



Chapter 10

Organ by Organ

the possibilities and practical solutions
–some further thoughts, tips and tricks

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Bleeding after trauma comes in many forms. While all bleeding should be taken seriously, all surgeons would agree that there is a difference between annoying blood loss that takes time to control but is tolerated by the patient's physiology and the audible exsanguination that spells immediate doom. As trauma surgeons, however, it is our calling not only to address each and every cause of bleeding correctly, but also to determine how and when to do so. Is there time or need for definitive repair? Or is it wiser in a particular situation to buy some time with temporary damage control maneuvers? **You need to make the call!** Everybody on the team is waiting for your decision.

When managing bleeding sources after trauma, it is important to remember that airway and breathing problems tend to kill more quickly than hemorrhage. Don't forget your ABCs. You must also appreciate that exsanguination is not the only way in which bleeding can kill. Even small amounts of blood in the wrong location – say, the pericardium or the skull – can have catastrophic consequences due to increased pressure on surrounding structures. These sources of hemorrhage, though smaller in volume, often require more emergency treatment. In examples like the skull and pericardium, there are no “EVTM solutions”, so we will not address them here, but they may be highly relevant to the patient you meet and treat using EVTm principles...

It is also important to appreciate that vessel injury can be harmful even when it does not result in active bleeding. A partial occlusion can result in an

embolism in a critical end organ, such as the brain. It might develop into a total occlusion of an end artery supplying a critical organ, such as a kidney. So, interpreting the patient and signs, and making decisions on management, have to be based on a good understanding of the situation and good clinical judgment. You need to use all your expertise and best judgment to optimize the outcome. The organs are different by nature and in terms of importance for survival. Access routes and management options for each organ represent unique challenges and there are different solution options. Let's have a look where you may find yourself next time on call – and consider the **options for each individual organ** that may challenge you. We will try to think “EVTM” here and see what we can come up with.

Pelvis

Pelvic ring and acetabular fractures are caused by blunt trauma. Ring fractures have mainly two possible directions of instability: horizontal (lateral compression and open book) and vertical (completely unstable pelvic ring). Pelvic ring fracture-related bleeding originates from fractured bone surfaces, soft tissues, and sheared veins and arteries. The most important and greatest impact on hemodynamic compromise is caused by posteriorly located major arteries and their branches (the internal iliac and superior gluteal arteries). Such bleeding is more often related to completely unstable pelvic ring fractures.

It is a busy Saturday evening in the hospital and Emergency Services are bringing in a hemodynamically compromised young suicide jumper. Your team intubates the patient and rules out breathing problems. FAST is negative for the abdomen, but clinically you find an unstable pelvic ring. The patient is bleeding and he is very likely bleeding from the pelvis. What do you do?

The first step is to apply pelvic binder and continue with a massive transfusion protocol. If hemodynamics are grossly compromised or the patient has a trend of continuous deterioration, you need something else, and you need it fast. You need proximal control of the bleeding and may start thinking of thoracic aortic clamping before you pack the pelvis. Stop for a moment. Let us challenge the traditional protocol and claim: There is no need for thoracotomy! It is more feasible to occlude the abdominal aorta at Zone 3 rather than to crack the patient's chest. You can cause damage by thoracotomy, not to mention the consequent morbidity. We have met some young people for



whom we could avoid thoracotomy successfully and it was worth it! Think about this young girl or boy in front of you. Thoracotomy might have other consequences further on in her life. It's a thought...

Remark:

- » As you understand, thoracotomy can be the correct treatment and we are not suggesting not to do it if indicated. We want in this manual to promote other tools that can be incorporated as part of the EVTm concept. So do what you are best at to save the patient.

Let's continue. Next, you need femoral arterial access to get in with REBOA, but you realize having the pelvic binder just in the groin area is preventing you from establishing it. **Do not open the binder** yet. Place another binder just below the original one, and open the original one only after the second binder is applied. Now, you have access to the groin area and you are still keeping the pelvis stable. Do the puncture and get the sheath in, either guided by ultrasound or via open exposure if needed. Push the REBOA catheter in and land in Zone 3. At this point, it does not matter which side, right or left, you go in, just go in. A right landing zone can be assured by fluoroscopy or US, but you can also find Zone 3 in a blind manner. Place the catheter on top of the patient's belly so that the balloon is just above the umbilicus, and check the site of the proximal end of the catheter. This will be your starting point. Push the catheter in just to the depth you defined at the first point. Start filling up the balloon slowly while pushing and pulling the catheter in and out with slow 5 cm movements until you feel resistance due to the balloon expanding against the aortic wall. With good resistance but with the catheter still moving, stop filling the balloon, pull the catheter out until it stops, and finalize the filling with two more ml of saline. Your balloon has very likely stopped at the aortic bifurcation due to the diameter difference between the aorta and iliac arteries. You can read the REBOA chapter, and do pREBOA here, as you monitor blood pressure if possible.

Now you have established proximal control of bleeding with REBOA in place. But, that only gave you some ten minutes, and you need something to continue with in terms of controlling the bleeding. The next step depends on the patient's condition and the capabilities of your particular hospital, how trauma care is organized. If the patient is relatively stable and you have an in-

terventional radiologist (or endovascular surgeon) readily available, transport the patient to an angio suite for immediate angioembolization. Even at midnight with a crossly compromised patient, if you have certain endovascular skills and a reliable team, you can “blindly” embolize internal iliac arteries using a mobile C-arm in the OR. Even formal pelvic angiography is not needed for such a procedure. Instead, you only need a basic set of wires, catheters and embolic materials (gelfoam, coils, NBCA, Onyx, plugs, or whatever you think appropriate). This is considered to be a borderline basic/advanced procedure for an experienced trauma surgeon.

Remark:

- » There is also the option of doing CTA, which will give you more information on other injuries (head? spine? etc.). This is highly dependent on where you are and your experience, but most importantly: **What is best for your patient now?** Some of us will always do CTA if possible.

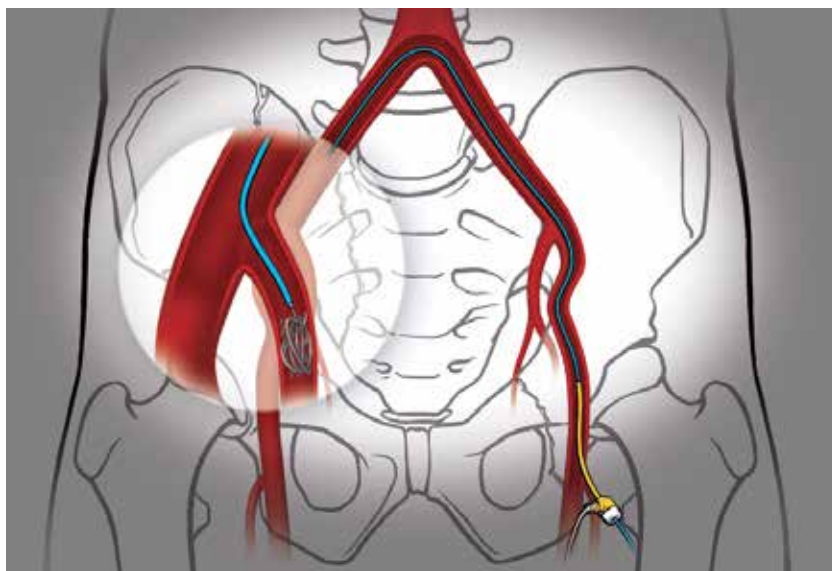


Figure 1: Pelvic embolisation of the internal iliac artery.

If you are not lucky enough to have the IRs available, a C-arm in the OR, you have no basic endovascular set, then you'd better proceed with a simple and very reliable maneuver – **preperitoneal pelvic packing**. You need to pack the pelvis and see if you can start slowly deflating the balloon. Your patient



should be able to tolerate the slow and staged deflation if the packing was done properly. If the patient does not tolerate this, consider **partial occlusion** (pREBOA) with the balloon to restore some circulation in the lower extremities. The patient also needs, as said before, more detailed diagnostics with whole body CT. Those are things you need to get soon after the first lifesaving bleeding-control tricks. Don't fall into an "instant happiness" syndrome even though the blood pressure is stabilizing after the packing, but be aware that there also might be other injuries to deal with; at least you need to rule out hollow organ and intraperitoneal bladder injuries. You need to stay alert.

Leave the packs as they are, continuing with a secondary survey and let the patient stabilize. After 24 hours take the patient back to the angio suite, pull out the swabs one by one and check for arterial bleeding. Embolize the bleeders if seen in angio.

Spleen

In the case of hemodynamic instability and free fluid in the abdominal cavity, take the patient for laparotomy and splenectomy. If the patient is relatively stable, and you managed to get WBCT scanning and do not see any reason for laparotomy other than a bleeding spleen, **consider taking the patient for embolization**, which is the basis for non-operative management. You lose the opportunity of having great fun in taking the spleen out, but embolization is certainly more convenient

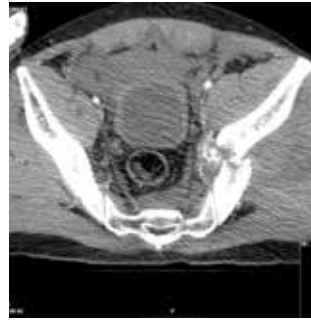


Figure 2.1



Figure 2.2



Figure 2.3

Figure 2 1-3: Extravasation on CTA with pelvic fracture. Angiography with extravasation and coils in place. REBOA was used in this case, while CPR. Patient survived.



Figure 3.1



Figure 3.2



Figure 3.3



Figure 3.4

Figure 3 1-4: A penetrating liver injury. Blood around the liver. In this case, open surgery with packing was enough. dREBOA (deflated REBOA) might be an option for this case as laparotomy might reveal huge bleeding. With hemodynamic instability.

for the patient! Bear in mind how long it takes to get the patient to the angio suite, how quickly the embolization can be done, and if it can be risky. **You are in doubt? Get the patient to the OR.** Splenic artery catheterization is not as simple as embolization. Sometimes, it takes tens of minutes even in experienced hands to pass through the celiac trunk manipulating different catheters and wires. This maneuver is not for beginners.

The spleen gets its blood supply mainly from the splenic artery, but some blood also comes from the gastrosplenic ligament (vasa brevia). Thus, the risk of splenic ischemia and necrosis is relatively low after proximal (non-selective) occlusion of the splenic artery, which is the method of choice for acute bleeding. Only in stable-enough situations with no other major injuries, such



as an intracranial injury, can a longer time be spent on selective segmental embolizations.

Splenic necrosis may occur after proximal embolization. The reason for this might be compromised gastrosplenic ligament vasculature due to primary trauma, leading to ischemia after blocking the inflow from the splenic artery. An ischemic spleen can be taken out after the patient has stabilized, but, fortunately, in most cases, splenic necrosis resolves itself spontaneously. Is there a need for vaccination after proximal embolization of the spleen as there is after splenectomy? Probably not, since if there is no total necrosis of the spleen, there will probably be enough spleen left to avoid this need.

Liver

There are three bleeding circulatory systems in the liver, two of them coming from a proximal direction (the hepatic artery and portal vein), and one filling in both from the liver and in a retrograde manner from the vena cava (hepatic veins). Roughly 75% of the blood entering the liver is venous blood from the portal vein, and the remaining 25% of the supply is arterial blood. In major hepatic bleeding all these three circulatory systems may be compromised. Thus, in most cases of major hemodynamic instability, the patient needs prompt laparotomy and packing of the liver. Temporary clamping of the hepatoduodenal ligament (Pringle's maneuver) stops effectively all the bleeding coming from the anterior direction (portal vein and hepatic artery), buying you time to deal with packing. Remember the 3P rule: Press, Pringle, Pack! On the other hand, when dealing with an unstable patient with positive FAST, you can start with REBOA and then go straightforwardly into the belly. When you struggle with uncontrolled bleeding from the retro-hepatic IVC, aside from Pringle's maneuver, you need to control IVC proximally and distally. To clamp suprarenal IVC, you just mobilize the duodenum using a Kocher maneuver, but clamping of the subdiaphragmatic or intrapericardial part of the IVC is a great challenge. You may use the same compliant balloon, brought from the femoral vein, for IVC temporary occlusion at the level of the hepatic veins. There is one known case of this being done with REBOA and a vena cava balloon (double REBOA) due to massive traumatic liver bleeding. We think this is a possible solution in selected cases.

In case of CTA revealing a blush in the liver, you need to make a decision.



Figure 4.1



Figure 4.2

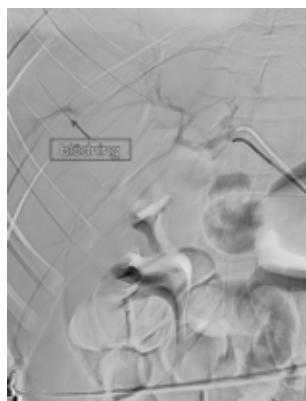


Figure 4.3

Figure 4 1-3: A liver penetrating injury with extravasation and coil embolization (not seen here).

Is there bleeding in some other place in the liver. The contrast blush is very likely to indicate arterial bleeding, but does not tell you much about the portal or hepatic veins.

Remark:

- » As mentioned before, it would be good to have the CT done at both the arterial and venous phase.

Is the arterial bleeding taking place only inside the liver parenchyma (traumatic pseudoaneurysm) or is it also leaking freely into the abdominal cavity? Traumatic pseudoaneurysm does not result in hemodynamic instability but may cause problems later on. In such a case, let the resuscitation proceed, stabilize the patient, and deal with the pseudoaneurysm by selective segmental embolization later on. In the case of arterial bleeding into the abdominal cavity, but no major hemodynamic instability, take the patient for immediate embolization.

Kidney

There are three kind of emergency problems related to kidney trauma; active bleeding, occluded renal artery with ischemic kidney, and leakage of the urea. Ureal leakage is due to deep injury to the kidney going down to the collection system or injury in the pelvic-ureteric junction area. The resulting leakage is not killing the patient in the first instance, but requires careful attention and treatment after the patient is hemodynamically stabilized. Troublesome bleeding in a kidney is



usually arterial and related to severe blunt or penetrating injury. From the endovascular point of view, it is possible to occlude the renal artery to stop the bleeding. That should also stop the ureal leakage, since after renal artery occlusion there should be no more perfusion, and thus no discretion, taking place. However, there is great variation in the numbers, sizes and origins of renal arteries which may make endovascular treatment too challenging and time-consuming when treating the patient in an acute setting, especially in the case of hemodynamic instability.

You have probably already heard too much about REBOA. Proximal balloon occlusion might be useful in the case of a major renal artery injury causing critical instability. It allows you to perform a maneuver of visceral rotation to explore the renal hilum and to assess the injury pattern. Remember that an aortic zone between the celiac trunk and renal arteries is also called a “no-occlusion” zone, so care should be taken to reduce ischemic time as much as possible.

Remark:

- » Here, also consider Zone I or II REBOA but with pREBOA if possible. It might give you some stability to continue with open repair.

There may be problems with elevated blood pressures later on if some, but decreased, perfusion remains in the injured kidney. Endovascular treatment is not the perfect solution for major kidney injury, but you need to consider nephrectomy if bleeding from the kidney is the reason for hemodynamic instability. However, in some cases, if feasible, and if the patient is in angio already, you can stop the kidney bleeding by endovascular means to stabilize the patient, and then finalize treatment with nephrectomy carried out at a second stage.

One more annoying remark:

- » In patients with multiple previous abdominal surgery, these maneuvers can give you time for exposure...

In blunt trauma, you may sometimes see a completely dark kidney on CTA without any contrast perfusion. The reason for this is a blunt stretching injury to the renal artery, leading to thrombus and occlusion. Now, you will



Figure 5: Traumatic kidney injury. CTA is valuable to get information on injuries and endovascular or hybrid possibilities.

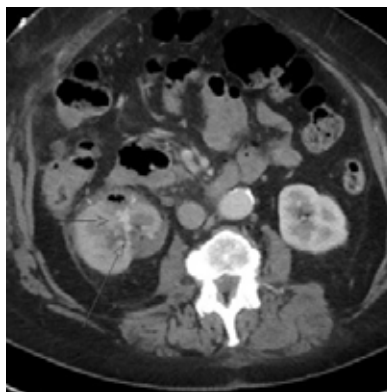


Figure 6.1

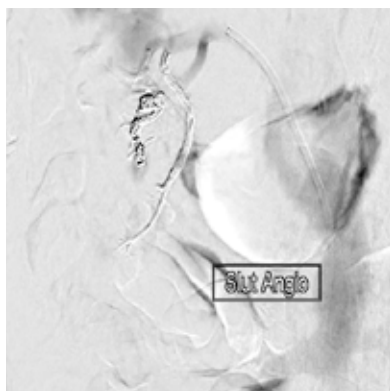


Figure 6.2



Figure 6.3

Figure 6 1-3: Kidney embolization using coils and Onyx.

obviously not have a bleeding problem, but you may consider revascularization of the kidney by stenting the occluded artery open. The kidney tolerates warm ischemia poorly, and the revascularization should take place within the first hour after hospital admission. The result is not guaranteed, and the risk of future blood pressure problems is relevant, but in certain cases it is worth trying. You just need to get the diagnosis and stenting done promptly. So, EVT might have a place for these patients.



Intercostal and lumbar arteries

Intercostal and lumbar-artery bleedings normally set spontaneously. In some cases you may have several arteries bleeding, especially in the presence of imminent coagulopathy, and you may find yourself evaluating the need for operative control of these nasty bleeders. The lumbar arteries are practically non-approachable. In severe bleeding cases, confirmed by prominent contrast blush on CTA and with the need for bleeding control, consider taking the patient into angio for endovascular embolization. Intercostals may bleed even more, since the chest wall and pleura are normally also injured, and there will be no counter-pressure due to free bleeding into the pleural cavity. Intercostal bleedings normally cease spontaneously, but especially in the case of compromised coagulation, you will have continuing blood drainage through the intercostal drain. At this point, you need to react. If you can't correct the coagulation very soon and the bleeding continues, **you have to intervene**. Embolization of such a bleeder can be only done by experienced hands. A few neighbouring intercostal arteries and an ipsilateral internal thoracic artery should be occluded to avoid rebleeding from collaterals. This usually takes time.

You must consider the pros and cons related to the endovascular and operative approaches. Thoracotomy is a large exposure but needs to be carried out if the patient is crushing, or for other reasons (associated lung injuries, cardiac injuries, evacuation of hematoma, lack of vascular access, and so on). In less unstable situation, endovascular embolization can be performed. However, it can take a long time to get into every single bleeding intercostal to occlude, compared with thoracotomy and putting the fingers on the top of bleeders for instant control. Also, both intercostals and lumbals will have some back flow after you have occluded the proximal site, and it may be impossible to control all the bleeding by endovascular means. Anyway, if you already happen to be carrying out endovascular treatment for some other reason, such as a bleeding pelvis, check the lumbals and control the prominent bleeders.

Tip:

- » You might also consider liquid embolization to close the “back door” of the bleeder.

Extremities

Life-threatening bleeding from the extremities can be temporarily controlled immediately by using a tourniquet or manual compression. If bleeding is in the groin or axilla, you probably can control it by very hard pressure just above the inguinal ligament or high and medial up in the axilla. After primary control, you need to have proximal control of the bleeder. In the groin, you may need to expose the iliac fossa extraperitoneally and clamp the external iliac. This approach is relative simple and feasible. You open above the inguinal ligament and dissect down to the vessel, trying to avoid entering the peritoneum. However, it is a completely different and much more demanding ball game in the axilla compared with the groin. In axillary bleedings, surgery and repair require expertise that general surgeons seldom have. But, think of endovascular means. If you can just control the bleeding with local pressure or balloon catheters filled in the wound canal, take the patient for urgent endovascular balloon occlusion of the subclavian artery for proximal control. It may even be possible to deal with the arterial injury completely with a stent graft. At least you will have gained time for relatively time-consuming surgical exposure of the subclavian artery, to which the surgical team can proceed after the balloon occlusion. Another options used clinically in inguinal bleeding is ABO from the contralateral side or even from the SFA as we showed before.

Remark:

» See the other chapters for more tips and tricks on these issues.

Following the idea of EVT/MT damage control, you just need to do something from inside a vessel to restore arterial patency or to prevent further bleeding. You see a sharp “cut off” of the subclavian artery upon CTA. If you have stent grafts of appropriate diameters on a shelf, then you can try to recanalize the zone of injury followed by covered stent (stent graft) implantation. It may not be optimal right now, but the artery is patent and there is less threat to a limb. The type and success rate of such a procedure is operator dependent. Even through-and-through recanalization from femoral to brachial/radial artery can be achieved in difficult cases. Again, not a beginner’s maneuver.

Said simply, there are two main types of extremity arteries: major and minor. In terms of EVT/MT, **minor arteries can be embolized** without any dan-



ger, and the **patency of major arteries has to be restored**. Bleeding branches, such as the deep femoral artery, circumflex arteries, the thoracoacromialis, should be embolized if possible. There is a temptation to stop peripheral bleeding, let's say, from the SFA or popliteal artery, by a simple endograft. Remember that a patient has to take anti-thrombotic medication for a long time after such procedures. You should give weight here to the age of the patient, compliance to treatment, the possibility of follow-up examinations, and so forth. **Might not be optimal for a young patient?**

If you consider endo is not optimal here, just set the balloon for proximal control and go straight to the bleeder. Lateral suture repair is not the worst thing in trauma surgery and works very nicely. Vein interposition grafting is a reliable solution, and should not be avoided if indicated!