

Chapter 8

Stent Grafts for major cervical and truncal vessels: Who, Where and How?

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Endovascular technologies continue to advance, with increasing utilization not only in the treatment of atherosclerotic and aneurysmal disease – but also for trauma. Recent literature suggests that these capabilities, including stent graft utilization, have become an integral part of modern care for patients with vascular injury. We think it is possible to take it further on to the integrated EVTm concept which means that endovascular tools can facilitate open surgery or replace it. In this chapter, we will discuss the basic principles of stent graft utilization for the aorta and its major branches, the brachio-cephalic trunk, carotids, subclavian, visceral and iliac arteries. Some of the information here might be discussed in other chapters and other authors but we think that this might give you some wider view of these developments. We will not discuss specific devices detail, as local traditions are important for product selection and as from the aspect that product development in this area is so fast. The intent of this chapter, rather, is to highlight the basic principles and tips for the successful integration of endovascular stent grafts into the tool kit of EVTm. The principles we shall focus on are for the acute and sub-acute management of vascular injury – and will focus on expedient solutions to emergent problems.



Who? – Vessel and Patient Selection

Essentially every major named vessel in the human body can accommodate a stent graft. The evolution in endovascular applications in the elective setting has provided us with outstanding examples of the techniques that can be employed to this end. When considering the applications of endovascular techniques in trauma management, however, one must consider both whether endovascular approaches are applicable or feasible for the given situation. In other words, just because you CAN use a stent graft, does not mean you SHOULD in every case.



Figure 1.1



Figure 1.2



Figure 1.3

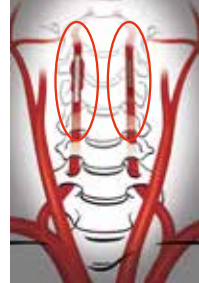


Figure 1.4

Figure 1 1-4: Some possibilities for endo-treatment seen here. TEVAR, vertebral artery balloon and stent graft.

There are several key questions that must be answered to define the applicability of EVT to any specific injury or patient. Can the injury be treated by other endovascular modalities with an equivalent outcome? Will the use of a stent graft occlude critical arterial branches or compromise needed collaterals? Will a stent graft placed at a specific location have a high likelihood of occluding rapidly? Is the risk of embolization high at a specific location? Is there a better, more expedient open operative solution associated with fewer potential complications? If the answer to any of these questions is “Yes”, then strong consideration should be given to the chance that stent graft deployment is not an ideal solution for the issue at hand. **One must also consider the expertise and equipment available to safely apply endovascular methods and the EVT approach.** No provider should intervene using a skillset that they have no experience in. Likewise, one often underestimates the time it might take

to muster the required expertise, imaging and devices necessary to optimally utilize the EVTm approach. In a stable patient, these time limitations can be afforded. In a patient with more emergent needs, however, waiting on tools or expertise to arrive at the bedside may result in adverse outcome or even death.

All these things considered, there remain important challenges in vascular injury that might be more safely, rapidly and elegantly managed using endovascular approaches than open counterparts. While the optimal selection of patients for endovascular treatment remains to be investigated, it is becoming clear that EVTm may contribute to improved trauma outcomes after vascular injury in properly selected patients. Whether endo used alone, or in conjunction with open approaches in a hybrid fashion, will be the optimal solution must depend on the individual situation but having both modalities available for trauma providers will be a strength facing challenging management scenarios.

Remarks:

- » EVTm is a whole concept. It does not mean “endovascular only”
- » You should decide if your patient is a candidate for any endovascular option
- » What are your time limits? Who can help me solve the problem? **What is the best option for THIS patient?** Consider these questions when deciding what to use.

Where and how?

The Thoracic Aorta

The treatment of Blunt Thoracic Aortic Injury (BTAI), in many ways, serves at the ultimate illustration of the potential utility of endovascular stent grafting in the setting of trauma. In the era prior to these capabilities, the repair of BTAI required major open thoracic incisions, often with the employment of cardiac bypass or distal aortic perfusion techniques. Thoracic Endovascular Aortic Repair (TEVAR) began to change the approach to these injuries in earnest, beginning in the first decade of the 21st century, and a wealth of data now supports TEVAR as the standard of care for BTAI in the majority of cases. Who should receive TEVAR after a BTAI? While a variety of grading system approaches have been proposed and employed effectively, the key point is that if the risk of rupture outweighs the risk of intervention then TEVAR should



be performed. In the contemporary era, emergent or urgent TEVAR is most commonly utilized for pseudo-aneurysms and true transections of the thoracic aorta. Patient condition and the severity of the injury dictate the timing of this repair. Current data and experience supports the use of initial blood pressure control to minimize stress on the injured aorta, followed by delayed repair (> 24 hours) for patients not at risk of impending rupture.

The technique of TEVAR has been well described for both trauma and in the setting of treatment for aneurysmal disease or aortic dissection. There are several important concerns related specifically to trauma, however, that deserve mention. First among these is the use of anticoagulation for access and stent graft placement. In particular, the larger diameter sheaths required for TEVAR represent a significant risk for occlusion to the outflow of the leg, especially in a hypovolemic patient! So, if you are using a large sheath in a trauma patient, expect thromboembolic problems! In elective situations, this risk is mitigated with the liberal use of systemic heparinization which cannot be used in a bleeding patient. Among trauma patients with BTAI, however, associated contra-indications to systemic anticoagulation do not only occur – they can be quite common. Traumatic brain injury (TBI) and significant solid organ injury may often be the rule rather than the exception in these patients. This fact should play into the discussion process and planning of team caring for the patient. If the TEVAR must be done emergently in a patient with these contra-indications, then the procedure should be done without anticoagulation and the ischemic risk to the limb accepted. In these instances, it may be wise to do a completion angiography or ultrasound to assess patency of the femoral artery. If thrombosis is suspected a femoral cut-down embolectomy can be completed at the end of the procedure as needed. A percutaneous inserted large-bore introducer normally allows some blood flow while choosing an open femoral access normally requires banding of the artery (around the sheath) to avoid oozing. In that case the peripheral circulation might be totally blocked.

Remark:

- » Take into consideration when doing urgent TEVAR that these big sheaths will occlude the flow in a patient that is hypovolemic! You don't just do TEVAR and go home...

In instances where the BTAI requires repair on a less urgent basis, delay of the procedure until after the risk of secondary hemorrhage from TBI or other trauma related sources has passed is advisable. A delay of as little as 48 hours may significantly decrease the risk of the brief systemic heparinization required for TEVAR, and can facilitate safe BTAI repair with a lower risk of associated thromboembolic events to a limb. Another issue that is commonly encountered in TEVAR for trauma is the need for left subclavian artery (LSCA) coverage. Current experience at large volume trauma centers suggests that this may be required in as much as 40% of trauma patients requiring TEVAR. The literature suggests, however, that in the typical trauma patient LSCA coverage is very well tolerated. Carotid-subclavian bypass, if needed, can be performed in a delayed fashion if symptoms of steal develop. As an aside, the risk of steal syndrome can sometimes be predicted by paying careful attention to pre-operative imaging obtained in the context of the trauma work-up. Careful review of the CTA images obtained can often be utilized to estimate the relative size of the left vertebral artery and the anatomy of the Circle of Willis. Dominance of the left vertebral artery or abnormalities of the Circle of Willis (a more common phenomena than most appreciate) may predict the need for increased vigilance and early carotid-subclavian bypass. Depending on the situation the bypass might be performed as the first step in the operation, prior to TEVAR but obviously, not in urgent surgery...

Tip:

- » In the majority of cases, probably you can do TEVAR and wait with the open bypass. Assess clinically your patient after surgery and see if bypass is needed!

An additional concern regarding coverage of LSCA is the increased risk of paraplegia; it is now accepted that carotid-subclavian bypass performed prior to TEVAR reduces this risk in elective cases. This is mostly relevant in long cover of the aorta (more than 15-20cm probably). However, in emergent cases whenever TEVAR should be performed without prior LSCA patency preservation, if paraplegia develops, it should be managed with cerebrospinal fluid drainage. With the advancement of endovascular technologies, including more common utilization of branched grafts in the thoracic aorta, coverage of the LSCA may shortly become an antiquated concern. Spinal drainage might also be problematic in trauma and hypocoagulative patients due to the risk of



spinal puncture and hematoma.

There are also other novel approaches that can be utilized to provide for early LSCA perfusion. There is an expanding experience with the use of parallel grafts (e.g., chimneys, periscopes) in treatment of complex thoracic aortic disease. Parallel grafts are now widely used in the subclavian and carotid arteries as an adjunct technique in treatment of aneurysm with extension into the aortic arch and has been especially valuable as an endovascular tool in emergent aortic abdominal repair where off-the shelf systems are not available (as fenestrated stent grafts). Such approaches could also be utilized to preserve other branches while covering injured arterial segments in the aorta and a variety of other locations. Off the shelf fenestrated TEVAR grafts are coming into the market and there might be place for them in these settings. They might be also very useful in sub-acute situations where you have time to plan the procedure and use highly experienced colleagues.

The key element to consider in the use of any complex attempt to re-vascularize the LSCA, however, remains the **time** required for procedure completion. For many trauma patients with BTAI, an expedient TEVAR with LSCA coverage affords the opportunity to rapidly transition the focus of care to more pressing associated injuries – thereby potentially improving outcome. It is important to note that more complex approaches to endovascular repair of BTAI are possible. In this sense, it would be wise and we advocate a



Figure 2.1



Figure 2.2

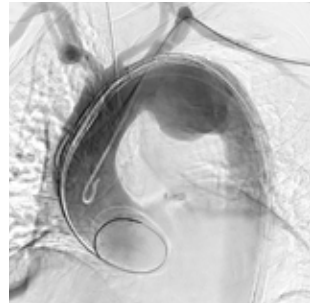


Figure 2.3

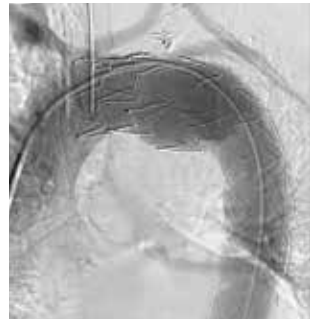


Figure 2.4

Figure 2 1-4: Stent graft deployment stages (non-trauma) from left to right. The stent graft is advanced to the area in the arch you want it to be. Angiography series will show you the takeoff vessels which is the major point here. Be aware that you have to rotate your C-arm so the aortic arch “opens up”. Note angiography access from the brachial-subclavian artery.

multidisciplinary approach for these complexed interventions.

If you decide that your patient needs TEVAR, there are some things to think about. Among them: **Do I have the facilities? Do I have the knowledge/experience? Is this the best option for my patient?**

CTA studies are paramount for the estimation of 3 key factors which are important for successful TEVAR in BTAI: 1) the length of the proximal aortic “landing zone”, 2) the true diameter of the aorta at the proximal and distal landing zones, and 3) the diameter and tortuosity of the access vessels (femoral and iliac arteries).

Practical Tips:

- » Look at different CTA series and try to follow the injury pattern on the vessel- any other vessel injuries? Where is the aorta normal and what is the aorta diameter there?
- » Look at you access ways (Femoral artery, iliac artery etc...): Can they contain a large sheath?
- » Usually the length of the landing zone should be >15mm, while for adequate sealing the diameter of the stent graft should be oversized by 15-20%.
- » In young patients with small diameter aortas the use of the commercially available stent grafts have diameters which are made for older patients and may be complicated by in-folding or collapse of the stent graft due to oversizing, so consider carefully if a stent graft is a good solution in a young patient- The aorta will change size and elasticity in time.
- » Stent grafts can be also used as bridge to surgery but removing them might be a technical problem as well...

If a patient which has a bleeding from the descending thoracic aorta (i.e. knife wound), you might be able use REBOA (see the relevant chapter and contra-indications) to stabilize the hemodynamic situation using one femoral access to insert a stent graft and a contralateral femoral access to insert the occlusion balloon. You might need a third access route to perform an angiography, which can be achieved by a double puncture of the femoral artery, by using a larger introducer that accommodates both the occlusion balloon and the angiography catheter or by using a brachial or axillary access. You can use other advanced methods that are best to learn by training with experts before trying on your own.

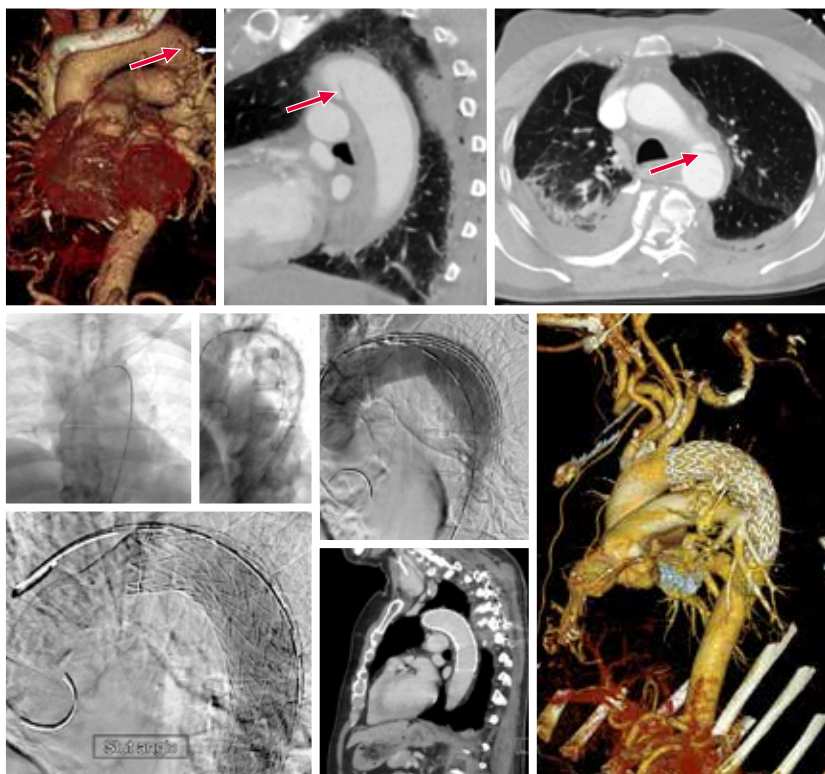


Figure 2 5-15: Patient with traumatic thoracic aorta transection treated by acute TEVAR. Wire and stent graft in place and deployed as well as control CTA. Note that the stent graft follows the great curvature of the aorta when deployed and covers the injury site well.

In the bleeding patient, think about solving the problem now: What is the best way? You can proceed later on to other solutions. Many of the lesions seen are stable, have some damage to the vessel and may not be bleeding at the moment. In these patients, you can do an endovascular repair with advanced technique with help of colleagues specialized in endovascular repair (interventional radiologists or vascular surgeons). But again, don't think only "we can do that". Think what the best option for your patient is instead. Don't go away from open surgery as you might need it! Think instead how an endovascular solution can help the patient now". This is what the EVTm is all about...

Practical tips:

- » If your patient has a bleeding from the descending thoracic aorta you might be able to use REBOA to stabilize the patient before inserting a stent graft from the contralateral side.
- » And no, some of us do not think that REBOA is contraindicated in thorax trauma. Not if you use it correctly as part of the whole EVTm concept and think before using it!
- » You might need a third access for angiography but this can be done by double puncture of the femoral artery, by two catheters in the same introducer or by using a descending angiography catheter by brachial or axillary access.
- » Consider open surgery. Any other organs at risk? What is best for the patient now? Don't avoid surgery just because you have the endo capacities.



Figure 3.1

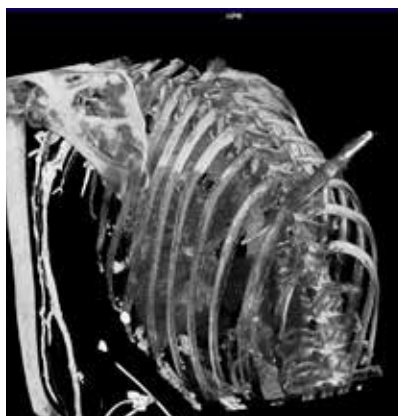


Figure 3.2

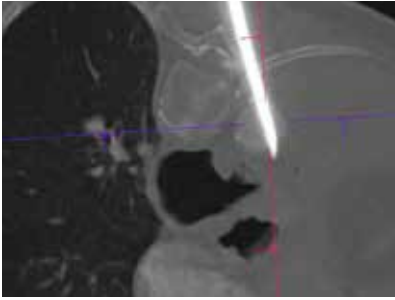


Figure 3.3

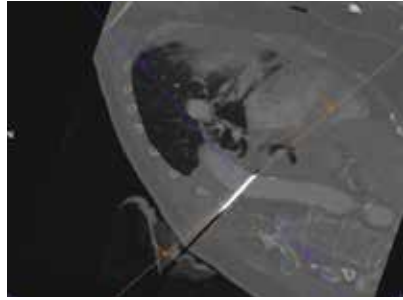


Figure 3.4

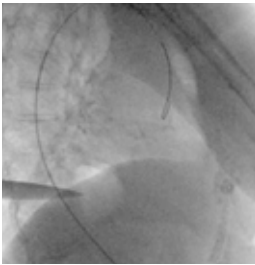


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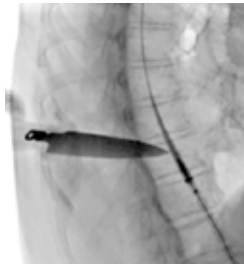


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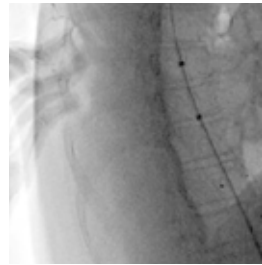


Figure 3.7

Figure 3 1-7: Penetrating knife injury to the back with direct aorta penetration, with successful stent graft deployment. CT reconstructions followed (3.2–3.4) by C-arm photos of the stages of deployment (3.5–3.7) (Courtesy of Manne Andersson, Håkan Åstrand, Werner Puskar, Jönköping hospital, Sweden).

Practical tip:

- » Get a femoral access and upgrade to the sheath needed (usually 18-24Fr) on a stiff wire. Advance a catheter with a slightly angulated tip (e.g., Bernstein) on a soft wire (e.g., Terumo) and change to an angiography catheter with cm marks (measurement catheter) up to the ascending aorta from a contralateral access. Sometimes an angiography catheter can be used directly.
- » Advance your stent graft on a stiff wire (e.g. Lunderquist) and advance beyond the lesion and the landing zone. Then, retrieve it to the proximal landing zone and do angiography to check the location. Don't forget to angulate your C-arm laterally (LAO) at around 40-50 degrees to see the arch (depends on the CT imaging).
- » The ventilator tube normally corresponds well to the origin of the left common carotid artery
- » The deployment depends on the type of stent graft as the mechanism and the way the stent grafts opens are different in every system. So, know your system before using it!
- » Do always a completion angiography to see that you graft is in place without any endo-leak and the side branches are open!



Figure 4: We showed this before but it's here again to demonstrate that stent graft can be used here. Depends on the location, access and clinical judgment!

Axillo-subclavian arteries

The axillo-subclavian arteries represent another ideal location for potential endovascular stent graft utilization. The density of relationship of important anatomical structures in this area represents a challenge in the setting of trauma intervention, particularly when the field is obscured further by hematoma and soft tissue disruption. This is commonly the case with both penetrating injuries and with significant stretch/distraction injuries. The vessels might be deep and vascular control might be challenging, especially in obese and short neck patients. There is an increasing wealth of experience with stent graft utilization in this context. The use of a stent graft at this location has some significant potential benefit in avoiding additional injury to the brachial plexus or lymphatic drainage pathways at the initial intervention.

The brachiocephalic trunk and even the ascending aorta are also regions of vascular injury where the application of stent grafts and EVT approaches may prove useful. Particularly given that repair of arterial injuries in these areas most often requires cardiopulmonary bypass and complex thoracic approaches, endovascular utilization may augment care by providing either a definitive or temporizing damage control solution. A growing body of case reports on the use of endovascular stents for iatrogenic injuries to these areas has demonstrated significant potential in this regard.



Figure 5.1



Figure 5.2

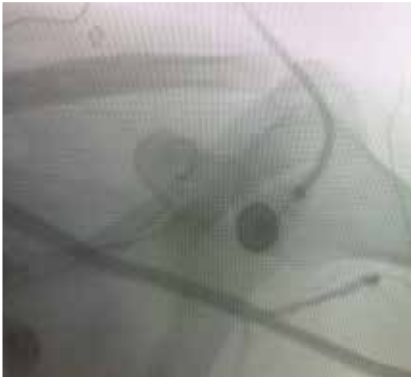


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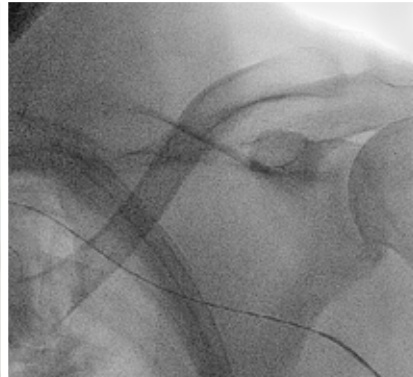


Figure 5.4

Figure 5 1-4: (left to right 1-4) Significant Axillo-subclavian artery disruption secondary to distraction injury. Employment of “Body-Floss” or “through and through” technique with use of brachial and femoral access and snared wire through disruption to obtain wire crossing of lesion. Completion angiogram after repair of traumatic axillo-subclavian arterial injury with endovascular stent graft. Passage of wire into the subclavian artery for possible stent graft placement might be possible in some cases.

Figure 4 is an example of how endo and open (hybrid) technique as part of EVTm, can help you in a challenging great vessel trauma.

Brachial access alone can often facilitate repair of these injuries, but in instances of significant disruption, alternative adjuncts may prove useful. In particular, “rendezvous” or “body floss” approaches using dual access from both the brachial and femoral arteries may prove paramount to success. This

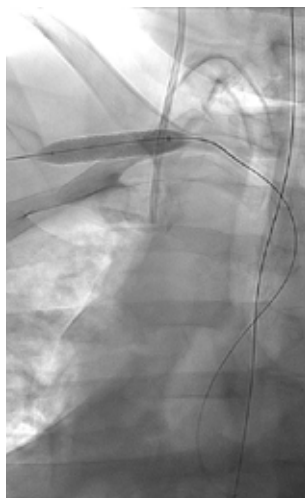


Figure 6.1



Figure 6.2

Figure 6 1-2: Stent graft deployment through a 5Fr sheath in the brachial artery under local anesthetics. Balloon expandable stent graft used in this case.

principle is outlined in greater detail later in this chapter but you can see here some examples. Some of us think that this might be time consuming and not a beginners move. There is also significant risk of damaging the artery during the procedure but it has been done and you should know about it.

Practical tips:

- » Get access both on the brachial/axillary artery and the femoral artery. You can do that while your friends are working in the thorax/abdomen. Leave the upper extremity 40-60 degrees extended on a side arm so you can work on the access.
- » With access gained, you will need to verify you guide wire location by fluoroscopy and will need space and some minutes for that. Communicate with your colleagues about it. Use a 7-9Fr introducer (yes, even in a brachial proximal artery) so you can get a PTA balloon in. You can place the wire over the injured segment (if you passed the injury with a wire), and then do surgery. Endo can help you here in case of major bleedings by taking in a PTA balloon (10-14mm should do well). Using a non-compliant balloon however has disadvantages as sizing is critical. An alternative option is to use elastic balloons if they are available and the size of the required introducer can be accepted. Traditional thrombectomy catheters over-the-wire can be a good option.
- » Again, you have to consider if this is the correct line of treatment for your patient!



Carotid

Stent grafts have also been utilized effectively in the setting of carotid injuries, most commonly for injuries to the proximal or distal segments of the carotid. As with the axillo-subclavian arterial injury locations, these extremes of the carotid artery may represent considerable open exposure challenges in the setting of the severely injured patient. As with the endovascular treatment at other locations, the use of anticoagulation here represents an issue for careful consideration. The inability to utilize systemic anticoagulation in the treatment of the carotid represents significant risk for possible stroke. Distal embolic protection devices commonly utilized in the setting of atherosclerotic disease treatment at this location may be useful in select situations, but their routine use for trauma applications has not been very well established. Probably endo treatment might be of great value in sub-acute cases and patients with former neck surgery or radiation therapy. In general, zone II-III are surgically treated. In some situations, you might need proximal low carotid bleeding control and in these situations, a femoral access and PTA balloon in place might assist you. You might do angiography through this route as well. In general, if you can stop the bleeding by compression, the solution is open surgery. Stent grafts in the carotid is a controversial issue and it would be hard to get a consensus on this issue. Most of us believe that open surgical repair is indicated in most carotid injuries. It is usually safe and you need to evacuate the hematoma as well as inspect other possible injuries. Zone I injuries are difficult to manage and the endo-solutions advantage there is clear.



Figure 7.1



Figure 7.2



Figure 7.3



Figure 7.4



Figure 7.5

Figure 7 1-5: Penetrating injury to the axilla towards the R carotid. Metal body on the Carotid that could be removed by open dissection and retraction with manual compression of the jugular vein and carotid. Wire and Bernstein catheter left in the common carotid artery during the procedure for proximal control if needed and angiography. In this case angiography showed exact localization and open repair performed with wire in place. Note that CT examination was impossible to perform in this case due to position of the injury and abducted arm.

Practical tips:

- » You might consider having a 0.038 or smaller wire in the carotid. The risk of it is minimal and you can use it for temporary control or for stent grafts. The treatment of carotid injury at zone II or III is, though, generally open surgery!
- » Your catheter can give you also an option for completion angiography
- » You opened the carotid and the injury is proximal at zone I? You might be able to use the wire and insert a balloon for temporary control. A PTA 6-8mm short balloon will do, but be careful, you might cause more damage with the balloon!



Abdominal Aorta

Abdominal aortic injuries are, fortunately, very rare. The majority of abdominal aorta direct injury patient with severe bleeding will die on the spot. There is very little experience with stent graft use for trauma at this location, but the utilization here makes sense in appropriately selected patients. The growing familiarity of endovascular providers with endovascular aortic repair (EVAR) for aneurysmal and atherosclerotic disease – even in the setting of aortic rupture – suggests that there is a clear potential role for EVAR in a very select subset of patients. The majority of these patients, after both penetrating and blunt mechanisms, are likely to have associated bowel injury. The use of EVAR may mitigate the subsequent risk of graft infection relative to open intervention. If utilized, the concerns regarding anticoagulation and risk of limb ischemia associated with larger delivery sheath sizes for EVAR are of importance as these patients are coagulopathic but you can read about this issue in the other chapters.

You might be able to use stent graft for isolated lesions or pseudo-aneurysms and always consider other injuries. Other options include a wire and REBOA in place for proximal control. So, while working on the patient, get a good femoral arterial access (see the first chapters in this manual) and work parallel with your other colleagues. As in everything with the EVTM concept – use the mobile hybrid suite concept by putting the patient on a sliding table and have a C-arm ready in the suite. You might need it!

In cases with penetrating injury to the aorta REBOA, you can be prepared by having the balloon in place during open dissection and suture of the aorta. Temporary balloon inflation can be performed if deemed necessary. If the injury in the abdominal aorta and there is no ongoing extravasation (low grade wall injury or pseudo-aneurysm), you might consider doing the repair in day time either by open or endovascular methods, and then use advanced endo methods. There is always a risk for infection in whatever graft you use in the abdomen but EVAR solutions have been used for trauma patients. So, you can use for example a straight abdominal graft for repair, but you always have to consider other injuries (bowels?) and what is the best solution for your patient. The age of the patient, mechanism of injury, previous abdominal surgery and type of aorta injury all play major roles in the decision making here.



Figure 8 1-2: Examples of aorta stent grafts (Courtesy of Cook Medical and Bolton). Consult your colleagues to know what is available in your hospital and what is appropriate to use in your patient. Deciding which graft to use in the Thorax or abdomen is not easy, especially in young patients.

Practical tips:

- » Look at the CT- size of aorta? What to cover?
- » Choose a bigger graft than what is recommended if the patient is in hemodynamic shock and plan it carefully. Ask someone to help you. These are challenging cases and you need all the help you can get. The majority would recommend over-sizing of 15-20% but there is no real evidence yet and this is based on relative small series and personal experience. It also depends highly on the age of the patient and hemodynamic status when measurements are done.

Viscerals

The mesenteric and renal arteries represent another location in which stent, stent graft or embolization technologies have the potential to be utilized. The specific technique of stent graft utilization after trauma does not differ considerably relative to atherosclerotic or aneurysmal disease indications. It is important to consider however, that these procedures may prove complex and take substantial time to complete in trauma patients. In a patient who is hypovolemic due to traumatic hemorrhage, the threshold for contrast complications may also be lowered. The specific impact of this lower threshold on the kidneys is difficult to quantify in what can be a heterogeneous group, but it must be acknowledged. Given these risks and the complexity of the required intervention there are situations where insertion of stents or stent grafts will be a good alternative as dissected arteries or when a pseudo-aneurysm is present.



Practical tips:

- » Remember that angiography might take time and you must consider that in applying these techniques. Cannulation of a visceral artery can be challenging but might be very useful if you suspect dissection. It can be used also to cover pseudo aneurysm or even bleedings (renal arteries, celiac and even SMA).
- » Crucial to have a CTA before so you will know where the injury is and what is the segment/size. You will need to work with a sheath catheter (long introducers) and might want to pick a 10% or bigger stent graft. Might be challenging- ask someone who has done that before to help you!

Iliac vessels

The iliac vessels represent a location where, as with axillo-subclavian injuries, endovascular stent graft utilization has been well described. In a similar fashion to the axillo-subclavian location, anatomic challenges and difficult surgical exposures are legitimate concerns. Anticoagulation use is also a specific issue here, as with all other locations. A key difference between the iliac and the thoracic inlet is the higher association with bowel injury and concerns for subsequent contamination of open repair attempts. In this fashion, the iliac artery may represent an ideal location for stent graft use after trauma in properly selected patients. In cases of significant disruption, the “rendezvous” or “body floss” technique (described below) can also be helpful.

In general, open surgery is a great solution, but imagine an obese patient with multiple abdominal surgeries in the past (adhesions). You can get a femoral access and even work while manual compression or REBOA from a contralateral access. Getting a wire through the vessel will give you the ability to deploy a stent graft. Some of us did this under vision with a finger on the injured iliac vessel. Remember to get a stent graft that is 10-15% bigger than the estimated iliac diameter which is around 12mm in men and 10mm in women but individual variations are large. The length depends on the lesion. You can also cover the internal iliac artery in these situations if you don't have a choice. If the internal iliac artery is involved in the injury, back-bleeding from that segment can cause problems even if the origin is covered. This might require embolization of the internal iliac artery before covering it. Remember to cover the artery/graft with peritoneal fat if you did a hybrid procedure (think about possible infection). This can be also done as a bridge to open surgery. This

procedure takes some minutes in experienced hands in acute situations if you have the vascular access and managed to pass the wire. This is not an elective case and the risk of contamination and infection are usually high. Depends of course on the scenario and injury.

Practical tips:

- » Know your sizes: The iliac size in a man would be around 12mm and 10-20% smaller in a woman (but individual variations are large). In young people they are straight but angulated in older people.
- » Preserve the internal iliac if you can. In emergency situations, cover it!

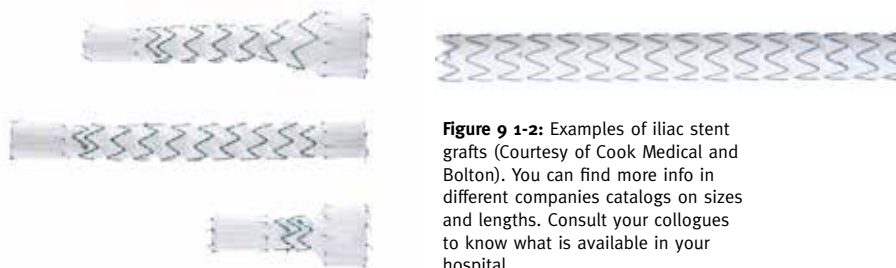


Figure 9 1-2: Examples of iliac stent grafts (Courtesy of Cook Medical and Bolton). You can find more info in different companies catalogs on sizes and lengths. Consult your colleagues to know what is available in your hospital.

How – some General Principles

Access planning

The general principles of access are outlined very effectively elsewhere in this text. Specific to trauma situations, specific consideration should be given to the use of large delivery sheaths and the associated risk of distal thromboembolic complications when anticoagulation is contra-indicated. Particularly in young or small trauma patients with large vessel injury, the size of delivery sheath required to deliver the required balloons or stent-grafts for endovascular approaches may be near or totally occlusive to the distal limb in which access is achieved. One approach that can be utilized to mitigate this risk is to obtain distal antegrade access through which perfusion can be maintained. This can be done through a variety of means, including connecting tubing from the larger sheath to a smaller distal antegrade sheath, or even through an extracorporeal pump or



circuit. This may though be time consuming. Consideration for such alternatives should be discussed whenever it is anticipated that total vessel occlusion with large working sheaths will be required.

Access is often the most challenging part of EVT/MT approaches, for a variety of reasons. The greatest advice that can be given to providers who are considering EVT/MT utilization for a patient is to obtain arterial access EARLY. Even if this access is obtained with a small diameter sheath initially, it can be rapidly upsized to facilitate either balloon occlusion of hemorrhage and definitive treatment. The most common mistake in the severely injured patient is to consider arterial access too late. It's much easier to get femoral access in a stable patient. Look at the “how to get a vascular access” chapter again!

Another general tip:

- » Always consider when intending to use a large vessel stent graft – what is my bailout option? Is it endovascular? Is it open? Does it require help from other specialties (for example – cardiopulmonary arrest via cardiac surgeon). Who can help me and, again, what is best for THIS patient?

“Rendezvous” / “Body Floss” / Through and through technique

The initial challenge of endovascular treatment at a variety of locations is the same– wire passage. The basic tenet of – “If you can cross it, you can boss it” predominates. In other words, if you can get a wire across the injury site, you



Figure 10.1

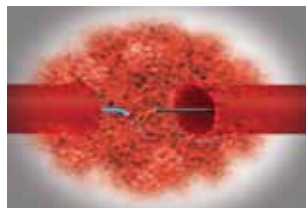


Figure 10.2

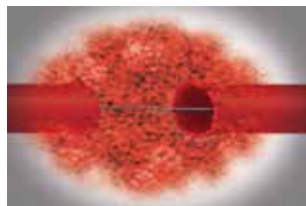


Figure 10.3

Figure 10 1-3: “through and through wire” or “Body Floss” technique.

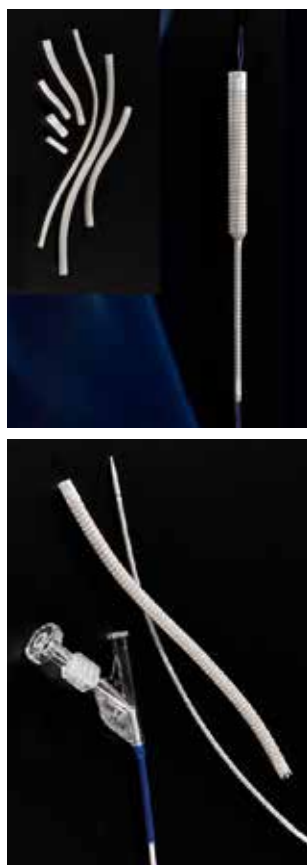


Figure 11 1-2: Viabahn stent graft (or other products) might be useful in these type of injuries. Courtesy of W.L. Gore.

can control it and treat it. You might still need to open and evacuate a hematoma, or do open reconstruction, but it's another tool that might be helpful. This is not infrequently a challenge in the setting of significant vessel disruption. When antegrade or retrograde approaches alone fail to cross the lesion, the “Rendezvous” or “Body Floss” technique can be particularly useful.

Significant axillo-subclavian disruption serves as a good example of the specific utility of this technique. While lesion crossing at this location can often be accomplished in the emergent setting through brachial access alone, in some instances of complete disruption the thrombosed ends of the vessel may sit in a contained hematoma through which the wire refuses to traverse. In this setting, an alternative approach termed “rendezvous” or “body floss” can be employed. This is accomplished by brachial access and the introduction of the tip of a long hydrophilic wire into the disruption area. Access from the common femoral artery is then utilized to place a snare into the disruption. The wire snared, and the end of the wire brought out through the femoral sheath. At the completion of this maneuver wire is then crossing the injury with the ends of the wire outside the body at the femoral and access brachial access sites – hence the term “body floss”. This wire now provides a stable rail upon which to position and deploy a reparative stent graft.

A similar approach can be utilized for any vascular injury location where antegrade and



retrograde access can be obtained on either side of the injury. The use of “body floss” in this fashion can be particularly useful. To expand upon the basic tenet of endovascular vascular injury management: “If you can cross it, you can boss it – but you might have to floss it”.

Venous applications?

It is important to remember that the principles of stent graft utilization for endovascular trauma management also have the potential to be employed for major venous injuries. Stent graft repair of vena cava injuries has been discussed, but not widely utilized. In select settings, however, stent graft utilization may afford valuable expedient control of significant major venous bleeding. If you have a bleeding from the inferior vena cava or the iliac vein. You can puncture the femoral vein, get a vascular access with a larger sheath (10-12Fr), and advance a wire up. There are today vein stent graft that can be used in the vena cava or in the iliac veins. The problem might be related to slow flow and coagulation that might lead to stent graft occlusion. The experience in trauma patients is limited.

Damage control or definitive?

Controversies regarding the use of endovascular stent grafts do exist. A primary central theme in many of these discussions is uncertainty about the long-term outcomes of stent grafts placed in younger trauma patients. The use of endovascular stent grafts for diseases associated with more advanced age, such as atherosclerosis, has accumulated considerable follow up data. Comparatively less is known, however, about the natural history of these devices over the more lengthy possible lifespan of a 25-year-old trauma patient. Long term data regarding durability corresponding to the expected survival for the young patient group is non-existent nor is it known what effects a relatively more and more undersized stent graft will cause in a patient who is growing. What is the optimal surveillance for a younger patient after placement of these devices for trauma? Should they be on anti-platelet or anticoagulation therapy for life? If so, what regimen? These questions are difficult to answer at this stage in the evolution of endovascular trauma management.

An often-overlooked perspective, however, is that the use of an endovas-

cular stent does not have to be considered a definitive intervention in every case. The potential utility of stent grafts in the emergent setting is apparent, as discussed above. The uncertain long-term risks, however, should necessitate an informed discussion with the patient after they have recovered from their injuries. The potential for long-term antiplatelet or anticoagulation utilization should be outlined. Uncertain long-term patency or device durability over the entire lifespan of a young patient should be discussed. These risks and uncertainties must be weighted with the patient against the risk of conversion to open bypass revision. To balance this, you can look at the experienced gained from EVAR and ruptured abdominal aneurysm (rEVAR) as well as TEVAR and rTEVAR which show very good results as well as long term patency. Obviously, this data is not equivalent to trauma patients, but it is of great interest and should be investigated.

In some instances, there may be other confounding factors that impact this discussion. Take the case of the axillo-subclavian distraction, for instance. In some cases of clinically apparent brachial plexus injury, interval attempt at nerve repair may be undertaken in a delayed fashion after other injury issues have resolved. If the subclavian artery had previously been repaired by stent graft, the delayed neurological surgery intervention represents an opportunity to replace the stent graft with an open bypass using the same exposure. Such an opportunity should be discussed at length with the patient.

While a variety of unique scenarios could be considered in a similar fashion, the “take-home” message is that endovascular stent grafts can be considered as either “damage control” adjuncts or definitive therapy – Depending upon the individual situation. By expanding our thought processes in this fashion we promote the innovative and effective utilization of endovascular trauma management techniques.

Notes on tunnel vision and the endo mindset

One of the greatest early dangers in attempting to employ stent grafting for the treatment of vascular interventions is the onset of “tunnel vision”. Providers should be cautious to avoid excessive focus on making stent graft utilization fit the situation... instead focusing on treating the situation with their full understanding of endovascular capabilities. In this fashion, it is important in any vessel to consider when to change from the thought of stent graft uti-



lization to balloon occlusion or embolization. Particularly in the significantly bleeding patient, struggling with challenging stent graft sizing, positioning and deployment may not make as much sense as simple balloon occlusion or even embolization. These latter two modalities afford expedient control of hemorrhage and give the endo operator a chance to “catch their breath” – not to mention permitting needed resuscitation of the patient. In this reconsideration of the problem in front of them, the provider may find that it makes more sense to convert to open intervention – but now has the opportunity to do so in the setting of controlled bleeding.

It is important to utilize the full range of endovascular considerations in addressing issues in the visceral arteries, or any of those vessel groups in this chapter. While these concepts are addressed elsewhere in greater detail in this text, we cannot emphasize enough the development of an “endo mindset” that is nimble and effective at switching strategies to most effectively and safely address the particular issue at hand. We emphasize here again that EVTm is not endovascular treatment but a tool box that might facilitate you in your struggle to save the patient.

Some words of advice

Great vessels might become huge problems. Endovascular solutions are great tools but should be used carefully. So, don't experiment on the patient. Ask someone that know the area to help you. You will do great cases together and the patient will benefit!

Closing remarks for this chapter

Stent grafts are increasingly being utilized to control and treat vascular injury, particularly at anatomic locations associated with challenging and time consuming exposures by open means. While the long-term outcomes of stent grafts in this setting are uncertain, preliminary experience suggests that there is a potentially significant role for these adjuncts in the trauma setting. The continued evolution of endovascular trauma management promises to expand the tools available for the care of the trauma patient with vascular injuries and a EVTm mindset will help you choose the correct way for THIS patient.