

Chapter 6

The hybrid OR and hybrid options for trauma and bleeding patients

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A hybrid operating suite might be the ideal location to treat hemorrhaging patients. It consists of much more than just a table amenable to fluoroscopy. It is a room modified to treat hemorrhage utilizing advanced technology, integrating both open surgical and advanced endovascular techniques. We will discuss some options and give some examples of the usage of hybrid suite and hybrid “set of mind”, as part of the EVTm concept.

The hybrid angiography suite allows the team to perform multiple procedures simultaneously, such as laparotomy and an extremity angiogram, without change in location or time delay. Preferably, it is stocked with modern devices, with immediately available experienced 24/7 staff in close proximity to the receiving unit or even door-to-door to the trauma bay. Until recently, few places had this capability, but the advancement of endovascular techniques for vascular surgeons has led to a rapid increase in the availability of hybrid suites.

Remark:

- » The availability of angiography/endo, the hybrid suite and other resources is highly dependent on your institution. What will work best **in your environment?** In some centers the vascular surgeons will be called in initially, in some the interventional radiologists, and in some others, the trauma (or general) surgeon is alone. Conditions are highly variable, so **tailor our comments and information to fit your center and your needs.**



A variety of imaging systems are utilized in hybrid rooms, each with different advantages and all with excellent imaging quality. The hybrid suite in Örebro Sweden is made by Philips and used extensively for hybrid surgical procedures, but, as for now, not for unstable trauma patients (location and logistics). Toshiba also has a similar system as do some other companies. The Artis Zeego (RA Cowley Shock Trauma, Baltimore) by Siemens combines high-resolution angiography with CT fluoroscopy. This advance in technology allows the acquisition of a CT scan while on the table. This “CT” is not as sensitive as the 64 slice or more helical CT but can give excellent-quality 3-dimensional views to supplement 2-dimensional angiography. The advantage for trauma patients is significant. It allows for additional imaging without the travel, delay and additional contrast usually associated with CT scans. Additionally, it can identify associated injuries, such as intracranial hemorrhage that might significantly alter the treatment algorithm. Just a simple thing like a C-arm for chest x-ray or fracture identification is very practical. Monitors, lights, anesthesia, surgical and endovascular supplies are obviously essential for a functional hybrid suite. Additional instruments, such as a duplex ultrasound, intra-vascular ultrasound (IVUS) and a transesophageal echo (TEE), should be available as well. The ability to utilize cardiopulmonary bypass, ECMO, and CVVHD in difficult situations is ideal. The full potential of these suites is still unclear as there are not so many up and running and the long-time experience with them is somewhat limited.

The technology for a hybrid OR is costly, approximately \$3-9 million total for the room, and 1.5-5 million for just the fluoroscopic equipment (US calculations, 2016).

Another major challenge is the design of the hybrid suite. Serious consideration should be given to the location of the angiography arms, and how they relate to the monitors and the anesthesia equipment, to maximize flexibility. A major factor impacting utilization is location. Optimally, this is in the OR, near the trauma bay and/or the emergency room.

Difficulties may arise surrounding utilization of the room. Should it be on stand-by for acute cases or be used for elective surgery? Who should work there during off hours? Should a specialized scrub/radiology team be utilized? Lots of operational issues around hybrid suites function depend on local routines. To the best of our knowledge, there are now only a few centers with the capacity but it is expanding.

Tips:

- » When planning the room, make sure it is **designed for acute situations**: from the position and size of the doors, ventilators, arms, ultrasound and monitors to storage for surgical and endo equipment. All personnel must know where the equipment is, including blood products, cell saver, etc. This is crucial for good function in stressful trauma situations. Decide who should work in the room and how to work there at night time and weekends. These questions will come up and you need to be prepared for them.

Appropriate staffing of the rooms is essential. The equipment and techniques are new to traditional surgical scrubs and nurses, and training is mandatory. The OR staff need to be comfortable with the acquisition, preparation, and billing of endovascular devices. A competent radiation technologist is essential to help provide images critical to decision-making and treatment (this function is less common in Europe). Radiation safety should also be practiced with vigilance. Essential staff needs to be present at all times, and depending on the acuity of the situation, the interventionist must be readily available. Waiting one to two hours to mobilize a team from home is obviously not ideal for a patient in extremis.

In addition, it is vital that the person leading the hemostasis team is familiar with trauma/surgery and has extensive experience in the management of injured patients. In most institutions, catheter techniques are performed by interventional radiologists who are usually not in-house at night; however, this varies significantly depending on the institution. These individuals are usually skilled with catheters, wires, coils and stents. They, however, often have little understanding (no offence, guys) of the dynamic nature of a multi-trauma patient, particularly one who is actively bleeding. Endovascular surgeons are performing these procedures with increasing frequency, although their experience with the management of these situations varies significantly. It is essential that trauma surgeons have an understanding of embolization techniques to help guide the proceduralists who lack the experience to make decisions. They are performing (at least in the USA) an increasing number of endovascular procedures themselves, with on-table angiography and REBOA both well within their scope of practice. Exactly what procedures trauma surgeons are capable of safely performing without advanced training remains unknown.

CTA is a useful tool for the critically injured patient. REBOA can help



stabilize the patient, but even in experienced hands or in a hybrid suite, **localization of bleeding with selective angiography is very time consuming.** A CTA head-thorax-abdomen-pelvis offers huge assistance and has a key role in EVTm. With the correct protocol (head first, as the contrast is injecting, continuing down through the pelvis as well as a 100 sec delay for the venous phase), the scan only takes about 3 mins (there are many different protocols). A “super acute CT” scan on the way to the hybrid room or OR may give valuable information and should be considered. The CT can be reviewed while colleagues continue treatment, and may be viewed “online” by senior colleagues. This may free the treating surgeon to direct all attention to the patient. The new generations of CTs are very fast, and can be placed nearby, in the ER or hybrid suite. “CT on rails” is a new technology that is spreading fast, and some of the equipment has the quality of a standard modern CT. If CT is used correctly, fear of the “tunnel of death” might be a part of the past. Train with the staff, make sure that the protocol works, and do a risk-benefit calculation for obtaining further imaging. The main problem with CT is transfer of the patient to and from the CT, and is a critical point in the chain of care for these patients.

Back to the hybrid suite issues. For treatment of an unstable multi-trauma patient, the hybrid room must be prepared for both open and endovascular procedures. As mentioned before, this might be the ideal location for



Figure 1 1-5: Transfer of trauma patient into the CT. Note a REBOA and sheath during transfer.

critical patients with multiple injuries, and also for hemodynamically unstable patients. The hybrid angiography suite will allow the team to perform multiple procedures almost simultaneously, for example, a laparotomy and an extremity angiogram without change in location or time delay. This is being recognized now in trauma and bleeding patients, as the concept of hybrid procedures can be applied in a standard surgical environment. A C-arm and a sliding angiography table is a reasonable alternative, and all trauma patients should, in our view, be placed on an angiography compatible table. Basic endovascular stock can be stored in the room or on a trolley and taken to multiple locations as necessary (your friends in surgery have an iatrogenic bleeding and need REBOA?). An ultrasound/FAST should be readily available. In addition to angiography, the imaging equipment can be used for many functions, including cystography and head CT, or just to get plain films for pneumothorax or fractures. So, lots of options, but you need to know how to use them.

Here is a list of procedures that, in our view, can be performed in the hybrid OR:

- » General anesthesia
 - » TEE
 - » Resuscitation; Lines
 - » REBOA, Arterial and venous balloon occlusions
 - » Pelvic packing
 - » Cardiopulmonary bypass, Continuous renal replacement therapy, ECMO
 - » Exploratory laparotomy, Thoracotomy, Thoracostomy
 - » Rib fixation
 - » Stent grafts of major vessels
 - » Esophagogastroduodenoscopy/PEG/Tracheostomy
 - » Orthopedic stabilization, External fixation/Extremity fixation
 - » Amputation
 - » Extremity revascularization/Shunts/Vascular repairs, Angiography
 - » Angioembolization
 - » Cystogram
 - » CT head
- And probably some more...



Figure 2 1-2: Shock & Trauma Baltimore hybrid suite



Figure 3 1-3: REBOA in different patients as part of hybrid procedures.

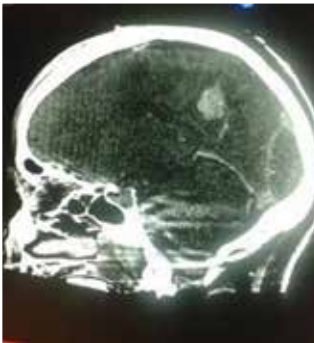


Figure 4.1: Intra-cranial hemorrhage imaging by hybrid suite C-arm. This might be highly relevant for the decision making process in this patient.



Figure 4.2: Patient in hybrid suite ready for TEVAR. Notice left arm scrubbed for potential brachial or axillary access.

How to think hybrid

As previously mentioned, hybrid surgery has been practiced in vascular surgery for the last 20 years with excellent outcomes. The idea is simple: You can combine endovascular tools with open surgery to control life-threatening hemorrhage. While simple in theory, the techniques are more advanced. Surgeons must make an effort to obtain wire and catheter skills in order to fully utilize advancing technology. Collaboration with colleagues is essential and is an essential part of the EVTm concept. A lot can be learned from other specialties and the techniques can be useful in difficult clinical scenarios. Remember that even if all these options are available, **you must decide what are the priorities** – What injury to be treated and when? What resources to use and how? This is highly dependent on your experience but the first rule in hybrid thinking is still the first rule of trauma: **When it is bleeding, stop the bleeding!** How to do it with endo or hybrid tools depends on many factors that we discuss later on.

Obviously, you can use a standard surgical suite and convert it into a semi-hybrid suite as seen in these photos.



Figure 5: A surgical suite converted easily into a hybrid suite (Semi-hybrid suite). C-arm on the left side, patient on a sliding (angiography) table. In this case, major liver and brain penetrating trauma in a hemodynamic unstable patient. Simultaneous laparotomy packing and craniotomy.

Tips and some words of caution:

- » All these fancy things...**But what do I have in my hospital?** That's the only important thing! Calculate the risk and benefit. Is it reasonable to do CT? If you don't have the time, take the patient to the hybrid OR.
- » Transfer time is the real time of CT, not just the scan itself.
- » Hybrid or endo solutions are frequently useful but **should not replace good surgical solutions**. Sometimes, minimally invasive methods unnecessarily complicate things and a good surgical exposure might be the easiest and simplest solution. It's a delicate balance.



Figure 6: Surgical suite in hybrid configuration (semi-hybrid). The size of the room is a limiting factor in trauma and bleeding surgery.



Figure 7: Sliding tables in the entrance to the surgical division in Örebro, Sweden (three tables available 24/7). All bleeders as well as all trauma cases are placed on these tables.



Figure 8.1



Figure 8.2

Figure 8 1-2: After pREBOA, Laparotomy, Exfix, Preperitoneal packing. Intracranial pressure monitoring (ICP), Extremity fixation and fasciotomy in the same semi-hybrid suite.

So, with a hybrid and endo state of mind, whenever possible, common femoral arterial access should be established already in the resuscitation area. It is one of the principles of EVTm. Blind puncture, ultrasound guided puncture and cut-down are all acceptable approaches. The access can be easily upsized for a larger sheath for REBOA or angiography if needed. There are many situations where a hybrid approach has its advantages. A deflated balloon (dREBOA) can be placed prior to abdominal exploration in certain situations, to be inflated if necessary. This may be useful in patients with previous abdominal surgery, when adhesions make timely exploration difficult. Again, the majority of experienced surgeons will easily get to the bleeding kidney in minutes, but is it so easy with dense adhesions or morbid obese/fetma patients? The risk of having a deflated catheter in the aorta for a limited, short time is **RELATIVELY** low. The same concept might be applied to the arch vessels as well (we are not talking about REBOA now).

For upper chest injuries, you can get a brachial or axillary arterial access. A PTA balloon can be used in a major vessel for proximal control while your colleagues approach surgically. Again, the risk of wire placement is relatively low, and a procedure can then be carried out quickly. In some centers, a wire will be placed in the target organ vessel whenever possible and the decision whether to use it will be taken later on. This can also be done simultaneously in some cases, especially if you are working in a hybrid suite.

Endovascular treatment of hemorrhage can be performed as a temporary bridge or definitive therapy. For vessels that are difficult to access, such as the subclavian, a stent-graft is a great option particularly in a large patient who is unstable. Occlusion balloons can be used for proximal control of great vessels prior to exploration (subclavian, innominate, carotid but also iliac, femoral and

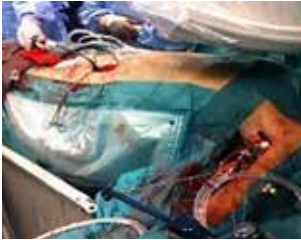


Figure 9: Hybrid Procedure (Iliac retroperitoneal approach and Axillary approach) in an elective endovascular procedure. Done here in a surgical suite with a mobile C-arm.

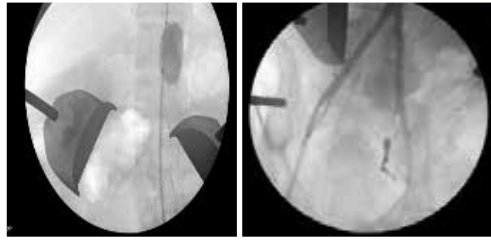


Figure 10 1-2: Embolization as part of the hybrid concept. REBOA during CPR, preperitoneal packing and ex-fix with angioembolization. Done with a mobile C-arm in a semi-hybrid surgical suite.

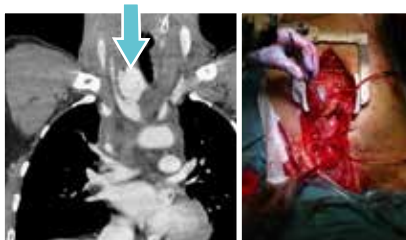


Figure 11 1-2: Innominate artery exposure and patch repair with PTA 14mm balloon in place for bleeding control via right axillary approach in blunt trauma (not seen in this photo).



Figure 12: CTA with hybrid set of mind. Manual compression of zone I neck bleeding during CTA to exclude thoracic vessel or parenchyma injuries. Open repair followed. This photo demonstrates that sometimes you can do CTA and get more critical information if your CTA is next door. At time it can be a very unwise (or even stupid) idea! Use these resources wisely.



Figure 13: Hybrid procedure for massive iatrogenic CFA bleeding. Notice 8Fr sheath on the patients left side, used for contralateral iliac balloon occlusion (ABO).

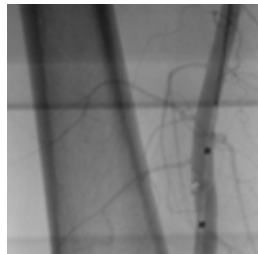


Figure 14: SFA injury and proximal balloon control as part of hybrid procedure.



Figure 15: Clinical photo of the patient.

obviously, REBOA). Care should be taken when instrumenting around the arch in patients who cannot be heparinized. Stent-grafts in the extremities (e.g., SFA) can also be used to control hemorrhage in patients with challenging anatomy. These can be removed if definitive interposition grafting is felt to be the best long-term option, and performed once the patient has stabilized and orthopedic injuries have been addressed.

We might suggest the following in the ENDO trolley (see also the other “What to use” text in the manual). This is only an example of the content.

Endo Trolley

- » Puncture sets (multiple) – 18G needles and Micro-puncture sets
- » 5-7Fr Sheaths, 11-24Fr Sheaths (depends on your needs, e.g., TEVAR?)
- » Soft wires (e.g., Terumo). Short and long.
- » Stiff wires (e.g., Lundeqvist, Amplatz, Back-up Meier)
- » Contrast medium, 10-20ml Syringe, Sterile saline
- » Aortic balloon/REBOA
- » 8-14mm PTA balloons (e.g., Cordis PTA balloon)
- » Birenstein catheter, Bolia catheter
- » Some other catheters (depends on your skills and your needs)

In this chapter, we tried to cover some issues regarding hybrid set of mind and some issues will be presented in other chapters. We want again to remind you that these are our thoughts and based on the experience of the authors but there is no right or wrong here. We believe that there are many options with a hybrid state of mind – from access to surgical maneuvers that can be performed in a hybrid suite or semi-hybrid room.

Let us repeat a word of caution: While hybrid and endovascular solutions sometimes have advantages, it is important not to delay hemostasis. An open surgical approach is frequently a reasonable and preferred approach, and the risks and benefits of each technique should be considered.
So, **think before using it!**