Advanced ENDOVASCULAR PROCEDURES *for* COMPLEX AORTIC DISEASES

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10 PARA AND JUXTARENAL ANEURYSMS

RESULTS FOR STANDARD DEVICES

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Open surgery with suprarenal crossclamping is a well-established treatment and represents the treatment of choice in suitable patients with juxtarenal (JAAA) and pararenal (PAAA) Aortic Aneurisms. However, the overall 30-day mortality rate in the open series has been reported in a systematic review of the literature [1-3] as 3.6%. Furthermore, surgical procedures are associated with higher early and late complications such as myocardial infarction, cardiopulmonary complications, impaired renal function, and abdominal wall hernias or small bowel obstruction.[4]

In patients with JAAAs or PAAAs and severe comorbidities, unfit for open repair, endovascular treatment may offer an alternative, compensating the absence of an adequate infrarenal proximal landing zone that could compromise the sealing of the endograft, extending the seal to the suprarenal aorta.

Fenestrated endografts (fEVAR) follow this concept and have been considered the standard endovascular solution in JAAAs or PAAAs. The fEVAR customized devices using covered stents through patient-specific o pre-packed main endograft fenestrations to the visceral arteries is a field which many manufacturers are venturig, even if Cook has been on the market and has delivered the best results for a long time.

Fenestrated devices have, nevertheless, some limits when it comes to emergent treatment, angulated anatomies and difficult iliac accesses.

To improve the feasibility of endovascular repair in such anatomies, several techniques have been introduced to optimize the proximal fixation and sealing, such as the chimney graft (chEVAR) technique.

Chimney techniques involving the combination of covered stents to the visceral branches parallel to and outside an infrarenal endograft have been widely used; the results with such techniques are very interesting and promising but the difference between the numerous reports on selection of patients, techniques and materials vary so much from one another that it is difficult to draw firm conclusions. A standardized approach is needed to define a role for this technique that, with the right combination of materials and steps, seems to deliver good results. At the time of the writing, no stent graft is currently indicated for chEVAR, relegating this technique to a 'bail-out' approach, even if companies like Medtronic and Endologix are exploring the usage of this technique as primary indication for their respective Endurant and Nellix grafts.

The goal of extending an endovascular option for aneurysms with short or no infrarenal necks or visceral artery involvement, or both, has encouraged the development of more standardized techniques to preserve visceral flow, taking advantage of a seal zone in the more proximal, usually healthier aorta below the superior mesenteric artery (SMA).[5]

Both chEVAR and fEVAR require advanced technical skills and adequate radiological equipments thus restricting a wide application [6] and show issues when it comes to branch durability and renal function conservation.[7, 8]

Given this, the use of standard devices with adjunctive usage of ancillary products to increase fixation and sealing has recently been suggested after devices that are able to mimic the surgical suture have been introduced in the market. The last adjunct to make standard devices effective in the endovascular treatment of JAAAs not suitable for open repair is now provided by Medtronic with an endovascular fixation system to improve secure and safer anchorage of the proximal neck of the endografts: the Heli-FX Endoanchor System. This system provides transmural fixation of the endograft to the aortic wall through a motorized catheter provided for the purpose.[9, 10] Initially indicated in the treatment of type 1 endoleak and endograft migration, this device could also become a very valid support in the use of Endurant endograft in the treatment of JAAAs to extend the indication of the device. An indication expansion is currently under evaluation pending a clinical validation from the ongoing

ANCHOR registry. The Heli-FX Aortic Securement System can be used with the majority of endografts available on the market, not only Endurant, opening the way to the future evolutions.

When the situation is not allowing a fEVAR, chEVAR or a standard treatment with adjunctive products, the usage of a stantard stent graft alone is reported.

Technical improvements in standard EVAR devices and mostly the introduction of new devices to treat very challenging anatomies above all angulated, short and very short necks have prompted the most experienced operators to hazard use of some standard devices to the limit and often beyond the limits of the IFU with short and midterm interesting results. Slowly, particular expertise operators have begun to treat JAAAs or PAAAs with standard devices as well.

However, the main concern remains the insufficient and inadequate neck tightness of the endoprosthesis. Whereas the use of ancillary techniques to deal with unfavorable or hostile proximal seal zones (*e.g.*, short, irregular, angulated, thrombus-laden) has had reasonable early success, a higher risk of adverse outcomes (*e.g.*, type IA or type III endoleak, migration, rupture) has been reported in the midterm and longer term.

Comparison between EVAR option and traditional open surgery for the treatment of JAAAs and PAAAs in the short term reports an advantage of endovascular treatment in terms of morbidity and mortality for high risk patients; endovascular treatment seems a safer alternative in the short-term management of JAAA and PAAA.[11] Nevertheless, in the long-term, open repair remains the gold standard when comparing the two techniques in terms of complications (endoleak, migration, etc.) as opposed to the classic endoprosthesis implantation in hostile anatomies.

Actually some devices, that have fairly recently been introduced on the market for EVAR because of their features, have been more implanted in the treatment of JAAA and PAAA: *i.e.* Nellix and Ovation (Endologix, Irvine, CA, USA); among the most frequently used devices in hostile necks we find Anaconda (Vascutek-Terumo, Inchinnan, Scotland, UK) and Endurant (Medtronic Inc., Santa Rosa, CA, USA).

The Nellix endoprosthesis (Endologix, Irvine, CA, USA) has introduced a new paradigm of aneurysms' exclusion: EndoVascular Aneurysm Sealing (EVAS). The Nellix EVAS is an innovative endoluminal system, designed to treat more aorto-iliac anatomies than the currently approved endovascular stent devices. The device consists of dual, balloon expandable ePTFE covered CoCr stents, each surrounded by an endobag, which is filled with an *in situ* curing polymer. Each stent supports the blood-flow through the aneurism sac to the iliac arteries. The polymer-containing endobags surround the flow lumen and fill the aneurism sac, thus blocking retrograde flow from side branches, eliminating the space for potential blood flow from above and from below (endoleak) and at the same time anchoring the device within the aneurism sac to provide stability, without the need for proximal and distal fixation. This sac-anchoring endoprosthesis can be used to treat patients with adverse aortic neck and iliac anatomy as well as patients with standard neck and iliac anatomy.[12] The aim of the Nellix device is to reduce the rate of all type of endoleaks and to avoid device migration, lowering morbidity for endoleak and further procedures. Because of the strong support of the endobag, the usage of the Nellix device in JAAA and PAAA positioning the two covered stents immediately below the origin of the renal arteries may offer advantages in the short term. The literature, with the EVAS Registry, reports the results of treatments with Nellix in a cohort study consisting of 38 patients, with aneurysms JAAA and/or PAAA showing the preliminary results at one year: low endoleak and reintervention rates in complex patient population; excellent one year aneurysm related and overall survival outcomes.[13] Despite this, the usage of this device in challenging patient population should still be considered experimental given some previously unreported failures mode recently presented (type I EL and migrations) that do not have an easy resolution with this kind of device.

Also from Endologix (Irvine, CA, USA) but born from TriVascular (Santa Rosa, CA, USA), the Ovation endograft has also been used in the JAAS and PAAs. The basic concept of Ovation is a classic tree modular endograft for EVAR but designed to overcome the limitations of similar grafts by accommodating a broader range of aortoiliac anatomy; with a low-profile 14 Fr outer diameter (OD) delivery system with the aortic body delivered by a flexible hydrophilic-coated catheter, it is the smallest profile of any currently commercially available stent graft at the moment. The proximal aortic neck seal mechanism is designed to conform to and accommodate the aortic wall. The Ovation technology is not based on a chronic expanding force on the aortic wall but on a new sealing technology, moving the fixation in a more proximal different site, far from the sealing zone. The aortic main body is composed by a low-permeability polytetrafluoroethylene (PTFE) graft and a suprarenal nitinol stent with integrated anchors; the fixation is allowed by a long nitinol stent (35 mm) strongly fixed with hooks to the healthier aorta above the *ostium* of superior mesenteric artery and celiac trunk to achieve active fixation.[14] The aortic body contains a network of inflatable channels and sealing rings that are filled during deployment with a low-viscosity, radiopaque fill polymer to create a conformable seal *in situ* to the patient's aortic wall. In such manner the sealing is ensured independently by a non expansive circumferential apposition of the polymer-filled rings conformable to aortic wall, avoiding chronic outward force at the infrarenal level. This sealing mechanism is quite different from the common self-expanding stent graft, providing uniform non expansive circumferential apposition of the polymer filled ring to the aortic wall, isolating the aortic neck from blood pressure too, living the graft

material free to move independent of the stent and preventing aortic neck evolution over time. In conclusion, there are no radial forces on the aortic wall like in the main body of the self-expanding endograft. The Ovation iliac limbs consist of highly flexible nitinol stents encapsulated in low-permeability PTFE packed in low-profile 13 Fr to 14 Fr OD delivery systems. With these design characteristics, during the pivotal trial, the Ovation stent graft was implanted successfully in 100% of patients, and nearly 50% were treated percutaneously, without any access failures, type I or III endoleaks, stent graft migration, explant, or aneurysm rupture. Furthermore, at 1 year, the primary effectiveness end point of the study was achieved in 99% of the patients, with limited MAEs.

As for its characteristics, the Ovation stent graft has the ability to treat a wider range of patients compared with other stent grafts, mostly short proximal necks and JAAAs or PAAAs, in addition to those with narrow access vessels, without sacrificing patient safety or device effectiveness.[15] In a small case series of 14 patients with hostile anatomy (aortic neck length <10 mm) reported in a study of Sirignano *et al.*,[16] it is shown how the results of the Ovation systems, even if limited to a short follow-up, are encouraging for the high technical and procedural success rate in absence of secondary interventions and complications related to implants, but longer-term follow-up is needed to prove such results.

Last generation endoprosthesis, Anaconda (Vascutek-Terumo, Inchinnan, Scotland, UK) is a further possibility to use standard devices for EVAR in the treatment of JAAAs and PAAAs. The Anaconda AAA Stent Graft System is a standard three-piece endovascular graft. The stents of the main body were made of multiple-element nitinol stents internally covered with woven polyester graft material. The top of the endovascular graft has a dual-ring stent design, similar to an Anaconda snake. The proximal ring stent has to be anchored in an infrarenal position by four pairs of nitinol hooks to prevent device migration. The body is unstented, resulting in zero column strength and good adaptability in angulated proximal vascular anatomy. The iliac legs are fully supported with independent nitinol ring stents, which prevent kinking and provide flexibility with fixation in tortuous distal iliac anatomy. The Anaconda AAA Stent Graft System can be fully repositioned by use of the control collar of the delivery system handle. The possibility to rotate the main body leaving the renal arteries in the bottom of the two corners of the 'fishmouth', fixing the stent in suprarenal positions, is the trick to treat JAAAs and PAAAs with this standard device. To be noted, this approach is a deviation from the stent graft manufacturer IFU deployment sequence, requiring the peaks of the proximal sealing ring stent to be below the renals.

Currently, cases of implants in complex anatomies also including the JAAAs and PAAAs are reported in literature, but the results are unclear because of the short number of patients and the short time of follow-up. The use of the Anaconda endovascular graft in AAA with a hostile infrarenal neck and short neck is feasible but could have clinical failures in the first year.[17]

The most used and studied graft when it comes to hostile necks is Medtronic Endurant. Based on more than 20 years of development in the EVAR field, Endurant has introduced features previously not available that dramatically increase the performances of the device in short necks giving a minimum on label indication of 10 mm.

Thanks to the M-shaped sealing stent, the effective peak-to-peak sealing area is down to 5 mm, thus allowing very good tolerance in extreme anatomies. A delivery system based on the Xcelerant micrometric wheel allows a precise deployment and, consequently, the use of all the short neck available.

Currently, real world ENGAGE data shows no difference between short and long necks up to 4 years when it comes to type I endoleak adverse events. To be noted, ENGAGE data include patients with neck down to only 8 mm.[18-20]

The independent trial EAGLE is currently evaluating the device in anatomies down to 5 mm without the usage of adjunct products but results are still pending.

As previously described, the combination of Hel-FX Endoanchor System may further expand the application of this device in JAAAs.[21]

In conclusion, despite the evolution of new technologies and the changes in sealing philosophy, the experiences in the treatment with standard devices of JAAAs and PAAAs without contemporary use of parallel graft are very few thus far, and are limited to patients unfit for open surgery and most of the time in emergency, but always outside IFU. In all the reports the follow-ups are too limited and need further future evaluations, leaving open surgery the current gold standard, when feasible. The evolution of the devices, the experience and the fantasy of skilled operators worldwide will certainly open new safer ways in the next future.

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