28 Current Trends of Treatment Options for Complex Aortic Pathology with Visceral Artery Involvement in a Large Single-Center Experience

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28.1 Introduction

Currently, there are no prospective randomized trials that compare open versus endovascular repair for thoracoabdominal aortic diseases. Open surgical repair represents the "gold standard" for the treatment of thoracoabdominal aortic aneurysm (TAAA) or dissection.

Over the last 40 years, advances in perioperative care, surgical techniques, and adjuncts for organ protection have greatly improved morbidity and mortality rates in experienced surgical centers, even in patients undergoing extensive repair [1] .The contemporary results of open surgical repair of thoracoabdominal aneurysms come from the very few centers with expertise in this area, so it is difficult to make a reliable comparison between open and endovascular repair. Furthermore, the mortality rates reported for open procedures are still high. The most encouraging results for open procedures including the repair of the visceral aorta are based on cohorts of patients aged 50 years or younger [1]. It is clear from the experience of the same centers reporting these good results that the mean age for these conditions is close to 70 years, so when speaking about complex aortic pathologies involving the visceral aorta, a less-invasive approach should be considered both for age and for comorbidities of this population [2]. The endovascular option shows an immediate advantage on the open approach, and this consideration is modifying the attitude toward such patients [3]. We herein report a retrospective analysis of patients treated for complex aortic pathologies with visceral artery involvement in the last year.

28.2 Decision-Making

When a complex aortic pathology with visceral artery involvement is present, patients' age and clinical conditions usually drive the choice of the surgical approach. Young patients, and those in good clinical conditions with pararenal pathology which may not imply a thoracotomy, may benefit from open or hybrid treatment. If the patient is considered unfit for open surgery, the anatomy should be the factor determining which endovascular option between Ch-EVAR, custom

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FEVAR/BEVAR, and "off-the-shelf" BEVAR should be chosen, while for thoracoabdominal aneurysms which would need a thoracotomy for the open repair, the endovascular option with FEVAR and BEVAR should be considered a good alternative [3] (treatment algorithm is schematized in Fig. 28.1).

28.3 Patient Populations

A retrospective analysis of our cohort of patients from December 2016 to December 2017 showed a total of 64 patients treated for complex aortic pathologies with visceral artery involvement (the intended meaning for visceral artery involvement is a primary aortic pathology with proximal extent to reno-visceral segment or an evolution of the index pathology after an infrarenal repair for which the correction would include an extent to the reno-visceral segment). Of these, seven were treated as an urgency/emergency. Distribution of treatment options with the number of managed reno-visceral branches is shown in Figs. 28.2 and 28.3.

28.4 Open Procedures

In our cohort of patients (11 male patients), all of them were treated by an open approach. The mean age in this subgroup was 65 years. The comorbidities are reported in Table 28.1.

The primary open repairs were nine; two patients underwent open conversion of a previous EVAR, one as an emergency. In these two

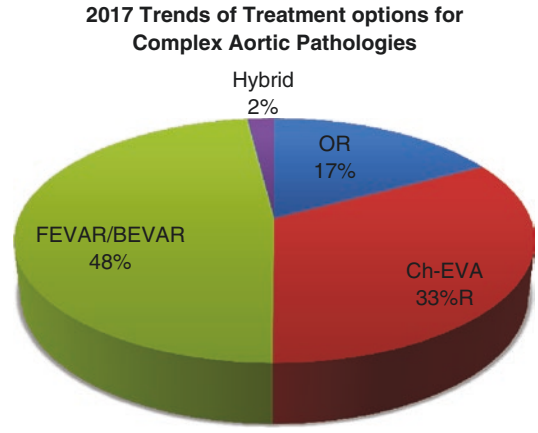

Fig. 28.2 Distribution of complex aortic procedure in 2017 at San Filippo Neri Hospital in Rome

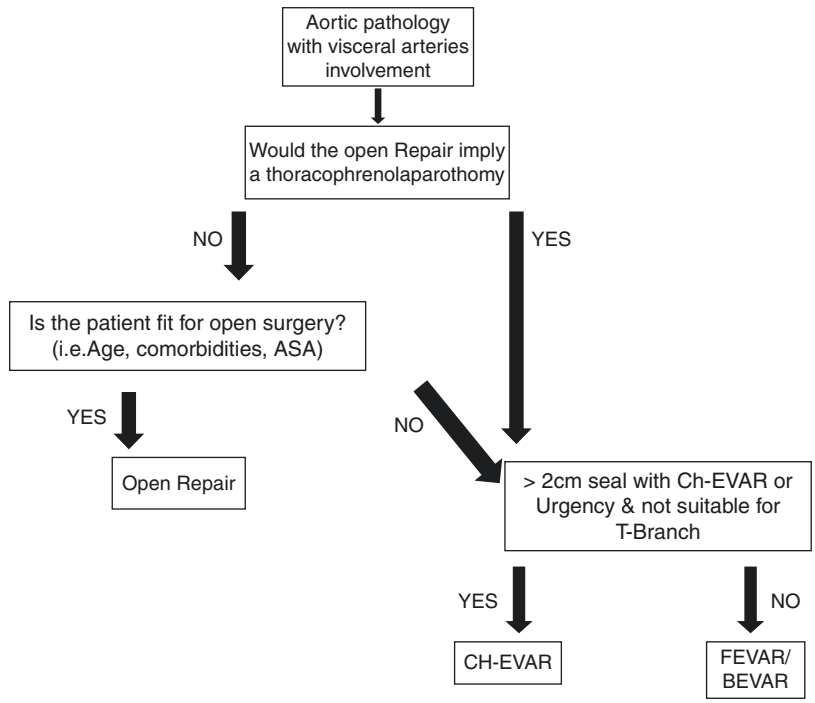

Fig. 28.1 Treatment algorithm for complex aortic aneurysms at our center

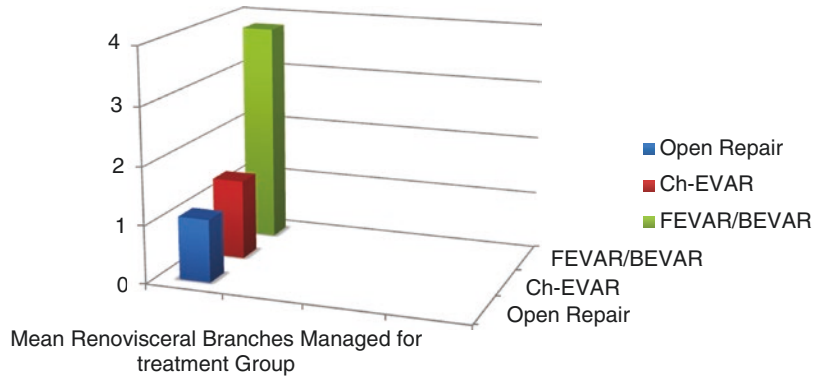

Fig. 28.3 Mean number of reno-visceral arteries managed in every treatment group. Only one patient was treated in the hybrid group with the debranching of all four reno-visceral branches

Table 28.1 Open repair group demographics

Demographic	*N* (%)
Age	65 (61–75)
Smoke	9/11 (81%)
Hypertension	9/11 (81%)
Dyslipidemia	6/11 (54%)
COPD	4/11 (36%)
Diabetes	3/11 (27%)
ASA III/IV	3/11 (27%)

patients, it was not necessary to surgically manage the reno-visceral branches. They are part of this population as the previously implanted graft was a suprarenal fixation endoprosthesis, so that the repair implied a supraceliac clamping. In both patients, the indication was a type I and II endoleak. The patient was treated as an emergency and presented with an aneurysmal sac rupture after being lost at 5 years follow-up. The index repair was performed in 2010 via a Jotec E-vita endograft, a type II endoleak was clear since the initial follow-up, and after 1 year, a 5 mm aneurysmal sac growth was evident. Unfortunately, the patient never returned for follow-up until presentation at the emergency room with abdominal pain. The CTA showed a rupture with an associated type I and II endoleak. We performed an emergent open conversion with graft explantation and aorto-bysiliac bypass. The patient died 5 days later in the ICU due to cardiopulmonary failure. The patient treated with open conversion in elective setting also had a mixed type I and II endoleak with associated aneurysmal sac growth. It had been treated with Endurant (Medtronic Vascular, Santa Rosa, California) 3 years earlier and had an overall aneurysmal sac growth of 1.5 cm. An open conversion was performed electively through a translumbar approach, with supraceliac clamping. The patient was discharged on the sixth postoperative day in a good condition. For the remaining nine patients, the open procedure was primary repair. In eight patients, the aneurysm had no infrarenal neck for EVAR, and they were in good clinical condition, so an open repair was planned with the reimplantation of one (seven) or both (one) renal arteries. One last patient had a horseshoe-shaped kidney, and so we provided the open repair of his aneurysm with reimplantation of three renal arteries (Fig. 28.4). In this cohort of patients, 30-day mortality was 0.9% (one emergent conversion), and the overall mortality was 1.8% (one death at 40 days in the ICU due to pulmonary complications). It is not possible to compare these results with the endo-cohort as the visceral artery involvement of this cohort of patients was limited in the large majority of cases to one renal artery and the patients were always in good clinical conditions.

28.5 Endovascular Procedures

28.5.1 Chimney Repair

This technique is preferred to fenestrated/branched technology, if based on the preoperative planning; a single/double chimney is enough to exclude the aneurysm with 2 cm of new sealing neck. Twenty-one patients have been treated

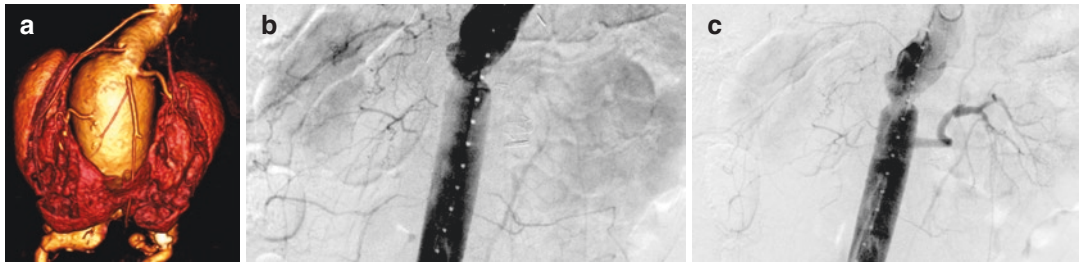

Fig. 28.4 (**a**) CTA of AAA associated with a horseshoe kidney; (**b/c**) control angiograms showing the good perfusion of the kidney after OR and renal artery reimplantation

over the last year with chimney technology (single, double, or triple), as they were all considered unfit for open surgery. Seventeen patients were treated in an elective setting, four in emergency. Out of the general population, two were treated with Nellix (Endologix, Irvine, California), plus Advanta V12 (Atrium Europe B.V., Mijdrecht, The Netherlands) as parallel graft (one single chimney on a right renal, one triple chimney on both renals and the superior mesenteric artery). Thirty-eight percent were treated by Endurant IIs plus Advanta as parallel graft (75% single chimney, 25% double, of which one case was a patient with a previous nephrectomy and in which the double chimney included a left renal and a superior mesenteric). Forty-three percent were treated by Gore C3 excluder and Viabahn (W. L. Gore & Associates, Inc., Flagstaff, Arizona) (67% single chimney, 33% double). The remaining 9.5% were treated by Cook Alpha Abdominal (Cook Medical Inc., Bloomington, Indiana) (one single chimney with Advanta and one double chimney with bare-metal stents).

We planned one case of chimney repair with bare-metal stent due to short infrarenal aortic segment, for which it was necessary to partially cover the renal ostia, which were coplanar, so since there were no sealing concerns in the infrarenal neck, chimney was necessary only to safeguard renal flow.

We prefer this technique to FEVAR technology when the repair includes one or two visceral arteries to reduce the extent of aortic repair and for compromised patients, with short life expectancy, and of course in emergency settings.

The main concern of this technique is still type I endoleak from gutters [4]. In order to reduce such complications, adequate planning is required, and the size choice of the parallel graft and the main graft is of utmost importance. We recently described our sizing method for arch chimney, which is basically the same as for an abdominal chimney. This method is described with the name of Over-SIRIX and consists in calculating the correct graft diameter with a disease-specific oversizing, based on the simulation of presumed circumferential graft length adjusted to fill the gutters between the main and the parallel grafts [5]. With the aim of reducing chimney numbers, a good adjunct in emergency situations is represented by homemade fenestrations (Fig. 28.5).

A crucial point in reducing gutters is the choice of the materials, as various reports suggest that similar materials perform better. For this reason, chimney with Gore C3 is generally made with Gore Viabahn as a parallel graft and reinforced if needed [6]. As far as Ch-EVAR with Endurant is concerned, the most often used parallel graft is the Advanta V12 stents based on the data reported by the PERICLES and PROTAGORAS registry [7, 8]: IFUs of the Endurant for the parallel graft technique do not force the use of this stent but advise the use of any balloon-expandable stent. It is now agreed that this technique should be standardized, just like the fenestrated and branched repairs. This is the reason the planning should be accurate and take consideration remove and angulate the side vessels, the need for reinforcement, and visceral landing zone, which should, when possible, be in a straight segment of the artery and not in unfavorable angulations.

It is noteworthy that favorable removal for the chimney configuration is typically a caudally

Fig. 28.5 (**a**) Homemade fenestrations; (**b**) triple chimney (SMA, CT, LRA) homemade fenestration on RRA

oriented vessel. When a cranial orientation is present, however, fenestrations or alternative parallel graft configurations should be considered.

Stroke and TIA are complications to consider in this technique and to always prevent with an accurate study of the arch since in well-experienced centers this complication still ranges around 1.9% with risk factors being bilateral upper extremity access, aneurysm rupture, and prolonged operation time [9].

Using this technique, we registered a type I endoleak rate of 4.7% in the last year, which is considered acceptable. Four cases (19%) of this subgroup of patients presented for correction of a type I endoleak. This is our technique of choice for type I endoleak with aneurysmal growth and resistance to endotherapy. Thirty-day mortality rate was 0%, with no major complications. The strength of Ch-EVAR over FEVAR for type I endoleak is the availability of the material, so that an emergency repair can easily be performed. The chimney method is easier than FEVAR in type I endoleak because no difficulties in orienting the markers which can be superimposed to the previous graft ones exist for Ch-EVAR. In FEVAR, on the other hand, this can represent a major problem. The technique is a valid alternative in cases of aortic pathology involving less than three visceral vessels and gaining a total of 2 cm sealing neck, with a new neck of at least 1 cm. This limitation comes from the results of PERICLES registry in which good early and late results, even in terms of effective aneurysmal sac exclusion, are reported for single and double chimney, because of the limited number of gutters. This technique should be indicated for pararenal rather than for thoracoabdominal aneurysm with the exception of the very few cases unfit for open surgery and/or for off-the-shelf thoracoabdominal grafts and those that cannot wait for a custom repair. Of note, very few reports have been published regarding thoracoabdominal repair with Ch-EVAR, mostly in emergency, and high rates of type I endoleak are reported [10].

28.5.2 FEVAR and BEVAR

Thirty-one patients were treated by FEVAR/BEVAR repair. This, in our opinion, should be the preferred option for aneurysm or dissections with the involvement of more than two vessels, as it is strongly standardized and has good results in the follow-up. Of our 31 patients, 7 were treated

with an off-the-shelf graft, the t-Branch from Cook, and 24 by custom fenestrated and branch devices with Cook, Anaconda (Vascutek, Renfrewshire, Scotland), and Jotec (GmbH, Hechingen, Germany) endografts. In cases of visceral artery involvement, with more than two vessels, we always check for feasibility of an off-the-shelf complex solution. t-Branch from Cook is indicated for aneurysms with important proximal extension, and one of the most frequent reasons for unsuitability is generally the diameter of the aorta which should at least be 30 mm at the visceral segment [11]. In cases of unsuitability, we then look for a custom solution. Our preference is to actively participate in the planning of our custom graft and, when possible, plan our own graft. One concern about this technique is the risk of spinal cord ischemia related to extensive aortic coverage. Whenever possible, even in post-dissected aneurysm, we try to obtain a graft with at least one branch. The reason for this is that in cases of extensive aortic coverage, more than 4 cm above the celiac trunk, the repair is always performed in two stages, supported by literature findings [12]: in the first one, the main graft is deployed every branch, and fenestration is completed but one branch, usually the celiac trunk, which is connected to the main graft only with a bare-metal stent; in the second step, under local anesthesia and from a brachial access, this branch is re-catheterized and a balloon is kept inflated for 20 min to simulate aneurysmal sac exclusion [13]. If there are no neurological alterations, the repair is completed with the reliance of a bare stent (Fig. 28.6). So far, in the subgroup of patients treated with this approach, we had one transient paraparesis noted at 4/5 but it was transient and fully recovered so that we have a rate of permanent deficit of 0%.

Beside the total aortic coverage, which should be minimized to avoid paraplegia, the planning of the custom graft should always take into consideration the removal of visceral branches to decide whether a fenestration or a branch is more convenient. The general rule is that upward vessels are better managed with fenestrations and downward vessels are ideal for branches. It is also very important to check for early branches: a visceral neck of at least 10 mm should always exist so that if there is a bifurcation before 10 mm, the larger branch should always be considered, and the smaller should be sacrificed. In cases of similar dimensions, a selective angiography is performed in order to visualize the amount of parenchyma supplied by every branch. In our cohort of patients, 29 (93%) were treated in an elective setting and 2 (7%) in emergency for symptomatic aneurysm or rupture. An iliac conduit was necessary in three cases, always planned, for both external iliac arteries <than 8.1 mm. Fourteen were type III TAAA (45%), seven (22.5%) type II, five type I, and five type II (32.5%) according to the Crawford classification. The total mean aortic coverage was 402 mm (210–570 mm), while the mean coverage above the celiac trunk was 285 mm (110–406 mm). We routinely use a preventive CSF drainage for supraceliac coverage of more than 4 cm.

In this subgroup of patients, 26 repairs included all four reno-visceral branches (1 case

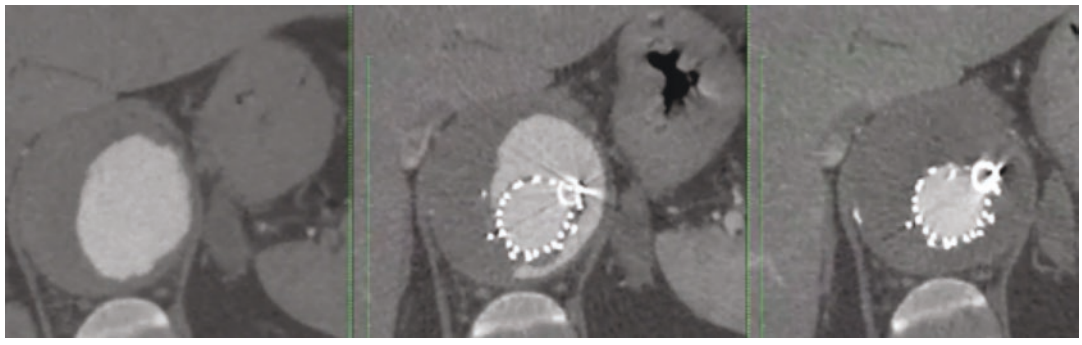

Fig. 28.6 Temporary perfusion of the aneurysmal sac in a "t-Branch" type III thoracoabdominal patient

of proximal evolution after infrarenal open repair and 1 of proximal evolution after EVAR), 4 included three (2 cases of previous nephrectomy, 2 cases of occluded celiac trunk), 1 case had only 2 fenestrations (SMA and CT) because the patient was already in dialysis, and so we did not manage the renal arteries for a total of 118 visceral arteries to target. Four repairs were for a post-dissective aneurysm.

In the last 31 TAAAs of our experience, we used BeGraft (Bentley GmbH, Hechingen, Germany) balloon-expandable stents, mainly because of their low profile. We usually reinforce them with bare-metal stent only if needed (i.e., landing in angulated segment with post-stenting kinking).

In this series, we registered a technical success of 96.7% with a successful revascularization rate of target vessels of 98.3%: in one case of type B aortic dissection, despite the correct alignment of the markers, it was not possible to catheterize CT and SMA, and they were rescued by periscope (Fig. 28.7). This accounts for an assisted patency rate of 100%. The SCI rate was 9.6%: one case of fully recovered paraparesis after a staged procedure and two regressive paraparesis in "four fens" one-stage repair, of which one had a partial recovery. The mean procedural length was 160 min (140–300 min), and the mean hospital stay was 8.9 days (4–10). The second stages were performed at a mean time of 7.5 weeks after the first stage (6–10 weeks) and were always performed under local anesthesia. We had a morbidity rate of 9.6% (three supracited cases of SCI), and minor complication rate was 6.4% (with two cases of brachial hematoma). In this cohort of patients, the type I endoleak rate is 0%, to note that we re-intervened on a t-Branch case with an endoleak from the CT stent which we misdiagnosed as a type III endoleak, but that was actually due to a fracture of the BeGraft which we treated with relining with a covered stent.

Fig. 28.7 Periscope for rescue of a CT and SMA in a FEVAR procedure for dissection

28.6 Hybrid Procedures

Hybrid repair can be a valid alternative and is more often considered since the VORTEC technique was first described [14]. In the examined amount of time, we only used this technique once. In our opinion, this has to be considered a major intervention because it implies an extensive dissection of the aorta and selection of the population is of utmost importance. There are no well-defined criteria for such a technique, but in our opinion, it should be reserved to the very few patients in good conditions but cannot undergo a thoracotomy.

28.7 Final Considerations

The approach to such pathologies should be tailored to the patient: knowing that the open repair is still the gold standard, patients unfit for open surgery may be sent to the endovascular repair which has demonstrated an early advantage over the open repair. The choice between chimney and FEVAR/BEVAR technology should always be based on the amount of the aorta to cover and on the life expectancy of the patient. Confidence with the technique and accurate preoperative planning are of paramount importance to achieve the technical success.

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