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Fate of the Visceral Aortic Patch After Thoracoabdominal Aortic Repair

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Objective. To analyse the fate of a visceral aortic patch (VAP) in patients that underwent thoracoabdominal aortic aneurysm (TAAA) repair.

Methods. We reviewed 204 consecutive patients (158 M, 46 F) treated for TAAA between 1988 and 2004. We performed VAP in 182 cases. Among the 149 survivors at 6 months, we followed 138 cases, mean follow-up 7 years (range 0.6–16 years). The mean graft diameter we used was 29 mm (range 24–34 mm) from 1988 to 1999 (83 patients), and 21.7 mm (range 16–24 mm) from 2000 to 2003 (55 patients). In 23% of cases we performed a separate bypass to the left renal artery.

Results. We observed 16 (12%) VAP dilatations (<5 cm), 6 (4%) VAP aneurysms (>5 cm) and one VAP pseudoaneurysm, at a mean time of 6 years after atherosclerotic TAAA was atherosclerotic repair. There were no VAP dilatations/aneurysms in the group of patients with separate left renal revascularization. Five VAP aneurysms were treated electively. In four cases the operation was performed with thoracophrenolaparotomy, in one case with a bilateral subcostal laparotomy. In all cases the visceral aorta was re-grafted. Reimplantation of a single undersized VAP was performed in one case, separate revascularization of visceral arteries was performed in the other four cases. Selective intraoperative hypothermic perfusion of visceral and renal arteries was used in all the patients. There was 1 perioperative death; 2 patients with preoperative renal failure required dialysis. The last VAP aneurysm has remained asymptomatic and stable at annual CT surveillance. The VAP pseudoaneurysm was successfully treated with an emergency thoracophrenolaparotomy and refashioning the left side suture line.

Conclusions. Aneurysm of VAP is not uncommon in the patients operated on using larger grafts with a single VAP that includes the LRA (7.4%, 5/67 cases). Its treatment carries significant morbidity and mortality.

Keywords: Thoracoabdominal aneurysm; Complication; Reintervention; Visceral patch; Aortic reoperation.

Introduction

Thoracoabdominal aortic aneurysms (TAAA) have an ominous natural history,^{1–3} surgical treatment greatly improves the long term prognosis; a significant price, however, is paid both in terms of perioperative mortality and morbidity, including paraplegia, renal insufficiency etc.^{4–8} As opposed to abdominal aortic aneurysms (AAA) and thoracic aortic aneurysms (TAA), TAAA have not yet benefited much from the advent of endovascular techniques for the exclusion of the aneurysm, in spite of anecdotal reports with existing materials and interesting research on new

grafts and techniques.^{9–12} Therefore open surgical reconstruction is still the preferred treatment for TAAA.

After surgical treatment patients are generally enrolled in a follow-up program in order to evaluate their general conditions risk factors and compliance with medical therapy; moreover, the evolution of the grafts, the untreated aorta and other specific arterial locations (carotid arteries, lower limb arteries, etc.), are followed with non-invasive diagnostic techniques.

Previous literature reports have showed that when the renal and splanchnic vessels are attached to the aortic graft as a single visceral aortic patch (VAP) or 'Carrell patch', this may progress into a dilatation or a frank aneurysm. Anastomotic pseudoaneurysms also may develop at this site and have distinctive features. In our experience several cases of both symptomatic and asymptomatic dilatations, aneurysms and pseudoaneurysms have been observed during the long-term follow up of patients surviving surgery for

Abbreviations: TAAA, thoracoabdominal aortic aneurysm; VAP, visceral aortic patch; CT, celiac trunk; SMA, superior mesenteric artery; RRA, right renal artery; LRA, left renal artery; MOF, multiple organ failure.

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TAAA. The aim of this study is to analyse the frequency of dilatations, aneurysms or pseudoaneurysms of the VAP, to evaluate their relationship between the type and time of TAAA surgery and finally to discuss the surgical treatment and outcome of this challenging medical condition.

Materials and Methods

We reviewed 204 consecutive patients (158 M, 46 F, mean age 66.3 ± 8.1 years) treated for TAAA between 1988 and 2004 at the IRCCS San Raffaele. In 182 cases a visceral aortic patch (VAP) was anastomosed to the aortic graft with the Crawford inclusion technique.¹³

Patients receiving a distal or proximal bevelled anastomosis including visceral vessels, patching of the aorta without tube-graft or single-vessel visceral grafting were excluded from this study. Among patients receiving VAP, 149 (82%) survived at a follow-up greater than 6 months. 138 patients complied with postoperative surveillance. We recorded and analyzed data from these 138 patients that had been regularly followed-up (mean follow-up 7.3 years, range 0.6–16 years).

Our preferred surgical technique for TAAA repair with left heart bypass, selective visceral perfusion and cerebro-spinal fluid drainage has been fully described elsewhere.^{14,15} We used Dacron woven double velour soaked in collagen. The mean graft diameter was 29 mm (range 24–34 mm) from 1988 to 1999 (83 patients), and 22 mm (range 16–24 mm) from 2000 to 2004 (55 patients). In 107 patients (77.5%) the relative proximity of visceral vessels allowed us to create a four-vessels VAP, in the other 31 cases (23%), the ostium of the visceral arteries, in particular the left renal artery (LRA), was set apart from the aneurysm and required individual anastomosis, either directly or using a graft. The presence of a severely calcified aorta required an endarterectomy of the VAP in 16 cases and open stenting of visceral vessels ostia in three cases. Visceral aortic patch was routinely reimplanted to the aortic graft with running polypropylene sutures (2/0 or 3/0) reinforced with pledgets (teflon) at points of maximum tension. Follow-up included clinical and radiological examination: chest X-ray, CT or MR scans at 3 and 6 months after surgical procedure and thereafter annually using CT or MR.

For operated patients, we defined as a VAP dilatation an increase in the maximum aortic diameter greater than 20% compared to the diameter measured at the first follow up image at the level of visceral vessels. We defined as VAP aneurysm as having a diameter of 5 cm or more. This definition of VAP

dilatation, was used in order to correct the possible errors related to the diameter of the graft used in the first operation. The diagnosis of VAP pseudo-aneurysm was clinical and histological from operative specimens.

Results

Among the 138 patients that were regularly followed, we observed 16 (12%) VAP dilatations (<5 cm), 6 (4%) VAP aneurysms (>5 cm) and 1 (1%) VAP pseudoaneurysm (Fig. 1). In all cases that developed a VAP dilatation or aneurysm, the original TAAA was atherosclerotic. There were no VAP dilatative lesions in the group of patients with separate revascularization of the left renal artery (LRA).

The mean VAP dilatation diameter was 4.3 cm. All 16 patients of this group were symptom free and were being regularly followed with yearly (Table 1) CT scanning. In this group the original TAAA repair was performed in nine cases for a Crawford type III, in four cases for a Crawford type II and in three cases for a Crawford type IV. The mean graft diameter implanted during the original TAAA repair was 29 ± 3 mm. The mean time of detection of aneurysmal expansion was 6.2 ± 2.5 years after the original operation.

The mean VAP aneurysm diameter was 5.9 ± 1.1 cm. In these 6 patients (Table 2) the original TAAA repair was performed in four cases for a Crawford type III, in one case for a Crawford type II and in one case for a Crawford type IV. The mean graft diameter implanted during the original TAAA repair was 3.0 ± 0.3 cm. The mean time of detection of aneurysmal expansion was 5.8 ± 2.3 years after the original operation. Five patients were symptom free with lesion detected on routine CT scans. One patient had back pain. One symptom free patient with a VAP aneurysm size of 52 mm that had been stable for 6 years is still being followed up. The other 5 patients of this group have had surgical repair. In four cases the operation was performed with thoracophrenolaparotomy, in one case with a bilateral subcostal laparotomy. In all cases the visceral aorta was re-grafted. Re-implantation of a single undersized VAP was performed in one case, placing the suture in the orifices of the vessels (Fig. 2); LRA was separately reimplanted in two cases, the right renal artery in another one and selective bypass grafts were performed in the other case.

We performed intra-operative hypothermic perfusion of the celiac and superior mesenteric arteries with cold crystalloid solution (Lactate Ringer at 4 °C) and of the renal arteries with cold crystalloid solution

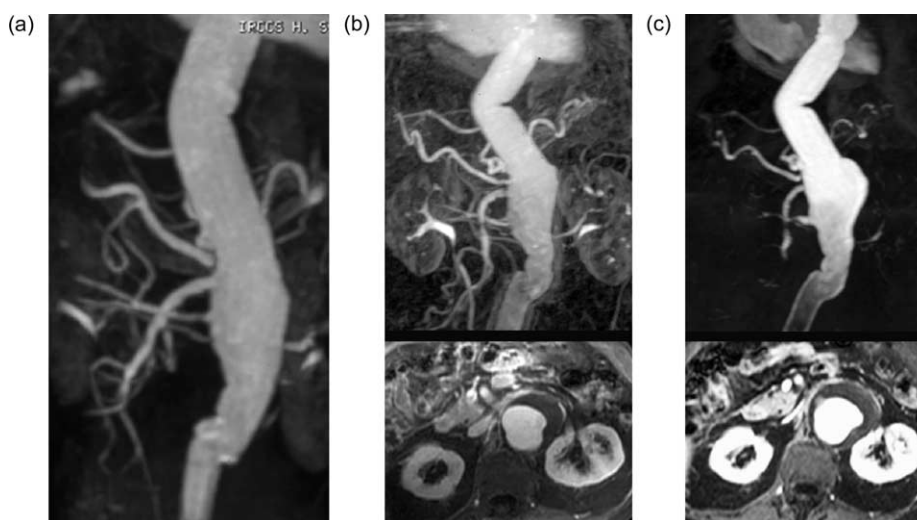


Fig. 1. Follow-up of a patient ((1) who developed a VAP aneurysm. (a) MR that shows the successful type III TAAA repair 1 month after surgical procedure. (b) The same patient at 4-year follow-up: MR scans reveal a dilatation of the visceral patch. (c) MR taken 1 year later revealed the progressive enlargement of the VAP that became symptomatic.

(Lactate Ringer at 4 °C) supplemented with mannitol and methylprednisolone. No cerebrospinal fluid drainage was used. One case postoperative anuria was observed and successfully treated with bilateral renal artery stenting. There was 1 perioperative death due to multi-organ failure; 2 patients with pre-operative renal failure required temporary postoperative dialysis. The four survivors are alive and well after a mean follow up of 2 ± 0.8 years.

The patient with the VAP pseudoaneurysm was originally treated for a Crawford class III TAAA. The graft diameter implanted during the original TAAA repair was 2.0 cm. He presented with rupture of the suture line, hemodynamic instability, and a large pseudoaneurysm 2 years following first operation (Fig. 3). The VAP pseudoaneurysm was successfully

treated with an emergency operation through a left thoracophrenolaparotomy. Selective intraoperative hypothermic perfusion of the visceral and renal arteries was used, refashioning the left side of suture line with polypropylene 2/0. The time of total visceral ischemia was of 14 min. No cerebrospinal fluid drainage was used. Microbiological study of the graft, suture and native aortic wall did not show any bacterial growth. After a long hospital stay the patient was discharged and is alive and well after 2 months.

Larger original grafts, with diameter greater > 2.8 cm, were significantly associated with VAP dilatation (aneurysm, dilatation, pseudoaneurysm) ($P < 0.0001$, Fisher exact test). Larger original grafts, with diameter greater > 2.8 cm, also were significantly associated with VAP aneurysm/pseudoaneurysm ($P < 0.04$, Fisher exact test).

Table 1. Preoperative characteristics of the patients of this series

| | |
|-----------------------|-----------|
| Age (years) | 66 ± 8 |
| Males | 112 (81%) |
| Maximum diameter (mm) | 68 ± 21 |
| Type II TAAA | 53 (38%) |
| Type III TAAA | 57 (41%) |
| Type IV TAAA | 28 (20%) |
| Emergency | 11 (8%) |
| Symptomatic | 30 (22%) |
| Etiology | |
| Degenerative | 115 (83%) |
| Dissection | 14 (10%) |
| Marfan | 9 (7%) |
| Diabetes | 12 (9%) |
| Hypertension | 81 (59%) |
| Cigarettes smoke | 73 (53%) |
| Dislipidemia | 26 (19%) |
| Chronic renal failure | 39 (28%) |
| CAD | 84 (61%) |
| COPD | 79 (57%) |

Discussion

Since Crawford proposed his 'inclusion technique' for treatment of TAAA in 1978,¹³ the results of this operation improved considerably, with the use of adjunctive procedures such as distal aortic perfusion, selective visceral perfusion and cerebro-spinal fluid drainage.¹⁶⁻¹⁹ Nevertheless several studies have demonstrated that survival after TAAA repair is worse than survival in the general population.²⁰⁻²² This might be explained by the invasiveness of this surgical procedure. Moreover these patients often present severe comorbidities. Finally, late events may be related to the ongoing aortic disease. In fact,

Table 2. Features of original TAAA repair

| Patient | Age | Sex | TAAA diameter (mm) | Crawford type | Graft diameter (mm) | Revised patch | Death | Renal complications | Visceral complications |
|---------|-----|-----|--------------------|---------------|---------------------|--------------------|-----------|---------------------|------------------------|
| 1 | 71 | M | 64 | 3 | 32 | CT, SMA, RRA, LRA | No | Yes | No |
| 2 | 77 | M | 58 | 2 | 28 | SMA, CT, RRA | No | No | No |
| 3 | 72 | M | 52 | 3 | 34 | CT, SMA, LRA | Yes (MOF) | Yes | No |
| 4 | 67 | F | 68 | 3 | 26 | CT, SMA | No | No | No |
| 5 | 68 | M | 56 | 4 | 28 | Selective bypasses | No | No | No |
| 6 | 74 | M | 54 | 3 | 20 | CT, SMA, RRA, LRA | No | No | Yes |

Patients underwent operation for VAP pathology (aneurysm or pseudoaneurysm) developed after a primary TAAA repair.

patients with extensive TAAA generally exhibit a tendency to aneurysmal degeneration at other sites; this is most common in patients with connective tissue disease or dissection.^{23,24}

Revascularization of visceral arteries is a crucial step of Crawford's inclusion technique, mainly because of the limited ischemic tolerance of the different organs. The most simple and expeditious surgical technique is to anastomose the graft with an aortic patch containing all visceral branches. The main advantage of this technique is the reduced number of anastomoses. The tissue of VAP however, is excised from aneurysmal aorta. Although Crawford's technique appears to give durable results for most patients, Dardik, Carrel and Clouse described aneurysmal degeneration and rupture of the VAP.^{25,26,27} Moreover some authors also report this problem in the intercostal patch in patients undergoing TAAA^{25,28} and specific technique of repair have been proposed at this level.²⁹

To make the size of VAP as small as possible and to benefit from the greater strength of the aortic tissues near side branches,³⁰ several authors suggest intentionally placing some bites of the running suture in the orifices of celiac and renal arteries. However,

sometimes this manoeuvre may be hazardous because of the risk of focal ostial plaque disruption and dissection. This may lead to visceral and/or renal arteries malperfusion as described in previous reports.³¹

In order to reduce the size of VAP, separate reimplantation of the LRA may be employed, directly or interposing a graft. Separate reimplantation of each visceral artery could be used in patients with higher risk of VAP dilatation and/or widely displaced visceral ostia. In patients with Marfan syndrome Safi, proposes the use of side-arm commercially available grafts during original TAAA repair because of the high incidence of VAP aneurysm in his experience (25%).²⁷ In patients with Marfan syndrome, Dardik *et al.*²⁵ purpose a separate bypass to celiac, to the left renal, and tailoring of a very small VAP including superior mesenteric and right renal arteries. When not possible they suggest individual grafts. In these cases the visceral revascularization procedure may be technically more complicated. The time of ischemia may be longer because of the increased number of anastomoses. The risk of bleeding and of branch occlusion may be increased.

The growth rate and risk of rupture of VAP

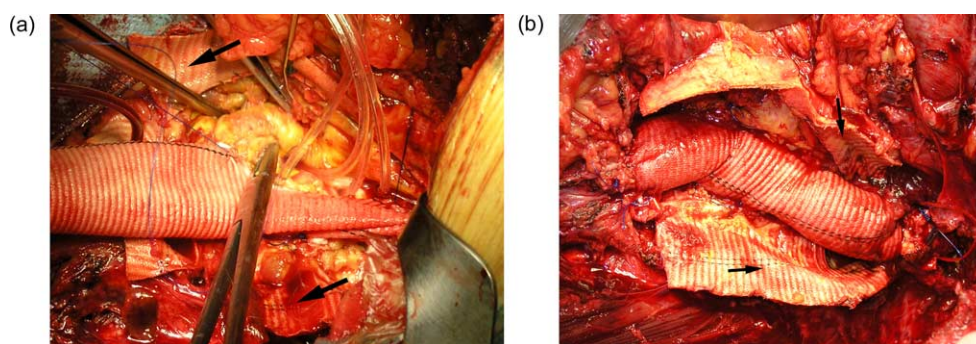


Fig. 2. (a) Refashioning of a single undersized VAP. Of note the original graft (arrows) and the selective cold perfusion of the four visceral vessels. (b) Successful repair of the VAP aneurysm with a 22 mm Dacron graft.

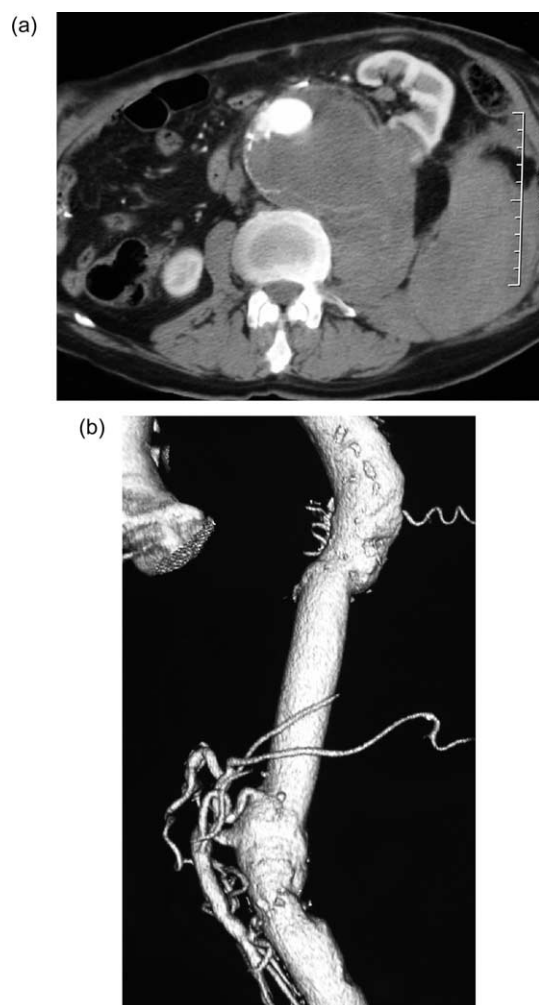


Fig. 3. (a) Emergent CT taken in patient (6 referred to our ER after hemorrhagic shock. The scan reveals the VAP pseudoaneurysm and a retroperitoneal haematoma dislodging the left kidney. (b) 3-D spiral CT showing successful repair of the VAP pseudo-aneurysm.

dilatations and aneurysms are currently unclear. The natural history of the graft may play a role in this late complication. Dacron prostheses in humans have been documented to develop long-term fiber alterations, that may account for late graft dilatation.^{32,33} Late dilatation has been documented mainly in knitted prostheses, implanted in the abdominal and thoracic aorta. During recent years, the manufacturers have improved their grafts. A recent prospective study reported that the Dacron woven double velour collagen-impregnated prostheses implanted in thoracic aorta have no significant changes in computed tomography diameter throughout the first 3 year follow-up.³⁴ In our series, we did not observe significant dilatation of the tube-grafts far from aortic anastomoses. Interestingly, we observed that from the first postoperative image study, the measured graft

diameter was always larger compared to the nominal graft diameter (range 2–4 mm), but later the diameter stabilised. Future evaluations should focus on very long-term results.

It may be hypothesized that VAP aneurysms behave like saccular aneurysms²⁵ and present a higher risk of rupture compared to fusiform aneurysms.³⁵ The ruptured VAP reported by Dardik occurred at a diameter greater than 6 cm. The appropriate threshold has to be assessed and further experience is required to establish if its criteria should be modified in presence of connective tissue disorders or other risk factors.

Repair of VAP lesions may not be standardized because of the small number of cases reported by the different group and heterogeneous results. Dardik reports in all his cases a large amount of inflammation around the VAP that is 'tremendously difficult to dissect'.²⁵ He performed VAP repair replacing a segment of thoracoabdominal aortic prosthetic graft and refashioning a smaller patch, placing the sutures in the ostia of vessels. The LRA was reimplemented separately in all cases, the right renal artery in one case. He performed distal aortic perfusion but he did not use visceral or renal perfusion. He controlled black-bleeding from visceral ostia with intraluminal occlusion catheters. He did not report postoperative renal failure but a lengthy and expensive hospitalization. Yue *et al.* also reported a case of VAP aneurysm repair using the same strategy and refashioning a smaller VAP.³¹

Lombardi converted 3 patients with VAP aneurysm from inclusion technique to separate bypasses to each vessel in the degenerated patch.³⁶ He preferred to use profound hypothermic circulatory arrest, because it provides additional visceral and renal protection during individual reconstruction of visceral vessels.

Dias and Coselli reported a VAP aneurysm successfully treated with interpositioning of a branched aortic vascular graft used for reinsertion of abdominal vessels.³⁷ The procedure was performed with cerebrospinal fluid drainage and renal perfusion with intermittent cold crystalloid solution.

Carrel reported a case of VAP rupture in a patient with Marfan syndrome successfully treated with an interesting strategy.²⁶ In order to minimize ischemic time of the abdominal organs, he implanted end to side three separate grafts into the side clamped thoracic segment of the previous aortic graft. Only after this manoeuvre he cross-clamped the abdominal segment of aortic graft, removed the VAP and performed selective bypasses to the visceral vessels. Finally the abdominal segment of the thoracoabdominal graft was replaced. Because the left kidney was atrophic its revascularization was judged unnecessary.

Endovascular techniques may also play a role in VAP pathology treatment. Juvenon *et al.* proposed combined surgical and endovascular treatment:³⁸ a retrograde revascularization of the visceral vessels was performed and a stent-graft was inserted into the aortic graft. This procedure is feasible and attractive in selected patients but long-term results and indications have to be assessed. Badran *et al.* successfully performed transluminal occlusion with thrombin injection of a pseudoaneurysm arising from an aortic patch containing intercostals arteries.³⁹

Visceral aortic patch pseudoaneurysms are different lesions from VAP true aneurysms.^{22,26} These are generally contained rupture by the inclusion technique and are not necessarily related to progressive VAP dilatation. The VAP pseudoaneurysm that we observed in our series was probably associated with VAP anastomotic suture line (polypropylene 3/0) rupture, as assessed intraoperatively. The VAP wall was particularly calcified and this may have led to suture damage at the time of initial surgery and late rupture in absence of VAP dilatation.

Aneurysm and dilatation of VAP was not uncommon in our series of patients operated for atherosclerotic TAAA, with a single VAP that included the LRA (7.4%, 5/67 cases). Careful postoperative yearly CT surveillance is recommended.

In our experience graft size has emerged as a risk factor for dilatating VAP pathology. Laplace's law states that wall tension is directly proportional to diameter. Previous reports did not correlate VAP expansion to the size of the graft. In our experience VAP aneurysms were more common in larger diameter grafts. We believe that the use of smaller diameter grafts may reduce the wall stress and the risk of VAP dilatation and VAP suture line rupture. Further evaluation will be required to assess the real impact of graft diameter on the risk of VAP dilatating disease. To investigate the effects of different graft sizes in terms of mechanical stress and strain on VAP wall, we are performing computational simulations with models of variously shaped VAP.

Repair of VAP aneurysm carried significant mortality and morbidity. The adjunctive procedures experienced in TAAA type IV^{40,41} may be successfully employed in VAP aneurysm repair.

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