter of the aorta at the level of the renal arteries was 41mm (35mm-50mm), whereas at the level of the origin of the visceral arteries was 33mm (29-41mm). The details about the anatomical features, the size and the extent of the aneurysms are listed in Table 1.

All patients were males with a mean age 68 years (range 55- 83 years). All had high blood pressure and most of them were presented with coronary artery disease and/or smoking. These and others co morbidities such cardiac arrhythmias, diabetes mellitus and chronic obstructive pulmonary disease (COPD) are presented in Table 2. All our patients received antiplatelets agents prior to surgery. Informed consent was obtained from all patients.

### *Preoperative assessment*

A comprehensive preoperative evaluation was undertaken for all patients. Computer tomography angiography (CTA) was performed on all patients with reconstruction of the aneurysm morphology, echocardiography and spirometry (figure 1 and 2). Patients were assessed by anesthetists, and consultant cardiologists.

| Patient | Max Aneurysm Diameter | Visceral Aorta Diameter | Renal Aorta Diameter | Accessory Renal Artery | Iliac Artery Aneurysm | Iliac Occlusion | Iliac Tortuosity |
|---|---|---|---|---|---|---|---|
| 1 | 53mm | 31mm | 50mm | No | No | Calcified Plaques Bilateral | Mild Bilateral |
| 2 | 59mm | 29mm | 44mm | No | Right CIA Dilatation | No | Severe Right CIA |
| 3 | 49mm | 34mm | 37mm | Left | No | Thrombus Left CIA | Moderate Bilateral |
| 4 | 77mm | 31mm | 35mm | Left | No | No | Moderate Left |
| 5 | 72mm | 41mm | 49mm | No | No | Severe Calcified Plaques Bilateral | Moderate Bilateral |
| 6 | 91mm | 38mm | 41mm | No | Right CIA 62mm Left CIA 47mm | Severe Calcified Plaques Bilateral | Mild Bilateral |
| 7 | 62mm | 28mm | 37mm | No | No | Left CIA Thrombosis | No |

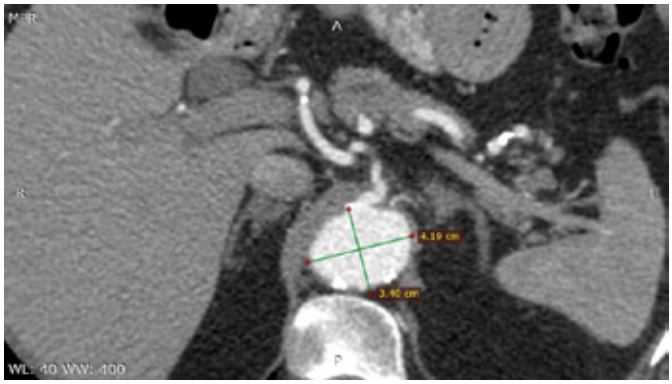
*CIA: Common Iliac Artery*

**Table 1**. Anatomical features, extent and size of the aneurysms treated.

| Patient | Age | Sex | Co morbidities |
|---|---|---|---|
| 1 | 63 | Male | Hypertension, Smoking |
| 2 | 55 | Male | Hypertension, COPD, Smoking, Psychiatric disorder |
| 3 | 63 | Male | Stable Coronary disease, Hypertension, Smoking, DM, AF |
| 4 | 83 | Male | Stable Coronary disease, Hypertension, Smoking, Dementia |
| 5 | 79 | Male | Stable Coronary disease, Hypertension, Smoking, DM, COPD |
| 6 | 71 | Male | Stable Coronary disease, Hypertension |
| 7 | 64 | Male | Mycotic pararenal aneurysm, EVAR, Ruptured Diverticulitis, Hypertension |

*COPD: Chronic obstructive pulmonary disease, DM: Diabetes Mellitus, AF: Atrial Fibrillatio*

**Table 2.** Baseline characteristics



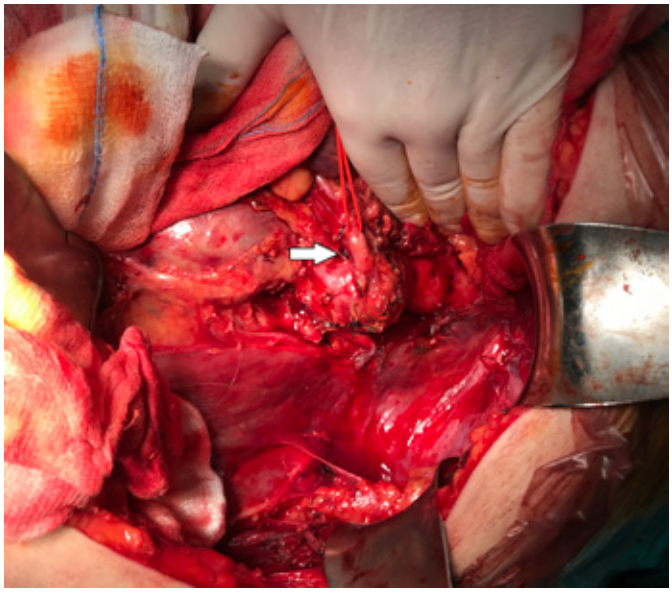

### *Operative management*

All patients underwent general anesthesia with detailed cardiovascular monitoring including invasive arterial blood pressure and central venous pressure monitoring. Near-patient testing of hemoglobin, arterial blood gases, electrolytes, glucose, was used to provide frequent intra-operative evaluation of these parameters. Activated clotting time (ACT) was not measured routinely. There was continuous monitoring of the cardiac output and stroke volume variation and after the proximal clamping antihypertensive agents were administered as needed. Cerebrospinal fluid drain was not sited, and motor evoked spinal cord potentials were not recorded.[5,6] In our series we did not use any cell saver or rapid infusion system, although we believe that the routine use of such devices will be of great advantage.

### *Operative technique*

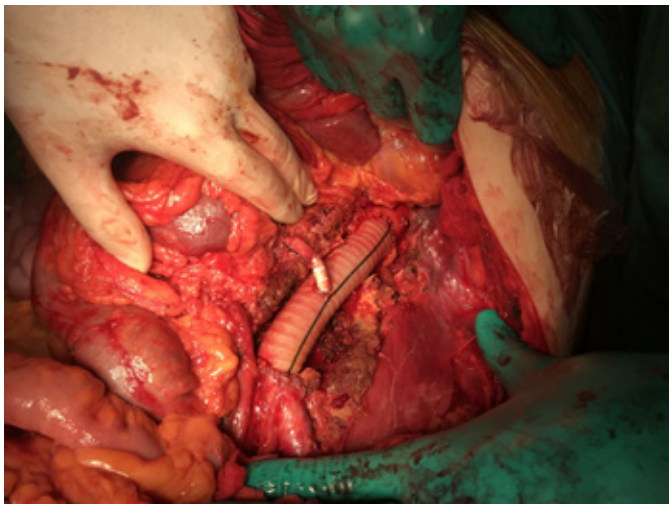
In the reported cases we used the roof-top incision which is also known as Chevron incision. The chevron incision is one that crosses the midline of the abdomen. It is a bilateral sub-costal incision that extends from the mid to lateral costal ridge, across the midline to the contralateral side. The patient is positioned with the left shoulder rotated superiorly and to the right by 60 - 80 degrees from horizontal and the pelvis in a slight angle, about 30 degrees from the horizontal. The operating table is bended in the middle with head and feet down to increase the space between the costal margin and iliac crest (figure 3).

The incision is commenced at the lateral edge of the rectus of the right abdominis muscle and extended at a point between the costal margin and the iliac crest to the left axillary line. Electrocautery is used to incise the abdominal wall musculature. After entering the peritoneal cavity, a retroperitoneal plane is developed with an incision in the left lateral peritoneal reflection, which is carried cephalad through the frenocolic ligament. Once the plane is entered the dissection proceeds medially and anterior to the psoas muscle. With gentle blunt and occasionally sharp dissection the left kidney, the pancreas, the ureter and spleen are displaced anteriorly. Care must be taken in that stage to divide all the ligaments of the spleen not only to avoid accidents but also to facilitate the exposure of the total suprarenal aorta. The lienorenal ligament (also known as splenorenal ligament), doesn't need dissection and division, so the left kidney and the spleen are retracted medially en block. The division of the descending lumbar vein, which is almost always present and travels from the psoas to the renal vein crossing the left side of the aorta, permits the visualization of the left renal artery. To have a clear access to the supraceliac aorta is obligatory to divide the left crus of the diaphragm. Dissection can proceed as far proximal as needed to place an aortic clamp. By this means the supraceliac aorta is fully exposed up to the diaphragmatic hiatus (figure 4). Heparin (5000 IU) is administered intravenously approximately three minutes before clamping. The aorta is clamped just below the diaphragm.

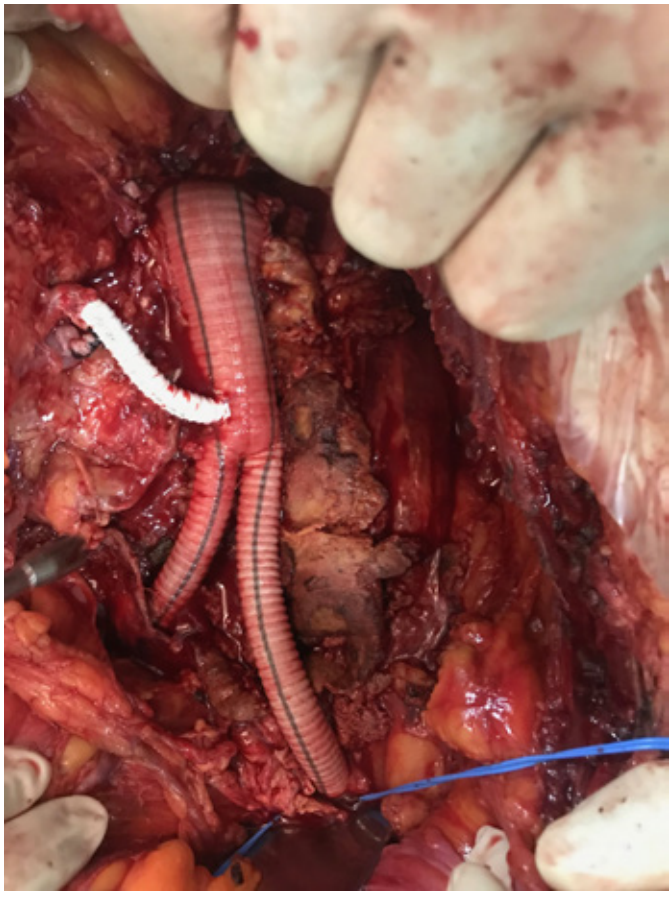


The beveled proximal anastomosis in our series incorporated the origins of the visceral vessels and right renal artery, with the proximal end cephalad to the celiac artery and the distal end just below the right renal artery. There was no need to control and clamp the celiac, the superior mesenteric and the right renal artery. 100ml of mannitol were always administered intravenously some minutes before clamping. We did not use enriched fluids for infusion of the renal or the splachnic arteries.

Separate jump graft was used to the left renal artery in all cases except for the first one, where the left renal ostium was also incorporated in the anastomosis. The jump graft was manually pre - anastomosed to the main graft (figure 5)



The site of the distal anastomosis of the main graft depended on the extent of the disease and was either the bifurcation of the aorta or the common / external iliac arteries (Table 3), (figure 6).



At the end, the aneurysmal sac was closed whenever possible and the incision was closed in two layers using loop monofilament continuous suture.


| Patient | Treatment | Time of Suprarenal and Infrarenal Clamping | Renal Revascularization | Intraoperative complications |
|---|---|---|---|---|
| 1 | Tube aortic Dacron graft 20mm | 25min + 25min | None | None |
| 2 | Tube aortic Dacron graft 20mm | 23min + 21min | Jump Graft ePTFE 6mm Left Renal artery | None |
| 3 | Tube aortic Dacron graft 20mm | 20min + 22min | Jump Graft ePTFE 6mm Left Renal artery | Left CIA Thrombosis, Thrombectomy |
| 4 | Tube aortic Dacron graft 22mm | 27min + 20min | Jump Graft ePTFE 6mm Left Renal artery | Left CIA Thrombosis, Jump Graft ePTFE 8mm to Left CFA |
| 5 | Tube aortic Dacron graft 20mm | 35min + 20min | Jump Graft ePTFE 6mm Left Renal artery | ↑ Trroponine |
| 6 | Bifurcated aorto-bi-iliac Dacron graft 22x11mm | 25min + 27min | Jump Graft ePTFE 6mm Left Renal artery | Right CIA Thrombosis, Thrombectomy |
| 7 | Endograft explantation, Bifurcated aorto-bi-iliac Dacron-Silver graft 18x9mm, Colectomy | 33min + 30min | Jump Graft ePTFE 6mm Left Renal artery | No |

*CIA: Common Iliac Artery, CFA: Common Femoral Artery, COPD: Chronic obstructive pulmonary disease, DM: Diabetes Melitus, AF: Atrial Fibrillation*

**Table3.** Operative details

| Patient | ICU Admission | Postoperative Complications | Pre- and Post-operative Creatinine (mg/dl) | Outcome | Follow-up |
|---|---|---|---|---|---|
| 1 | Yes (8days) | Hemopneumothorax (Right) Pneumothorax (Left) | pre:0,6 max:1,2 post:0,6 | Survival (23 days hospital stay) | 4 years Left Renal artery thrombosis, No Renal Insufficiency |
| 2 | Yes (37days) | Cardiac arrhythmia, Pneumonia, Respiratory failure, Tracheostomy | pre:0,6 max:0,8 post:0,6 | Survival (51 days hospital stay) | 2 years No Complications |
| 3 | No | None | pre:1,2 max:1,2 post:1,1 | Survival (11 days hospital stay) | 3 Years No Complications |
| 4 | No | None | pre:1,3 max:2,4 post:1,6 | Survival (11 days hospital stay) | 1Year No Complications |
| 5 | Yes (27days) | Cardiac arrest, Pneumonia, Respiratory failure, Sepsis | pre:1,2 max:2,7 | Death | – |
| 6 | Yes (52days) | Ischemic colitis - Colectomy, Sepsis | pre:0,8 max:2,4 | Death | – |
| 7 | Yes | Renal artery thrombosis, Pneumonia, Respiratory failure, Sepsis | pre:0,9 max:6,5 podt:5,0 | Survival | 1 year Renal Insufficiency No need for Hemodialysis |

**Table 4.** Complications and outcomes

### *Post-operative care*

Patients were admitted to intensive care for a period of post-operative ventilation if needed. Fluids replacement therapy, vasoactive drug use, antibiotic therapy and nutrition were guided by the clinical picture and followed standard protocols. We used CTA scanning for the follow up of our patients at the first month and a year after surgery, whereas we used colored duplex ultrasonography to those with longer follow up.

## RESULTS

We had no intraoperative death. There was one death in the 30 days postoperative period (25 days after the surgery, the patient facing cardiac and respiratory problems), but we had also another in hospital death (58 days postoperatively due to large bowel rupture the 26$^{th}$ p/o day), so we had two post-operative deaths. Postoperatively five patients were driven to the Intensive Care Unit, whereas two were extubated immediately after the surgery (Table 4). The mean length of stay of patients treated for aneurysm was 24 days (11-51days), whereas the patient with the aorto-enteric fistula needed hospital services for several months. The mean follow up of our patients was 26.4 months (varying from 1 year to 4 years). (Table 4)

The most common complications were due to respiratory problems and in one case this, together with cardiac ischemia, was the main cause of death. Totally five patients presented some sort of respiratory problems (one pneumothorax - need for reintubation, one respiratory insufficiency and three some degree of lung infection), but in all cases except one the problem was addressed effectively. Cardiac complications occurred in two patients, one presented transient severe cardiac arrhythmia that was addressed effectively and in another one myocardial ischemia that was lethal along with respiratory insufficiency in the same patient.

In all but the first case a PTFE 6mm graft with rings was used to jump to the left renal artery, which was anastomosed to the main Dacron graft in vitro just before implanting

it. In the first case the ostium of the left renal artery was incorporated in the proximal anastomosis. The sizes of the grafts are reported in diagram. Two patients presented one - renal artery thrombosis (one left and one right). In the first one the renal function was fully_compensated by the other kidney, where in the second one the patient needed dialysis for a short period till creatinine level stabilized at 5.0mg/dL but without further need for dialysis. One more patient had a mild temporary postoperative elevation of creatinine levels. Biochemical evidence of renal dysfunction was classified as an abnormal creatinine on base line blood tests.

In five patients a tube graft was used whereas in two patients a bifurcated aorto - iliac graft was used due to extension of the disease to the common iliac arteries. Two patients needed thrombectomy intraoperatively (one through left and the other through right common femoral artery), while another case needed intraoperatively an 8 mm PTFE jump graft to the left common femoral artery. At the end there wasn't any case of postoperative limb ischemia. There were neither neurologic complications nor non - pulmonary infections (Table 3).

The time of splachnic ischemia varied from 20 to 35 minutes, with a mean time 25 min. The extra time of the left kidney ischemia varied from 20 to 22 minutes (mean time 21 min). (Table 3)

## DISCUSSION

Exposure of the suprarenal aorta and moreover of the upper abdominal aorta with the traditional midline transperitoneal approach is limited by the overlying viscera.

The difficulty of exposing that section of the aorta and the related morbidity has driven surgeons addressing diseases in that segment to other solutions such as endovascular techniques[7] or hybrid operations[8,9] Although these treatments seem to provide comparable and even better results than open repair, they are also challenging operations.[10,11,12]

Apart from that, there are cases with anatomy unsuitable for endovascular repair due to iliac access limitations, patent aortic lumen diameter and angulation. Also, there are problems of endograft availability because manufacturing can be delayed up to 8 weeks (except for the uncommon off-the-shelf devices), and restrictions due to the number of fenestrations and visceral vessels anatomy and orientation[13] Moreover, the long term durability is yet unknown[14] raising concerns especially to the younger patients, in the same way that open repair of an infrarenal AAA is preferred to EVAR in younger population. Furthermore, the chronic radiation exposure after fenestrated endovascular aneurysm repair (fEVAR) and branched endovascular aneurysm repair (bEVAR) follow up possibly increases the risk of malignancy[15,16,17] Finally, there are some diseases that open repair is mandatory. These cases include the mycotic aneurysms[18,19,20,21], the resection of infected aortic grafts[22] and the open conversion after juxtarenal EVAR failure.

So, even in the endovascular era, there is still need for open repair of aneurysms involving the supraceliac aorta. The traditional approach to access this section of the aorta is retroperitoneal, which can be extended as left thoracoabdominal. This method provides perfect access to the total abdominal aorta but at a cost of two body cavity exposure. There is a variety of approaches to expose this site of the aorta, like a transabdominal medial visceral rotation, but few data are available to compare between them.[23]

The "roof top" approach with the left sided medial visceral rotation is another method that provides excellent exposure of total the abdominal aorta from the diaphragm to the iliac arteries entering only the abdomen. Only true thoracoabdominal aneurysms involving the descending thoracic aorta need the traditional thoaracoabdominal incision with two body cavity exposure.

De Bakey et al were the first to report the thoracoabdominal approach with left to right visceral rotation for exposure of the distal thoracic and abdominal aorta in a plane anterior to the left kidney[24]. Shirkey et al.7 followed describing a transabdominal medial visceral rotation to treat a SMA trauma in a plane anterior to the left kidney[25]. Buscaglia et al reported their experience with left to right medial rotation of the viscera to approach vascular injuries of aorta lesions involving the celiac, superior mesenteric and renal arteries[26]. Many papers followed advocating the left to right medial visceral rotation to approach the upper aorta and its branches, usually after traumatic injuries[27,28,29,30].

Crawford published his experience of treating electively aneurysms involving the proximal abdominal aorta[31,32].

The 'roof top' approach to treat lesions of the upper abdominal aorta has theoretical advantages as well as disadvantages. The main advantage as already mentioned is the one cavity approach. It provides excellent exposure of the segment of the aorta where the splachnic vessels arise. The mean visceral ischemia time of only 25 minutes in our series reflects the convenience providing by this approach[33,34]. Another advantage of the method is that it gives_access to both iliac arteries. The exposure of the iliac arteries is very difficult and troublesome when the retroperitoneal - thoracoabdominal approach is used. In two of our patients we used bifurcated graft to the bifurcations of the common iliac arteries without facing access difficulties.

We think that the ability of encountering right (common or external) iliac lesions is a clear benefit provided by this method. Finally, as another possible advantage of the method we can add the diligent observation of the total abdominal cavity for another pathology and especially of the intestines for possible intraoperative ischemia. On the other hand, the intraperitoneal part of the operation may be adds an extra charge to the patient, instead of a single retroperitoneal - but not thoracoabdominal- approach.

Although the number in our series is small, we tried to identify deaths / complications that may be related to the method. A possible complication of the method could have been a spleen injury, as mobilization of the spleen is mandatory, and this complication is too often described in the retroperitoneal approach[34]. In our series we didn't encounter such a problem. Finally, we didn't face any clamp injury to the lateral

aortic wall, which is another recorded complication.[35]

A possible complication that might be related to the left sided visceral rotation is the visceral ischemia or infarction. This retraction and traction has the potential for injury to the pancreas and the visceral vessels or may create a low-flow state in the viscera by compressing or occluding the SMA and to a lesser extent the celiac axis. In our series there wasn't any obvious intraoperative ischemia. In the case with the large bowel ischemia and rupture that was lethal to the patient, the rupture happened at the 26th postoperative day. In that case, apart from the big abdominal aneurysm, there were also very big aneurysms of both common iliac arteries and the extensive mobilization that was needed during surgery, may be suspect of the bowel rupture. The patient was re operated two times, but finally he died of sepsis. This type of complication suggests the necessity for appropriate handling of the viscera during mobilization. The viscera must be retracted without being pressed, the retractors should be well padded, and the viscera should be assessed regularly during the operation. As it is already mentioned, the "roof top" method has the advantage of providing easy observation of the intrabdominal organs during surgery.

Although most patients were extubated within 24 hours of surgery, the most common postoperative complications still were due to respiratory problems. One patient died due to combined respiratory - cardiac problems and one initially extubated did require reintubation and drainage of pleural effusions that were not associated with a concurrent pulmonary or intraabdominal process but was successfully re-extubated. Three patients were treated for some degree of lung infection. Although these complications were manageable it is interesting the high frequency of respiratory problems.

Two patients presented renal artery thrombosis. The first one had a left renal artery thrombosis, our first treated patient, were we incorporated both renal arteries, together with the mesenteric and celiac artery, in the proximal anastomosis. After that we changed our practice and always performed a bypass to the left renal artery using a 6mm PTFE graft. After all, this patient was discharged without any renal insufficiency problem due to a total compensation of the other kidney. In the other patient it was the right renal artery that was thrombosed. It was the complex case with aorto-enteric fistula, were an endovascular graft with suprarenal fixation was removed. An injury of the ostium of the right renal artery from the removal of the endovascular hooks is a possible cause. The patient needed dialysis for a three months period after which the creatinine level was stabilized at 5.0 mg/dL, but without need for dialysis[36,37]. Although there is an option of re-implanting the left renal artery to the graft, we prefer to perform a bypass. The creation of the left renal bypass is a tricky point of the operation as there is always a chance of kinking when the left kidney takes its final position, thus there are some tips that may reduce this risk. The PTFE graft is anastomosed to the left side of the Dacron main graft, in an inferior level of the orifice of the artery, so it has an upward direction that facilitates handling and makes kinking less possible, and when the PTFE graft is longer than 4 cm, we keep its rings. The final check comes after loosening the viscera and putting them in their natural place.

It is known that increasing durations of acute visceral ischemia can lead to significant multiple organ dysfunctions after TAAA repair and methods of limiting visceral ischemia or the systemic effects of visceral ischemia may decrease both the morbidity and mortality[38]. In our series there wasn't any evidence of postoperative hepatic dysfunction (measured by lactate dehydrogenase, serum transaminases and bilirubin levels), nor acute visceral ischemia and this may be due to the short time of cross clamping.

The closing of the incision in two layers using continuous monofilament suture was proved both efficacious and relatively painless. Despite the length of the incision, there was less need for painkillers than in a normal midline incision and there weren't any postoperative hernias.

## CONCLUSION

The 'roof top' approach with left sided medial visceral rotation adds another option for the treatment of complex aortic aneurysms involving the splachnic vessels, when open repair is mandatory. Although outcomes, like in all demanding operations, are volume depended, the 'roof top' approach is a feasible method offering certain advantages to surgeons who address this severe disease.

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