The Art of EndoVascular hybrid Trauma and bleeding Management

JOSEPH J. DUBOSE, JONATHAN J. MORRISON, VIKTOR A. REVA, JUNICHI MATSUMOTO, YOSUKE MATSUMURA, MÅRTEN FALKENBERG, MARTIN DELLE, PER SKOOG, ARTAI PIROUZRAM, MEGAN BRENNER, MELANIE HOEHN, THOMAS SCALEA, ELIAS N. BROUNTZOS, TIMOTHY K. WILLIAMS, THOMAS LARZON, KOJI IDOGUCHI, LAURI HANDOLIN, GEORGE OOSTHUIZEN, JOSEPH D. LOVE, BORIS KESSEL, LARS LÖNN, MIKKEL TAUDORF, MARTA MADURSKA, JAN JANSEN, LISA HILE, JAMES DALEY, JOHN HOLCOMB, KRISTOFER F. NILSSON, PANTELIS VASSILIU, AND TAL M. HÖRER
Top Stent

The art of EndoVascular hybrid Trauma and bleeding Management
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"If I have seen further, it is by standing on the shoulders of giants"

Newton, Isaac
Notice

This is a book written in good will to help doctors and medical teams treating trauma victims. None of the authors or the editor received any compensation for the work. There was no involvement of the industry in the manual in any form, but some photos were given without any commitment, as courtesy. The manual is written as part of the clinical research done in Örebro University Hospital and received financial support for printing from the hospital research division. The work was performed in accordance with the ethical and legal guidelines of the Swedish government and European Union. The manual is published by Örebro University Hospital, Sweden. All rights are reserved to the editor. The editor, hospital and authors take no responsibility whatsoever for the usage of the information in this manual. The book expresses solely the authors’ opinions, and none of the author team or editor can accept any responsibility for any misusage or harmful treatment. All material in this book may be used for teaching and demonstrations, but without financial compensation, and with clear mention of its source. All photographs were taken with permission, and applicable and unique authors’ own material was used whenever possible.

Editor in chief:
Dr. Tal M. Hörer tal.horer@regionorebrolan.se, talherer@yahoo.com

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We hope that this collaboration will help save lives and decrease morbidity!
Introduction

Many of the readers of this text have been inspired by “Top Knife”, a great book by Mattox and Hirshberg that has provided many surgeons with great approaches to the open surgical management of bleeding trauma victims. In “Top Stent”, we have aspired to develop a similarly useful resource that is applicable for the modern era of **EndoVascular hybrid Trauma and bleeding Management (EVTM)**. Although stents and stent grafts do not encompass the entirety of EVTM capabilities, we have called this text “Top stent”.

Why is this text necessary? In the last 20 years, the use of endovascular capabilities for trauma applications has continued to expand. While the use of modern endovascular treatment modalities for bleeding patients began with the treatment of aortic aneurysmal disease, it has since spread into trauma care. In truth, there are anecdotal reports of centres treating bleeding patients with basic endovascular methods for many years, but the continued evolution of technologies and the arrival of the “endovascular era” has heralded a new age for the use of EVTM approaches. Advances in devices utilized in modern endovascular treatment, as well as improved diagnostic tools (CT and ultrasound, angiography, Doppler etc.), have resulted in the increased utilization of EVTM approaches all over the world. There is today a great variety of rapid diagnostic capabilities and endovascular tools suitable for use in a wide variety of clinical trauma scenarios. As a community, there is a need to better share lessons learned from these applications, and collaborate to define the optimal utilization of EVTM principles.

It must be recognized that, at this time, endovascular therapies continue to be viewed as complementary elements of initial trauma care. This is evident in both daily practice and general trauma guidelines such as the American College of Surgeons Advanced Trauma Life Support ™ guidelines as well as other guidelines. With continued experience, however, the collaborators of this text believe that EVTM is poised to become an integral element on trauma care in the earliest phases after injury. In brief, we envision that EVTMM represents a paradigm shift in trauma care. It should be, and already is in some places,
part of the initial treatment algorithm of the trauma patient, and combined with open surgery, as part of the hybrid concept. In other words, EVTM can be incorporated into the primary management of the trauma patient, already from the emergency room, on arrival. Probably, it could be established in the battlefield or, even in selected cases, in pre-hospital care.

Valuable examples of this paradigm shift are emerging from leading centres throughout the world. An important emerging example is the use of Aortic Balloon Occlusion (ABO) or Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA – the term we will utilize for Aortic balloon occlusion throughout this text). REBOA (“the new kid on the block”) is being used now in many centres to gain hemodynamic temporary stability in severely injured trauma victims- even replacing to some extent traditional resuscitative thoracotomy.

The basic technologies necessary for REBOA and EVTM can, in most instances, be found in the majority of hospitals treating trauma victims. There remains a need, however, to better define the questions of “When”, “Where” and “How” these approaches should be optimally utilized. A multidisciplinary approach to answering these questions is required – combining the existing knowledge of trauma surgeons, vascular surgeons, interventional radiologists, thoracic surgeons, orthopaedic surgeons, medics, emergency medicine and anaesthesiologists. While the utilization of EVTM principles will be dictated by many variables (local capabilities and local egos and credentials to name but a few) we believe that the effective integration of EVTM principles into modern trauma care will require the development and maintenance of multi-disciplinary, multi-national and multi-institutional collaborations.

This “manual” represents the personal view of a small, but dedicated group of EVTM professionals gathered to document how they think and act in the management of trauma and bleeding patients. These are all doctors with “blood on their hands”, meaning they are active clinicians and working within this field. This text is the result of their efforts to cooperate and gather ideas on how to effectively conduct EVTM. There are probably many other ways of doing things, and time will show if some of the things we do, or want to do, are correct. As with all procedure-based interventions, there is less likely “one perfect way”, and more likely several safe and effective approaches to any specific EVTM challenge. In Top Stent, we will not mention references
A list of some of the major points of EVTM

or discuss any evidence, that the reader can find elsewhere. We will only give a personal view and try to outline hard learned “tips and tricks” of our collective experience with EVTM. You, the reader, must filter this information and decide what is acceptable, doable, and **what would fit your workplace and your environment**. It is also very important to recognize that EVTM does not replace open surgery, but combines with it into a comprehensive system of trauma care capability. In some cases, the only and best treatment is the “good old” open surgical exposure and bleeding control!

You might also notice that in this manual, different parts are written in different styles, which we tried to merge during the editing process. We find it important though, that different experts express their views and tips in a collective format – and adopted this format accordingly. The combination of different nationalities and conversion of a variety of native tongues into English represented an additional challenge, – but we hope the reader will appreciate, as we do, that language should not be an obstacle to knowledge sharing. At times you might feel that some points are repeated, but we find it useful as it reflects many authors’ views in a text collection. We should also mention that, despite the frequent possible use of masculine pronouns (“he”) – EVTM is and will always be gender, race and ethnicity blind. We are all “one” in the use of EVTM principles. We should mention that this text is not a consensus but a collection of expert opinions gathered into a manual friendly format. As so, the manual is done on a goodwill basis, with no economical compensation provided to any contributor. Feel free to use it as a resource as you see fit or even to distribute the material herein. We only request that as you cite or use the opinions or discussion of our work, that you refer to “Top Stent” as your source. This will be the first, or Beta edition of this manual. We hope to develop it further in the coming years, including through the use of other platforms such as www.jevtm.com.

In our view, there is no right or wrong as long as you collaborate to achieve the ultimate goal of every trauma provider, i.e. **saving life**! So, let’s see if you think it has been worthwhile producing this first version of Top Stent. You will be the judge. Enjoy.

The authors
Some guest words on this manual

**Todd E. Rasmussen** MD

United States Combat Casualty Care Research Program, Fort Detrick, Maryland
The Norman M. Rich Department of Surgery, the Uniformed Services University of the Health Sciences, Bethesda, Maryland

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**Corresponding author:**
Todd E. Rasmussen, MD, FACS
Colonel USAF MC

Director
US Combat Casualty Care Research Program
722 Doughten Street, Room 1
Fort Detrick, MD 21702-5012
Office: 301-619-7591
Email: todd.e.rasmussen.mil@mail.mil

“A new era for surgery would become, if we were be able to stop the flow in a major artery without exploration, external compression and ligation…”
(circa 1864)

Professor Nicolay Pirogov
Russian surgeon & founder of field surgery

In his quote, the Russian scientist and medical doctor Professor Nicolay Pirogov foresaw a time in the field of medicine when the bleeding vessel could be managed from a remote location without the need for an operative incision and direct exposure. Although he did not use the term “endovascular”, one can infer he may have pictured the use of devices deployed inside of and proximal to, the disrupted vessel to control bleeding and repair the injury. Less than 100 years
after Pirogov, Lieutenant Colonel Carl Hughes from the Walter Reed Army Medical Center reported on the use of a primitive intra-aortic balloon catheter to control hemorrhage during the Korean War. Fast forward another half century and the field of surgery is immersed in a technological revolution in which ever smaller and easier catheter-based devices are being innovated and applied to manage vascular disease. As documented in this Top Stent manual, today’s advances promise to extend beyond the management of just vascular disease and will make the aspirations of Pirogov and Hughes to use endovascular techniques for injury and hemorrhagic shock a reality.

In the pages and chapters that follow, a stellar line-up of authors has provided a timely summary of the most germane topics related to learning, performing and instructing a basic skillset of endovascular techniques to manage vascular injury, hemorrhage and shock. In its inaugural edition, Top Stent has struck a balance with comprehensive and candid content in a brief and versatile format. Included are chapters dedicated to proper and usable vascular access and the three main categories of endovascular techniques (i.e. the “toolbox”) for trauma and injury care: 1. resuscitative endovascular balloon occlusion of the aorta (REBOA), 2. stents and stentgrafts and 3. embolization tools and devices. The manual also dedicates space to addressing less conventional, non-aortic uses of balloon occlusion and even speaks to the emerging model of the hybrid -open and endovascular- operating room.

Reflecting the military expertise among its contributors, Top Stent reports on the potential for endovascular techniques to be used across a spectrum of combat casualty care settings: point of injury, en-route and fixed facilities. This perspective is forward-leaning and sure to inform a diverse range of providers (military and civilian) as they consider the most appropriate location for application of these new and potentially lifesaving technologies; today and in the years to come. As evidence of its honest structure, Top Stent dedicates a chapter – and comments throughout – to the limitations of endovascular techniques and possible complications associated with their use. The text provides a “how to” summary of performing, learning and training these techniques and concludes with a fitting list of major points or “pearls”.

To the credit of its leader and senior editor Dr. Tal Hörer, the Top Stent manual extends and formalizes past work from the Endo-Vascular hybrid Trauma and bleeding Management or EVTM movement. The Top Stent manual is
timely and sure to serve as a resource for cases at hand and to spur the movement in a more informed manner to maximize the life-saving potential of endovascular approaches in years to come. Congratulations to the cast of dedicated authors and contributors on this impressive accomplishment – Pirogov and Hughes would certainly find this discussion fascinating!

**Thomas Larzon**

Pioneer in endovascular surgery

With cane and hat, without any delay, please send the patient to the operating room! These were the rules when I started to learn vascular surgery 30 years ago. Abdominal or back pain, a palpable pulsating abdominal mass and hemodynamic chock were the clinical signs, the triad for a ruptured abdominal aneurysm. That made sense when the scanning time for the abdomen was almost half an hour and the only available method was open surgery.

The diagnosis was not always correct and I have found myself with one and another kidney stone or pancreatitis but that was accepted by my senior colleagues as well having a 50% mortality rate. Over time treatment has drastically changed as you know well and EVAR has been accepted and now dominates treatment of ruptured aneurysms.

We all have moments we never forget and one of these golden moments was in 2000 when a patient literally dropped dead in the OR in front of me. A pending thoracic aortic aneurysm had actually ruptured. But it turned out that her days were not counted. We were to meet many times in the coming years – thanks to an aortic occlusion balloon, simultaneous CPR and a thoracic stentgraft.

I have been fortunate to have the right work at the right time in the right place and I now see that history repeats itself when it comes to trauma care. It will be very interesting to follow the development that up to now only is in its infancy with the REBOA concept. I congratulate all of you, young, established and future doctors who will dedicate your work to create the future of trauma care. Together we can do it. What a challenge!
List of authors and contributors

The following experts took part in writing and contributing to the Top Stent manual. There is no special order here. These experienced doctors just made great efforts and wrote, edited or gave advice on how to formulate the manual.

Jonathan J. Morrison MD, PhD Vascular surgeon
Dept. of Vascular Surgery, Queen Elizabeth University Hospital, Glasgow, UK.  
The Academic Department of Military Surgery & Trauma, Royal Centre for Defence Medicine, Birmingham.
jjmorrison@outlook.com

Joseph J. DuBose MD, FCCM, FACS Trauma and Vascular surgeon, Surgical Intensivist
David Grant Medical Center, Travis AFB, CA, USA
Division of Trauma, Acute Care Surgery and Surgical Critical Care & Division of Vascular Surgery, University of California – Davis Medical Center, USA.
jjd3c@yahoo.com

Viktor A. Reva MD, PhD Trauma surgeon and vascular surgeon
Dept. of War Surgery, Kirov Military Medical Academy, Saint-Petersburg, Russian Federation.
vreva@mail.ru

Junichi Matsumoto MD, PhD, Interventional radiologist
Dept. of Emergency and Critical care medicine, Saint-Marianna University Hospital, Kawasaki, Japan.
docjun0517@gmail.com

Yosuke Matsumura MD, PhD Interventional radiologist
Dept. of Emergency and Critical care medicine. Chiba University Hospital, Japan.
R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, USA
yousuke.jpn4035@gmail.com

Mårten Falkenberg MD PhD, Vascular surgeon
Dept. of radiology, Sahlgrenska University Hospital, Göteborg, Sweden
marten.falkenberg@vgregion.se
A list of some of the major points of EVTM

**Martin Delle**, MD, PhD Interventional radiologist
Dept. of Radiology, Karolinska University Hospital, Huddinge, Sweden
martin.delle@karolinska.se

**Per Skoog**, MD, PhD Vascular and general surgeon
Dept. of Vascular surgery, Sahlgrenska University Hospital, Göteborg, Sweden
peraskoog@yahoo.se

**Artai Pirouzram**, MD Vascular and general surgeon
Dept. of Cardiothoracic and Vascular surgery
Örebro University Hospital and Örebro University, Sweden
Artai.pirouzram@regionorebrolan.se

**Megan Brenner**, MD MS RPVI FACS Trauma and vascular surgeon
RA Cowley Shock Trauma Center
University of Maryland School of Medicine, Baltimore, Maryland, USA
mbrenner@umm.edu

**Melanie Hoehn**, MD, FACS Vascular surgeon
RA Cowley Shock Trauma Center
University of Maryland School of Medicine, Baltimore, Maryland, USA
mhoehn@smail.umaryland.edu

**Thomas Scalea**, MD, FACS Trauma surgeon
RA Cowley Shock Trauma Center
University of Maryland School of Medicine, Baltimore, Maryland, USA
tscalea@umm.edu

**Elias N Brountzos**, MD, EBIR Interventional radiologist
National and Kapodistrian University Athens, Greece
2nd Dept. of Radiology, Division of Interventional Radiology
General University Hospital “Attikon”, Greece
ebrountz@med.uoa.gr

**Timothy K Williams**, MD, RPVI Vascular surgeon
David Grant Medical Center, Travis AFB, CA
UC Davis Medical Center, Sacramento, CA, USA
timothykeithwilliams@gmail.com

**Thomas Larzon**, MD, PhD Vascular and general surgeon
Dept. of Cardiothoracic and Vascular surgery
Örebro University Hospital and Örebro University, Sweden
Thomas.larzon@regionorebrolan.se
A list of some of the major points of EVTM

Koji Idoguchi MD Trauma and vascular surgeon
Division of Endovascular Therapy, Senshu Trauma and Critical Care Center, Rinku General Medical Center, Japan.
idoguchi@ares.eonet.ne.jp

Lauri Handolin MD, PhD Trauma surgeon
Helsinki University Hospital Trauma Unit, Finland.
lauri.handolin@pp.inet.fi

George Oosthuizen MBChB, FCS(SA), FACS Trauma surgeon
Pietermaritzburg Metropolitan Trauma Service, University of KwaZulu Natal, Pietermaritzburg, South Africa.
george.oost@gmail.com

Joseph D Love DO, FACS Trauma surgeon
McGovern Medical School at UTHealth
Dept. of Surgery Memorial Hermann Hospital, TMC and Life Flight.
Houston, Texas, USA
josephdlove@gmail.com

Boris Kessel MD Trauma surgeon
Trauma unite and division of Surgery
Hilel Yafe Hospital and Technion Institute of technology, Hadera and Haifa, Israel
bkkessel01@gmail.com

Lars Lönn MD, PhD, EBIR Interventional radiologist
Dept. of vascular surgery and dept of radiology, National Hospital and University of Copenhagen, Denmark
lonn.lars@gmail.com

Mikkel Taudorf MD, PhD Interventional radiologist
Dept. of Radiology
National Hospital, Copenhagen, Denmark.

Marta Madurska MD Vascular Surgeon
Department of Vascular Surgery
Queen Elizabeth University Hospital
Glasgow, United Kingdom
martamadurska@hotmail.com

Jan Jansen MD, FRCS, FFICM Trauma, general surgeon and intensivist
Aberdeen Royal Infirmary, Aberdeen and St Mary’s Hospital, London, UK
jan.jansen@abdn.ac.uk
Lisa Hile  MD Emergency medicine physician
Dept. of emergency medicine, Johns Hopkins University, Baltimore, Maryland, USA
lhile1@jhmi.edu

James Daley  MD MPH Emergency medicine physician
Yale New Haven Hospital
New Haven, USA
James.i.daley@yale.edu

John Holcomb  MD, FACS Trauma surgeon
McGovern Medical School at UTHealth
Dept. of Surgery Memorial Hermann Hospital, Houston, Texas, USA
John.holcomb@uth.tmc.edu

Kristofer Nilsson  MD, PhD Anesthesia and Intensive care physician
Dept. of Cardiothoracic and Vascular surgery
Örebro University Hospital and Örebro University, Sweden
kristofer.f.nilsson@gmail.com

Pantelis Vassiliu  MD, PhD, FACS, Surgeon
4th Surgical Clinic, “Attikon” University Hospital Athens, Greece
pant_greek@hotmail.com

Tal M. Hörer  MD, PhD Vascular and general surgeon
Dept. of Cardiothoracic and Vascular surgery; Dept. of Surgery.
Örebro University Hospital and Örebro University, Sweden
tal.horer@regionorebrolan.se or talherer@yahoo.com
List of words and acronyms used in Top Stent

HYBRID open and endovascular management
REBOA Resuscitative Endovascular Balloon Occlusion of the Aorta
ABO Aortic Balloon Occlusion (or IABO)
tREBOA total REBOA (used frequently as REBOA in general)
iREBOA intermittent REBOA
pREBOA partial REBOA
fREBOA field REBOA (as well as transfer REBOA)
dREBOA Deflated REBOA in situ
RB Rescue Balloon catheter
ER REBOA Emergency room REBOA catheter
ER Emergency room
IFU Instructions for use
Sheath = introducer
SBP Systolic Blood Pressure
MAP Mean Arterial Pressure
US Ultrasound
OR operating room
BTAI Blunt Thoracic Aortic Injury
TBI Traumatic brain injury
TEVAR Thoracic Endovascular Aortic Repair
EVAR EndoVascular Aortic Repair
LSCA left subclavian artery
CTA Computer Tomography Angiography, at times we use the word CT
BCT Brachiocephalic trunk (or Innominate artery)
FAST- Focused Assessed sonography in Trauma
GI Gastro-intestinal (bleeding)
IR Interventional Radiology
GS Gelatin sponge
ATLS Advanced Trauma Life Support
PTA Percutaneous Transluminal Angioplasty
CFA Common Femoral Artery
SFA Superficial Femoral Artery
DFA Deep Femoral (profundal) Artery
ACS abdominal Compartment Syndrome
SIRS Systemic Inflammatory Response Syndrome
IVC Inferior Vena Cava
IIA Internal Iliac Artery
EIA External Iliac Artery
Chapter 1

It is all about the vascular access

Yosuke Matsumura, Junichi Matsumoto, Lauri Handolin, Lars Lönn, Jonny Morrison, Joe DuBose and Tal Hörer

Modern Advanced Trauma Life Support (ATLS) principles have revolutionized the treatment of trauma patients, providing a common protocol for treatment and diagnosis of the injured. ATLS principles (the ABCs of initial trauma care) emphasize early diagnosis and management of airway problems and major bleeding control, providing a protocolized approach that affords effective initial evaluation and treatment of a wide array of trauma victims. At present, however, ATLS does not provide guidance on the early utilization of evolving endovascular or hybrid management (EVTM) adjuncts to trauma care. For providers with appropriate skillsets and capabilities, EVTM adjuncts can provide additional tools for the early care of the severely injured trauma patient.

As a modification of the traditional “ABCDE” mnemonic advocated in the ATLS protocol approach to initial trauma evaluation and treatment, an EVTM enabled provider might consider using an “AABCDE” (airway and simultaneous vascular access, breathing, circulation etc.). Why might the use of the AABCDE-centered thought process prove useful? Very simply: this mnemonic may better represent actual modern trauma practice, including the establishment of vascular access in the peripheral or central veins for the early administration of fluids and medications. It is also important to consider that simultaneous vascular access in the early trauma setting also affords the medical team an opportunity to achieve IV access that may prove critical to patient survival – namely cannulation of the common femoral artery (CFA).
It is all about the vascular access

While venous access is often critical in obtaining blood samples and facilitating life-saving blood product and medication administration, early arterial access may also provide crucial additional capability and should be routinely considered. Vascular arterial access enables the use of a variety of diagnostic and therapeutic adjuncts pertinent to trauma care – including REBOA (Resuscitative Endovascular Balloon Occlusion of the Aorta) and a variety of diagnostic and therapeutic capabilities. Continuous invasive central arterial blood pressure monitoring can significantly aid the assessment of hemodynamic stability, as can serial arterial blood gas chemistry. Arterial access can also permit formal angiography, affording precise and effective localization of the bleeding focus. In addition, arterial access can provide a platform from which to deploy a variety of hemorrhage control maneuvers, including REBOA, angioembolization and stent graft deployment. In extreme cases, arterial access can even be utilized for fluid administration (though this pathway is not as effective as venous administration). So, the femoral artery (and vein) can prove to be a critical pathway to your patient’s cardiovascular system and subsequent patient salvage. Try to remember the last significant trauma case you helped care for – were the common femoral artery and vein accessed during the primary survey? It is likely the answer is no – and an opportunity to promote an improved outcome may have been missed.
The common femoral artery is relatively easy to access, is commonly characterized by a uniform anatomical position, and is typically reasonably sized (around 6-9 mm but depends on hemodynamic status and age). This vessel is relatively easy to access in young patients, and when done correctly, access is a relatively low risk endeavor – the term “relative” is emphasized here. Every procedure performed at the initial phases of trauma is associated with some risk. These include bleeding, arterial dissection, and thrombus formation. However, when a patient presents in hemorrhagic shock, the risk-benefit ratio is firmly on the side of expeditious and direct intervention. Femoral access can provide a platform from which to tackle some of the most challenging injuries as we mentioned above.

The general relationships of the femoral vasculature are fairly consistent from individual to individual. The femoral vein lies medially to the artery and both are relatively easy to control by compression, provided they are healthy. We will discuss the anatomy and specific concerns of arterial access: not only how to establish access, but also how to utilize it, maintain it, and close the site safely when vascular access is no longer needed. While our discussion will be thorough, we encourage you to seek out additional anatomical details from any of the established textbooks or atlases on the topic as you see fit. With that said, let us start our discussion by thinking about how “vascular access” can be incorporated into the early care of the bleeding patient – be it bleeding from trauma or other non-traumatic etiologies (gastro-intestinal, iatrogenic, post-partum etc...)

**How to identify the femoral artery and access guidance techniques**

The first rule in establishing vascular access is to avoid puncture on the side of any significant lower extremity injury if possible. Access on the contra-lateral side is preferable, but if the injury involves both inguinal areas, there are other solutions that we will discuss later. You also must consider if there could be a vascular injury ABOVE the site you intend to puncture. If so, access may not only prove useless (for example, infusing fluids through a vein that is lacerated
just above the injury site) but may prove outright dangerous (advancing a wire from the femoral artery into a dissected proximal iliac artery or aorta, for example).

**Ultrasound (US) guided puncture:** This is a very useful tool for all kinds of things in medicine, but its Achilles heel is “inter-user variability” – not everyone is able to obtain the same quality images in the same patient. As a first step, you must understand how your department’s machine works – at minimum, how to engage a vascular setting, and how to set the depth (how far the scan will penetrate) and the gain (the greyness of the screen).

We would recommend that you go on a formal course or train with people who are familiar with ultrasound and FAST scanning. Doing it 10-15 times will give you basic (!) knowledge on how to recognize the structures and, most importantly, on whether you are following the procedure in a safe way. There is a learning curve, and we believe that this is highly dependent on your motivation and not your profession! (We know great cardiologists who can obtain vascular access faster than the blink of an eye…).

So, again, especially in emergency cases, when you have someone that can do it better or faster (or just an experienced colleague next to you), ask him or her to do it. Trauma bay patients are not training cases and you need a functional and safe access now. Again, do not let your ego rise, **do the right thing for your patient**, which may involve calling on your colleague.

**Advice:**

» Start training in an elective setting before working up to the critical patient.

In terms of practical approach, we would recommend the following sequence:

1. Check the US probe orientation. Does the left side of the probe correlate with the left side of the screen?

2. Scan the groin in a transverse view, where the vein should be medial and compressible. The artery should be pulsing – but not always! Ideally, you should also be able to identify the division of the common femoral artery (CFA) into the superficial (SFA) and deep/profundal (PFA) branches. This is an important landmark!
3. Turn the probe into a longitudinal view and see if you can obtain an image that demonstrates the external iliac coming up out of the retroperitoneum, the CFA with the femoral head behind it, followed by the division of SFA and PFA. Your ideal puncture zone is in the CFA, over the femoral head. While this view sounds complicated, it is great practice to get into the habit of seeking out all these structures.

4. Having picked your puncture zone in the artery, make a skin incision below (not all of us do that in acute settings) and insert your needle using the technique described above. You can see the needle in either longitudinal or transverse probe view. The longitudinal view is good if you can get comfortable with it, but the transverse view is what most people use.

5. Once you get a flashback, put the probe down, but do not discard it. Advance the wire into the vessel – if it travels in easily, great, discard the probe. BUT, if it does not travel easily, put the probe back on the patient and have a look. If you can see the “J” tip of the wire is clearly in the lumen, then great, but chances are you are not intra-luminal. Not sure? Time to think again!

Figure 5: Ultrasound assisted puncture in a trauma patient.

Tips:
» Get to know the ultrasound in the ER and make sure it’s “on” in the trauma bay. It is a powerful tool when used for FAST but you can use it for arterial or venous vessel puncture.
» The ultrasound should be on and ready 24/7, with a vascular probe at hand.
» Make sure you use an “echogenic” needle – these are designed to stand out on the screen and make the procedure easier.
» Train US guided puncture! It’s a great tool. The more you train, the better you become.
Access without imaging, or the “blind” puncture – how to do it

In the modern era, ultrasound guided access has emerged as the safest and most effective means for accessing the common femoral artery and vein – even in emergency situations. Ultrasound should always be considered an invaluable tool when attempting vascular access for trauma. If you have it available in a timely fashion, USE IT!! As mentioned, when using ultrasound to support access, the bifurcation of the SFA and deep femoral artery is typically easily visible, allowing identification of the CFA. This imaging modality may not be available when needed, however, for a variety of potential reasons. If ultrasound is not available, be aware of common placement pitfalls. Without ultrasound, a precise appreciation of anatomic relationships becomes paramount to successful venous and arterial access in the groin.

The inguinal ligament can typically be palpated and distinguished at the thigh upper border (although this may be more challenging in obese patients). You do not want to puncture too high, or above the ligament. You can palpate the iliac crest on the lateral side, and the pubic bone on the medial side, to identify the origin and insertion of the inguinal ligament in most patients. Punctures above this ligament might result in damage to both intra- or extra-peritoneal structures such as bowel injury or retroperitoneal hemorrhage. High punctures also complicate closure – making arterial repair challenging and time-consuming. We would suggest staying approximately two fingers below (distal to) the inguinal ligament with puncture attempts. As a reminder, the femoral vein will be located medial to the artery.

When attempting an arterial puncture, if you inadvertently access the vein, do not be discouraged; the placement of a 5-7Fr sheath in the vein may be of great benefit to your patient. This large vein access can prove very useful in the resuscitation of trauma patients. It is important to remember that communication and appropriate labeling of all placed sheaths is also important – your team must know which sheath goes where.

Comment:
» When we speak about the access “sheath”, it is synonymous with “introducer” – meaning a catheter with valve that is a working entrée tool to the vessel.
Another piece of useful advice – if you access “something”, but are not sure if it is successfully in the artery or vein, leave the sheath in place and try again with a new puncture. You can remove the faulty access later, after the chaos of the initial situation is resolved. If you take it out in the midst of trying to obtain emergent vascular access, the site might bleed and contribute to additional blood loss. Any attempt to hold pressure at this site in these situations takes hands away from tasks that might be useful at other locations – i.e. you cannot hold pressure and get vascular access at another site at the same time.

Advice:
» Leave the sheath in place even if unsuccessful (it might bleed). Deal with it later in the ICU or in the OR.

A common “failure” in groin puncture is the puncture that is undertaken too low / distal – usually in the case of arterial access this results in a superficial femoral artery (SFA) puncture. The SFA might be palpable and you might think this is the CFA, but you should rely on the external landmark mentioned above, more than just palpation. Large-bore sheath placement in the SFA (a smaller-diameter vessel than the CFA) may be associated with a greater risk of leg ischemia, especially in a patient in profound shock. Got a functional access? Use it and worry about these details later, but don’t forget it.

When utilizing anatomic landmarks as the primary means for facilitating
vascular access in the groin, it is of vast importance to appreciate common pitfalls and how to avoid them. You may be too high, too low, outside, or too deep even when you are using only palpable arterial pulsation to guide placement – particularly if the patient is hypotensive and the pulse is difficult to palpate. A useful approach is to start puncture attempts at a point 1/3 of the way down the inguinal ligament from the pubic bone, approaching laterally to the vein (if the vein has been identified by access), 2 fingers from the pubic bone edge – the artery is typically at this location.

If the patient has an appreciable blood pressure, palpate and find the strongest pulse impulse. Keep in mind that, in older patients, pronounced calcification of the artery may make the vessel more easily palpable, but it also should raise suspicion of potential access challenges in the vessels (heavy calcifications).

If your patient has acceptable blood pressure (e.g., > 80mmHg), you might feel the pulse, see the pulsation with your ultrasound, or hear the sounds on hand-Doppler. If your patient is skinny, you are lucky – it is much easier than in obese patients. Furthermore, be conscious of the longitudinal (cranio-caudal) anatomical direction and continuity of the artery to ensure that you stay luminal. Try to imagine the “3D course” of the artery as this will help you to “catch” the vessel.

Practical tip:

» Use two fingers to palpate the pulse and arterial structure. Move in lateral-medial directions slowly (side to side) to catch the area of maximal pulse. Yes, test it on yourself!
Puncture methods and blind puncture

There are several ways to get access to the femoral artery or vein, but in our view the safest method is an ultrasound-guided single puncture technique. The principle of access is to introduce your needle into the vessel, so-much-so that you obtain a “flashback” of blood, whereupon you can advance a wire into the vessel lumen. The needle ideally should penetrate the vessel as close to the 12 o’clock position (i.e., most anteriorly) as possible. The wire is used to secure luminal access and to guide endovascular devices into position (sheaths, catheters, balloons etc.). This method is referred to as the “Seldinger” (or over the wire) technique, in deference to the interventional radiologist that to who described this method in the fifties.

The “flashback” of blood is important to observe as this tells you a lot about the vessel you have punctured, as well as the state of your patient. A flashback of cherry red pulsatile blood is clearly arterial; however, that is rarely the whole story. In the setting of a bleeding patient, who is hypotensive, the pulse may be weak and the blood may be dark or non-pulsatile. It is important to hold your nerve in such circumstances and to proceed with obtaining access in the vessel you have punctured. If you have punctured a vein – then use it for IV access (both sampling and resuscitation) – your team will thank-you. A venous puncture is usually dark and continuously flowing.
Remark:
» Yes, it’s bleeding from the needle and you lose some drops until you get the wire in. This is negligible now and usually not more than some 10-20ml blood. So do not get stressed now, continue and get the wire in! As long as blood is flushed out, you are in the lumen.

In trauma, the majority of clinicians would use a big needle (18G) with a reasonable sized wire (0.035”), but you could consider a micro-puncture set. This generally consists of a 21G needle, followed by a narrow 0.014” wire. In the bleeding patient, some experienced providers would encourage the use of the larger needle (18G), as it provides a more brisk and re-assuring flashback of blood – making it more likely that you have performed a “good” puncture and will secure access easily. The use of a micro-puncture set can be challenging as the flashback is often less brisk. We can’t get a consensus on that yet, but at least for REBOA it seems that the big needle wins.

Tips:
» Make sure your needle is clean and washed with sterile water after every puncture or change needle! Make slow movements when you puncture. and once there is a flow of blood, try not to move the needle and get the wire in. You don’t have flow suddenly? You are not in or against the vessel wall. Manipulate the needle slowly and carefully to restore flow. Not sure? Go to plan B (the other side? ask for help?)

In terms of the puncture, there are two main methods described

Single wall puncture: This is probably the most intuitive technique, where the needle is introduced at around 40-45 degrees to the vessel. Remember that due to this angle, the skin puncture and vessel puncture are not at the same location! That is why we recommend staying 2 cm distal to the inguinal ligament. Once you see the flashback, lower the hub of the needle somewhat to bring it near parallel to the vessel and advance a couple of millimeters (different ways to do it. Some of us do not move the needle when there is good flow). Keep the needle stable, confirm a constant flashback of blood, and advance your guide wire into the vessel. Yes, it is bleeding through the needle, but this is a negligible volume of blood and you must be sure that you are in the vessel! The risk of this technique is that, if the needle has not cleanly penetrated the anterior vessel wall, when advancing the guidewire, it can trav-
el into the media of the artery, dissecting the arterial wall. This can create a major ischemic problem, especially if you follow the wire with a sheath. The “quality” of the flashback is key to avoiding this; if it is clearly strong, then the risk of dissection is likely minimal...perhaps easier said than done in a hypotensive trauma patient.

**Tips:**

- Try puncture on different training models (plastic, simulator or whatever). It will give you an idea how it feels when you are in with the needle and how the wire feels when advancing!
- **Never force you wire in.** It should glide in and if it does not, you are not in the luman.

**Double wall puncture:** This is a slightly less controlled method of arterial access – when the flashback is observed, deliberately advance the needle until the blood flow stops. Then reduce your needle angle (as described above) and withdraw slowly. If you are using a small syringe with the needle, pull back on the plunger of the syringe to apply slight negative pressure. After getting a flashback again, advance the guide wire. The needle is more stable in the vessel with this approach, so it may prove a more useful when employed for access of small or collapsed vessels. Although passage of the wire through the artery is a concern with this method – it rarely occurs when done correctly. More common perhaps is the risk of posterior hematoma made from the posterior puncture hole – which can result in retroperitoneal hematoma.

**Figure 9 1-3:** Puncture in an elective endovascular case: Palpation and orientation. Needle 45 degrees in; when blood flow is stable, the guide wire is inserted, while the needle can be redirected to a more horizontal position.

More material and videos can be found on [www.jevtm.com](http://www.jevtm.com)
So, to summarize about blind puncture:

The idea is to locate the vessel with your fingers and puncture as mentioned above. Blind puncture is not optimal, but knowing how to do it might save you when the US is not available or in panic situations…

Some of us are using blind puncture as routine in acute situation, but we do recommend US if possible.

**Cut-Down**

Arterial or venous cut-down – or open exposure of the vessels can be an approach of either first or last resort – Some providers use this procedure as the first resort in the critical trauma patient. If you think that a puncture will be difficult, it may be prudent to go straight to a cut-down. Do not try and do something that you think will have a low chance of success in a critical patient – get the odds on your side – cut down early is a good advice.

When conducting open cut-down it is important to remember **this is not elective groin surgery**; this is a dying patient. In a crisis, accept that there may be no time for optimal sterility or local anesthetics; however, if you can have a pre-prepared cut-down pack, which has everything, then all the better. Get a surgical knife, do a 5 cm longitudinal cut on the medial-central side under the inguinal ligament, and get down with the knife or Metzenbaum scissors, while palpating your way to the CFA. When you have dissected down onto the artery, it can typically be palpated and, ideally the anterior wall can be visualized for puncture. You do not need full proximal and distal control now; puncture the artery as described above, and get a wire into the lumen. A small self-retaining surgical retractor often helps with the exposure.

**Remark:**

» Let us add a word of caution – this might be a stressful situation and you should avoid doing any further damage! You dont want to have a new arterial bleeding or dissection now!

**X-Ray guided puncture**

Another described technique that may prove useful to know involves the use of portable x-ray (static images) or fluoroscopy (dynamic images) to help guide the puncture; however, such support is rarely available quickly in acute...
Figure 10.1-7: Cut-down arterial access on a cadaver model from left to right. Dissection by landmark and palpation, exposure of the anterior vessel wall. Puncture by Seldinger method, wire and sheath. The puncture done here is percutaneous but can be done directly in the anterior vessel wall.
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**Figure 10.9:** Cut down REBOA in a trauma case. Seldinger technique used. From left to right puncture, wire, sheath in place. Last photo shows suturing of the artery to remove the sheath.
situations. X-ray imaging is used to locate the femoral head (caput), where the artery will be on the medial side, mid-caput – that is your puncture site! X-ray imaging can be used as an adjunct to support both percutaneous and open access and has the advantage of allowing the procedures that follow to be conducted with x-ray guidance. It is mainly used in the angiography or surgical suite but can be used in the ER in select settings.

**Comment:**

» When using x-ray guidance in an emergency situation, do not forget radiation safety. The ER (or OR) often has a lot of people coming and going, and not all will have lead ware on. Use any ionizing radiation sparingly and communicate with your team before you “press-the-button” to ensure that all precautions have been followed. In some centres, we all wear protection gear when entering the surgical suite with trauma cases.

**Ok, you are in? What to do and what to use now?**

Once you have obtained needle access to the vessel, **do not move the needle** and get the wire into the needle and vessel! Keep your left hand on the patient’s body to maintain a secure and stable needle position. The choice of wire is important as they all have risks and benefits. A safe wire is a short 0.035” “Starter-J” wire, which is introduced straightened; the “J” tip re-forms in the vessel, presenting a benign profile when advanced. A more advanced option is a Bentson, which has a straight, floppy tip,
but has a greater risk of side branch cannulation – ideally, this wire would be observed with x-ray guidance. **Advance the wire slowly and stop if there is any resistance.** You must “feel” the wire, as sometimes you may not see it, if you do not have fluoroscopy. Before the wire gets into the needle, you might change the needle angulation to be more parallel to the vessel, and continue checking for resistance. If things do not feel right, use available imaging adjuncts, such as x-ray or US, to help you.

Once your wire is in at least 20cm, it is time to take the needle out and position the sheath. **Ensure that the sheath diameter is big enough to accommodate what you are planning on doing** – a 4 or 5Fr sheath will permit most diagnostic maneuvers, but a larger size is needed for stents and balloons (>6 or 7Fr). Remember to check that the sheath has been prepared properly before insertion – in an acute setting, it is best to do it yourself! Generally, a sheath comes with a dilatator and both components need to be flushed with sterile saline before inserting the introducer into the sheath. Make sure the introducer “clicks” into the hub of the sheath – you do not want the introducer to be pushed out of the sheath as you advance it into the patient.

You should not use long sheaths (25-30cm) without confirming by fluoroscopy or ultrasound (due to risk of dissecting the aorta), so use the short
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ones (11 cm usually). Guide wires that have advanced smoothly may not be positioned in the iliac or aorta – there is always the risk of an aberrant side branch cannulation. A short sheath should permit safe access into the common femoral and external iliac, but not beyond. Short sheaths are the safest choice in blind cannulation in the ER. Once your sheath is inserted, this is your entry to the vessel – take good care of it!

So, now you have a 5Fr (or 7Fr) sheath in place – great, you have a vascular access. Do not forget to flush it with sterile saline and now you can use it (upgrade for the REBOA or fluids, or just connect to the blood pressure module for monitoring). Take a skin stapler or do a 3.0 skin suture – just **make sure it stays in place**! Do not forget to secure the sheath with a suture, staples or a viscous tape at least before moving to another department (CT/angiography suite/OR) or connecting to an arterial line. This is crucial as iatrogenic withdrawal might cause severe bleeding that you cannot afford now! Do not forget to **inform your colleagues** about the access – which sheath goes where if there are multiple devices. If the sheath is not to be used in the coming hours, keep it in connected to the arterial blood pressure set, or flush it with around 10-20 drops/min (or just a slow flush) saline to prevent thrombus formation.

Here comes a table that shows what you might need for simple femoral artery or vein access. You should have multiple sets in place since you might need both arterial and venous lines and both for possible failure. The costs

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**Figure 13.1**

**Figure 13.2**

**Figure 13.3**

**Figure 13.4**

**Figure 13 1-4**: Preparation and sheaths in place (5Fr) in trauma patients and acute bleeding patient before laparotomy.
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are not dramatic and every intervention department/vascular department can help you pick them to be available in the trauma bay. We recommend having an “ACCESS kit” and with it, separately, a “REBOA kit”.

**Your vascular ACCESS kit**
(should be marked as one)

- Local anesthetics (Carbocaine) and 2x10ml syringe/needles
- Puncture needle (18G or another that can take the wire)
- Standard wire (i.e. Cook) or Bentson wire (0.035inch)
- 4-5-7-10 (and 12) Fr sheaths (i.e. Cordis or Cook) (>12Fr for certain REBOAs)
- Sterile water and 10-20ml syringe
- Skin stapler, 3.0 skin suture and skin tape
- Simple drape (with hole preferred)
- Contrast material and some extra 10ml syringe
- REBOA kit (different companies available, with different sizes of sheaths)

**Tips:**

» Build your own kit based on what you have or your experience. Keep it fresh and available at all times. You and the team must know what is in it and how to use it!

**Troubleshooting Access**

You think you are in with the wire, but you are not certain? Take a small catheter (such as a Bolia catheter, which is a small, 4Fr short catheter, easy to use) and push it in over the wire to verify that blood is coming out, or
that contrast is seen on angiography if available. Than push in a 0.035 wire when you know you are in the lumen and to upgrade. Get it up, take out this small catheter and position a sheath. Any resistance should raise suspicion of malposition. This small catheter will usually not do major damage to the vessel, even if dissected, but be careful. If there is a problem, try a new puncture, use the ultrasound, or ask for help from a colleague who has just arrived. Don’t waste time! You need this access now. Your colleagues are busy intubating and getting brachial venous access. The patient needs you now, so take a deep breath, a new needle, and get the work done! You might even leave a failed introducer in place for now. You can take it out later. If you have taken out the needle, compress with your hand or ask someone else to do that, and change your strategy.

What about the timing of the vascular access?

If you feel your patient is hemodynamically unstable, now is the time for vascular access. Even if the patient has no obvious ongoing bleeding, consider femoral access, EVTM has a lot to offer your patient. Especially if he deteriorates later on.

Some decisions can be made even before patient arrival, judging from mechanism of injury, vital signs, and evaluation by paramedics as reported before arrival. If your patient has good vital signs, getting access might be easy. However, some hemorrhagic shock patients are compensated at the early phase. Your patient seems “stable” looking at blood pressure, but might have ongoing bleeding and collapse within the next few minutes! As we said before, an arterial sheath is useful for various reasons, such as arterial invasive pressure monitoring, access for IR or REBOA, and, of course, you can take a blood sample. Don’t hesitate to get early access. Do it while the patient is being intubated or during primary survey by the ATLS (anyway, nobody is working on the inguinal area at this time point).

If you judge that your patient not an “easy access case”, you can ask your colleague to support you on the other side and place bilateral sheaths. If your patient has a pelvic fracture and embolization is required, bilateral access will reduce your procedure time. If the patient needs REBOA, arterial pressure monitoring from a counter side sheath is helpful to assess distal perfusion during partial occlusion (pREBOA). It will be difficult to position another
It is all about the vascular access

Figure 16: REBOA in place under T-pod pelvic binder. The patient has also a femoral 5Fr sheath on the left side.

Figure 17: Manual compression and Femo-Stop (St. Jude Medical). Most of us will use it up to 8Fr sheath size but it has been used even with ECHMO 18-20Fr sheaths. Be careful and think before using it: do I trust this to work in my patient?

arterial sheath after REBOA insertion. You will no longer feel an arterial pulse at the patient’s groin. Therefore, if you consider using REBOA, try bilateral accesses at both groins simultaneously. You can stabilize your patients by REBOA and embolize for pelvic fracture from a contralateral side introducer. If using a T-pod or any other pelvic stabilizing instrument, make sure you puncture site can be seen. Lift the T-pod a bit and make room. Let everyone know that you have a sheath there.

How and when to remove the sheath?

Well, the easiest answer would be: when the patient is hemodynamically stable, with a normal coagulation profile and needs no more interventions. The problem is that you never know. It might be a venous bleeding, or something else missed on CT like intermittent bleeding. We have seen stable patients with no ongoing extravasation of CT that had later major bleedings! A small-size sheath (5-7Fr) can be placed overnight (sometimes for several days, but we do not recommend such an approach). Large size sheaths (10-12-14Fr) should be removed as soon as possible after essential procedures to avoid ischemia and thrombus complications. But, in patients who are unstable, you can leave the sheath in place if you make sure you flush it as mentioned previously. Assessment of the peripheral circulation should be done hourly (!) and before you remove the sheath, aspirate blood. If you see a clot on aspiration, think thrombus and potential embolization. In this setting, it is
best to go on with open femoral artery exploration and embolectomy if needed.

**Word of caution:**

» A sheath is a source of emboli/thrombus as long as it is there...

When you remove the sheath, you can use one of several different methods: external compression (by hand or device), closure device, fascia suture, or direct surgical repair.

**External Compression:** This is appropriate up to a 7Fr (some say 8Fr) sheath size, and can be accomplished manually or via a device. However, if the patients become coagulopathic, there is a risk of re-bleeding. Make sure that your staff examine the puncture site at least every hour (yes, we repeat that!) and **don’t cover the puncture site in the first hour** (if possible). You don’t want to lose your patient due to femoral bleeding when you have just saved him. Mechanical devices are available, such as the Fem-Stop, but only use these if you are very familiar with them.

**Closure Device:** Various devices are available, such as the Perclose, Starclose, Exoseal, Angioseal or others. All of these devices require formal training and cannot be just picked up and used. If you are familiar with the deployment of such devices, then excellent – but do not give your first patient a high-risk puncture! See IFU of each device to know what sheath size they can manage!
**Fascial Suture:** This is a practical method (formally described in the literature), and it is a useful skill to have. It can be done in the ICU in selected patients and can be used also for downsizing sheaths (e.g., from 12Fr to 5Fr). The idea is to open the skin and feel the femoral fascia. Than place a suture around the sheath with a gliding knot. **This requires training** and we will not describe it here in details. Excellent method in selected situations.

**Direct Suture Repair:** This is a gold standard; although it requires an OR and a vascular surgeon. Formally dissect and control the vessel and place interrupted 5’0 prolene sutures in the arteriotomy. The advantage of this approach is that you can assess the back bleeding and perform an embolectomy if required. You can also do control angiography and get some additional information.

So, again, “if there is doubt, no doubt”- **Do a full cut-down and check the vessel flow.** Use a Doppler at the end to be sure you have good flow. Not sure? Angiography and embolectomy might be indicated. Use open surgery and do not avoid it!

**Upsizing your sheath**

If you decide to place a large endovascular device, such as a REBOA catheter, you will likely need a larger sized femoral sheath. Sheaths between 7-12Fr are used in clinical practice and depend on available REBOA catheter size.
Tip:

» Remember that the sheath can take a certain diameter of catheter or REBOA. If you want to use it for flushing or angiography, you will need a bigger sheath in diameter than the REBOA catheter. It is not always so bad to have a bigger sheath that you can flush. When you really need it, the size of the sheath matters!

Before upsizing, fill up the sheath’s lumen with saline, put the dilator in the new large introducer. Insert the guide wire to the aorta and DO NOT LOSE THE WIRE POSITION! The guidewire should be at least twice the length of the introducer in order to swap the smaller sheath for the larger access device using an over-the-wire exchange technique. Usually you already have one in the introducer kit. Insert the guide wire to the aorta, then the dilator and introducer. When using the dilator, you will feel resistance against soft tissue, but this is ok – do not rush! You don’t want to deviate from the correct way. To avoid kinking the dilator and guidewire, grab the dilator 2-3cm above the skin. Twist the dilator, and keep moving the guide wire to and from. Don’t push the dilator or introducer blindly. Moving the guidewire smoothly means the dilator will follow the guidewire appropriately. Gently pushing the dilator in a stepwise fashion will also help you (some of us call it the “Parkinson maneuver”).

**As a word of caution, watch out for hydrophilic coated guidewires**, as they can easily migrate without your knowledge during these maneuvers. Your partner should grab the guide wire so as not to change its tip position. Unfortunately, you must perform all the procedure by yourself, to make sure the wire will not be removed when you withdraw the dilator. This is the most dangerous point. Unexpected removal of the guide wire will induce hemorrhagic disaster.

**Figure 20.1-3:** Upsizing your sheath. You change your sheath over a wire.
Maintaining a vascular access

You really do not want a clot in the sheath or around the catheter. After insertion, flush with saline. If you use this sheath for angiography or embolization, periodic flushing will help you avoid any clot in the sheath. We might be repeating here, but it is for a reason – been here, done that! Cloth formation might be a problem.

The situation becomes more complex when you have no flow in the vessel and a large sheath. This is the case during REBOA, where your sheath might occupy the entire lumen in the CFA lumen – such an arrangement is at high risk for clot formation and ischemia of the leg. Slow and continuous saline flushing by pressure bag might help prevent the thrombus. Local heparin might be useful but is problematic in trauma/bleeding patients due to general coagulopathy, and we cannot yet get a consensus on that, so make your own choice. We can say that you should remove the large-bore sheath as soon as possible. Again, if you don’t want to remove it, take care of it as your best friend. It might save you that night, but when the next day comes, it might bring you some problems. So, again take care of it!

There are some advanced methods to downsize the sheath with the help of fascia suture. You can use this method to maintain a vascular access with a 5 or 7Fr sheath but it is doubtful if it has a place in trauma management. Take it out when you don’t need it anymore.

Other vascular accesses (veins, brachial, axillary)

As we mentioned, CFA access is essential for severe trauma patients. But at times your catheter will be placed in the femoral vein, unexpectedly. Don’t remove it! Femoral vein access gives a good route for resuscitation fluid. Always remove some blood for lab work if you can, just take a 10ml syringe and aspirate. However, if your patients have severe pelvic fracture, assume common iliac vein injuries. Femoral vein access will not work well, but in selected cases might be used for endo repair as well as being your highway to the vena cava and liver (via portal vein) or even a vena cava filter later on. In general, though, femoral vein access is safe and can be removed with manual compression, even with very large sheaths (some of us do manual compression on 18-20Fr venous sheaths).

The subclavian vein can be used as a good venous access without removing
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Of course, you must assume the risk of iatrogenic pneumothorax. The axillary vein can be accessed by ultrasound puncture. We will not deal so much with these access possibilities, since they are widely used and you can read about them elsewhere.

On the arterial side, the brachial artery is an option. There are cases of REBOA performed via brachial or axillary access, but the majority of the modern endovascular surgeons dealing with trauma prefer the CFA. Why? Well, the brachial artery is easy to expose (not so easy to puncture, as it is small, around 3-4mm). The problem is that you have to manipulate it across the subclavian artery into the aortic arch and then downstream to the descending aorta. For this, in general, you need fluoroscopy and it is time-consuming to place the REBOA using this route as well as problematic in unstable patient requiring airway attention. Dealing with the arch might be challenging and there is a risk of emboli going up the carotid. You will find some more information and illustrations in other places in this manual.

All methods have merits and demerits, and you should use the method you are comfortable with. Initially train on models, progressing to elective arterial punctures, before you throw yourself into the ring with a bleeding and hypotensive patient. Access, as part of the EVTM concept is vital – do what you do best and if a colleague next to you can do it better or faster, let him or her do that. This is no time to play around, you can do it next time!

Figure 21: The aortic arch with wires from the femoral artery and brachial artery. Observe the tracheal tube and the anatomical complexity. An elective TEVAR case.

Figure 22: REBOA with axillary access. Most of us do not recommend this approach in trauma, but at times it might be useful.
When some of us teach REBOA or discuss these issues, we recommend as a first step to do femoral A-lines or small sheaths in some patients (elective cases or trauma cases when clinically indicated). Succeeding with femoral artery and vein placement of sheaths will make it much easier for you to place a REBOA when needed. There has been a tremendous amount of publicity regarding REBOA these days but remember: “It’s not the REBOA, it’s all about the vascular access”!

**Some summarizing tips:**

» Get your access early; Some of us think that every major trauma patient should get it during the primary survey as AABCDE!

» Get a femoral vein access as well if possible and time allows it.

» Take care of the access – suture or hold. Communicate about it. You have a powerful tool in your hand.

» **Think before using it** – what do I need. What's best for the patient NOW?

» Don’t forget the risks – embolization, bleeding, dissection etc.
Notes
Chapter 2

The bleeding patient and your tool kit
What and how to use?

Practical tips and tricks

Yosuke Matsumura, Märten Falkenberg, Martin Delle, Mikkel Taudorf, Lars Lönn and Tal Hörer

You just had a call from emergency services. Motor vehicle accident, patient seems in deep shock and is on his way in. Estimated time of arrival is 10 minutes. It is late in the evening, weekend.

How to prepare even in the Emergency Room?

Ok, the first thing is to take a deep breath. Evaluate the situation and consider who you need. If your institute has clear routines, activate them. If not, which resources are available, who is in the team, and who will be the team leader. Act upon that.

Arterial access

As we have mentioned earlier, the first active step in EVTM is to insert a common femoral arterial sheath. You might have already used a small diameter (4 or 5Fr) CFA sheath in the ER. You have more catheter choices via a larger sheath of 5-7Fr, and therefore recommend a 5Fr short sheath and a J-tip guide wire as the start kit. There are many types of wires, but try to get something you can work with, not too stiff and not too soft. Standard (e.g., Cook Medical), Schneider wire or Bentson wire might do. Check with your colleagues in radiology or vascular surgery, they can guide you. You will need
to set up a kit for access and a kit for REBOA (as we mentioned before). Some of the sheath kits include a short wire and this can be also used for access. The most common sheaths are short (7-11cm), which might affect usage of REBOA later on, but, for vascular access, they are great and will minimize the risk of iliac dissection. You can choose to have bilateral accesses and place a second sheath on the contralateral side, for angiography while the REBOA is in the ipsilateral sheath. Also, bilateral pelvic embolization can be performed with a shorter procedure time.

So, a short 5Fr sheath is your first access tool after a successful puncture. However, with growing experience, we recommend starting with a larger 7Fr sheath when REBOA is considered a must. Some of us use a 7Fr sheath on any patient showing a hemodynamic instability or a major trauma mechanism. Remember, it is an early move so it is safer to deploy a small sheath (4Fr/5Fr) if you do not know if it will be used or not. Some of us use a 4Fr sheath that is used only for blood pressure measurements when not upgraded (arterial line). Femoral access before a circulatory collapse gives you a safe entry for REBOA. The majority of us though would start with 5-7Fr, as mentioned above. This is because you can use more tools (as embolization catheters) with 5Fr, and the potential risk of the size difference is minimal. Note though, that the authors here are experienced in endo/REBOA methods.

Figure 1.1: Introducer kit, Puncture needle (by Cook Medical and Cordis, with permission). There are many products on the market and these photos illustrate how a kit might look like.
Tips:
» Get a kit with all you might need, mark it and have it available.
» Get to know what you have and how to use it.
» Staff working with you should also know its content, where it is stored and how to use it.
» Maybe you should do some team training in the ER...

Oops, you punctured the vein? Slow dark blood flow without pulsation? Use the puncture as a venous access. Do not remove it; get a 5-7Fr sheath in instead. Just use it for fluids (blood) as you may use the internal jugular or subclavian (axillary) veins for access. Your 5-7Fr access is a massive transfusion tool, and you can always upgrade it to > 9Fr, getting an even higher caliber massive transfusion tool. Just get the sheath in and go on to the artery (you don’t want to stand with hand compression on the vein now when you are needed for other things). We should mention again that during CPR (or when there is no flow in the CFA), there will be no pulsatile flow, and the color of the blood can be darker, which my be misleading. Anyway, if you have it in, keep it in, and decide what to do with it later on.

Tips:
» Don’t remove your sheath until the panic is over. Do it in a “safe” place (ICU/OR).
» In the femoral vein, use a bigger sheath. The risk of bleeding after removal is relatively low and it is a massive transfusion access.
» Reconsider if there is a potential ipsilateral iliac vein injury before using vascular access on the injured side

General on upgrading to a REBOA sheath
If your calculated risk decision is that it is time to use REBOA, you will need to prepare for it. It depends, of course on where you are (pre-hospital, ER, hybrid suite, surgical suite) and time is your limit. Upsizing from 5Fr to an appropriate (7-14Fr) sheath should be performed over a stiffer guide wire, as the larger sheath will be easier to insert and the REBOA balloon requires the stiffness to be located safely. So, either you do a puncture with a 5Fr sheath and upgrade to an appropriate sheath that depends on your REBOA, or if you have already a low profile REBOA (Rescue Balloon or ER-REBOA), you can puncture directly with a 7Fr and use it for REBOA.
The bleeding patient and your tool kit: What and how to use?

**Figure 2:** Mobile vascular access/REBOA trolley in the surgical department, Örebro, Sweden. Used in any iatrogenic or gynecological bleeding in the OR, or in rAAA for vascular access and aortic balloon. Should include all basic tools for percutaneous and open surgical cut-down vascular access.

**Figure 3.1-2:** The entrance to the surgical suites in Örebro, Sweden. Note the three angiography tables ready for use. Surgical suite with hybrid capabilities (right). You can build a very simple hybrid room with just a few “accessories”. We call it “Semi-hybrid suite”.

**Tips:**

» Get early femoral arterial access with a 5Fr sheath and upgrade if needed.

» Remember, REBOA is just a bridging tool and will not replace definitive treatment! Don’t delay the treatment if you cannot get access; change strategy and move on.

So, it depends on where you are and this affects the choice of the “tools” for access and REBOA. In the ER you have to build this kit while in the hybrid suite it is there (among other products, so you need to be able to find it fast!). You might want to fix a mobile trolley in the hybrid suite, so you can take it to other places if needed (i.e., iatrogenic injury in the orthopedic surgical suit or post-partum bleeding). The different REBOA products are discussed elsewhere.

**Tips:**

» Decide if you want one REBOA kit with everything and then build one. Some of us have two kits: one for vascular access, and one for REBOA.

**Figure 4:** Trauma patient (penetrating abdominal injury) in the surgical suite. The C-arm ready to use if needed. The patient is placed (always) on a sliding or angiography table. The C-arm, when not in use, is “on” and stays at the side with its monitors, ready-to-use.
Ultrasound and/or CT

Are you familiar with ultrasound? You will use ultrasound (US) in the FAST exam, of course. If you prefer to access the CFA by an US-guided puncture, the vascular probe (linear) gives you a clear image. The US or FAST machine should be “on” and the linear probe available. We will discuss the US puncture in other sections, but it can be used for vascular access, REBOA or wire arterial lumen confirmation and much more.

Experiencing difficulty in getting your access? This is rarely a problem in experienced US guided hands, but if it happens, do not hesitate to do a cut-down. Remember to have your equipment ready. An open vascular access kit with surgical knife, scissors, retractor and pincett should be at hand. All this basic stuff should be in your “Access Kit” and you should know how to use it!

You have to consider whether to do a CT and how fast you need it. It would be wise to inform the CT staff that you need them (depends on your institute). Some of us inform them about every major trauma and get a CT scan available directly, but in other places it can take some time. Today, with modern imaging, scan time itself is short (up to one minute for a whole-body scan). The time-consuming matter is the transfer of the patient to and from the CT. These patients require many tubes, monitoring lines and people around them. Before and after scanning, how long does it take to fix and move these lines? Make sure that you know what to do with all the lines and monitors, and use a transfer bed, if possible with place for the equipment. Some of us will not use FAST but can get a very fast CTA (even in the emergency department, door-to-door), where you can get much more information on the patient’s status and exclude, for example, cerebral bleedings. We cannot reach a consensus here. Practice what you think and what your institute allows.

Remark:

» Remember that time is running, and you don’t want to be in the CT scanner when things happen, unless you have a hybrid suite in your trauma bay (a CT-on-rail hybrid solution). Remember: CT does not stop bleedings...

» Even in the CT scanner, plan your moves, where to go, who you need, etc. Always have a Plan B.

Training of transfers can be advocated as this might reduce errors and time of transfer. The CT protocol itself should be a fast one. You can use different
protocols but you need both an arterial and a venous phase (with a 60 seconds’ delay between the phases). Some of us use a “trauma CT protocol” or “massive bleeding protocol”, with a head-to-knees one scan with contrast, and then, 60 seconds later, a new scan. A majority use highly concentrated contrast media with high volume (e.g., 370mg/ml Visipaque, 100–150ml total volume). Talk to the CT staff. They can adjust the protocol. The CT time today, with both phases, will be less than three minutes! But, you need to prepare the patient and transfer to the CT.

**Tips:**

» For fast CTA you need fast, safe transfer; train on it and get all the things on the patient’s bed that you can move quickly. Take good care of the catheters and tubes!

» Get a good trauma CTA protocol (trauma CTA) and cooperate with the CTA staff. In major trauma, do not use an elective CTA protocol.

» Monitor your patient at ALL times during the transfer and procedure.

**And a word of caution:**

» You don’t feel the patient should go through the CT, too unstable? Take him to the place you feel is best in your hospital and solve the problem! CT should be done only if you know what you are doing, on the proper patient and with a proper protocol!

» What’s the plan? where should we be after the CTA? prepare the next step now!

**Figure 5.1-4:** Transfer to CT. The logistics may be complicated. Good transfer kit/bed and training as well as good communication might solve many problems. The patient must be monitored during transfer and examination, which is challenging.
In the Angiography Suite/Hybrid OR

Guidewires, catheters and sheaths: As we mentioned above, a femoral sheath might be placed in the ER, but again, it depends on where you work and your settings! When you place the sheath in the angiography suite, you can see your wire using fluoroscopy. You might decide to use a long sheath in the angiography suite (>11 cm). A long sheath will make your catheter operation smoother, particularly in atherosclerotic and tortuous arteries/older patients. Your advance with longer sheaths in the vessels might save time in the long run due to fewer obstacles when exchanging wires and catheters. Some of us use a 7Fr sheath and then upgrade to longer and larger sheaths, depending on the situation. You should know that in young patients in hemodynamic shock, even small sheaths will block the flow (occupy the whole vessel lumen), and with longer sheaths it is the entire femoral and iliac length. Something to think about and bear in mind when you are there and when you want to take them out!

The choice of type of sheath is up to you: what do you have, what are your hospital routines, and what do you feel comfortable with?

Guidewires: Guide wires are fundamental tools in endovascular procedures. You should know that there are different lengths of wires. They are used to change the systems you are working with and to guide you to the target. For example, in REBOA, short wires are enough (about 150cm) but longer wires are necessary for exchange when working in the thorax region. Especially in tortuous and dilated aortas, a 45-60cm sheath (12-14Fr) in combination with a stiff guidewire (Lunderquist, Back-up Meier or Amplatzer, around 260-300cm) gives the necessary support for the occlusion balloon in REBOA. Tortuosity is less of a problem in young patients but is a major issue in older ones.

When using fluoroscopy to place the catheter in the target artery, angled nitinol hydrophilic guide wires (0.035inch) may be the standard for most people. When you want to navigate to a visceral organ, 150cm is long enough. If you expect to exchange the catheter over the wire, you need at least 180cm (depending on what you have and are going to use). However, longer guide wires, 260cm or longer, are inconvenient to handle. Some of us would recommend long wires at the start to prevent problems. Don’t expect any clear consensus here. These things will come with experience!
Next, you have to decide on which angiographic catheter to use. There are many kinds. Expert opinions may be inconsistent about the best or preferred catheter. However, you should be familiar with three types (only a suggestion, there are many types!): Berenstein, Cobra, and a catheter with a reversed tip like Shepherd’s Hook. Using one of these three types, you can exchange and cannulate most branches below the aortic arch. The important thing is that you need support from the opposite aortic wall when navigating into branches; thus, in elderly patients with larger aortas you need wider loops of the catheters.

In principle, the Cobra is useful for branches going upwards, cranial, from the aorta, and the Shepherd Hook is handy for branches heading downwards. Of course, there are many other catheters: Headhunter, Michaelson, Simmons, SOS Omni and VanSchie just to mention a few. Catheters work in different ways depending on variations in the aorta and their different forms.
Most likely you will change tools on your way to the target. A straight catheter (like Bernstein) will allow a smooth exchange (but, as said, you can use others). An angulated catheter (as Cobra and others), will allow your wire to get into the artery you aim for. There are some catheter sheaths that are long and provide support to embolization or other angiography procedures (all major companies has some of these products). You will get to know them if you train in a IR or vascular unite.

If you try to enter the branches of the aortic arch (carotid, internal mammillary, subclavian or axillary artery), constant perfusion to avoid thrombus in the catheter might be recommended, in principle. However, it consumes time and its use depends on whether your patient is life-threatened or not. Some of us do not use this method, and a majority just flush with saline in the sheaths. If you are not trained in angiography, just aim to get as fast and safely as possible into the target vessel and embolize it.

Tips:
» We are getting into more advanced angiography methods and you should be aware of it. Train if you can. Call someone experienced if there’s something you cannot do. Don’t play around with bleeding patients! Probably, there are people around you who will do it very fast and safely!

Figure 7.4-8: Some examples of catheters in different forms as well as sheath catheter (courtesy of Cook Medical).
**List of some common catheters and wires that can be used in emergency situations:**

- 5-7-10Fr sheaths
- Standard Cook or Bentzon wire (Standard catheterization)
- Terumo 150cm (or longer) floppy angled wire (selective catheterization)
- Terumo stiff wire, Lunderquist or Amplatzer wire (support for ex occlusion balloons)
- Berenstein (short and long 45-110cm) catheter (selective catheterization and exchange)
- Cobra (selective catheterization)
- Shepherd Hook, reversed tip (selective catheterization, angulated take-offs)
- kink resistant sheaths for catheter support (6-9Fr) 45-90cm
- Sheaths for REBOA support 45-60cm 12-14Fr (depends on your REBOA catheter)

**Microcatheters:** If you need to go further, more peripheral, micro catheters and micro guide wires will be needed. Various companies offer you many kinds of microsystems. Difficult to say which is the best in which situation. But if you plan to use coils, you have to consider an appropriate combination. If you want to select a small diameter vessel (particularly in GI bleeding or peripheral liver), you should use a “selective” type (2.7 or 2.8Fr) of microcatheter. In general, a microcatheter system is put into a 0.035 catheter that has been placed in the desired main branch from which the more distal bleeding branch can be reached. There are some new smaller catheters on the market and your choice depends on your experience. We will not get into details here as these are advanced methods that should be used by experienced people in our opinion.

**Figure 8:** Sheath (black arrow), macro-catheter (black and white arrow), and, inside, a micro-catheter (red arrow) used in an elective case of embolization.
Embolization – what can be used and where?

Your catheter is in the target vessel. You check by contrast injection (fluid a bit diluted, 70/30) that you are near the target. Which embolic material do you use? You have many options. In a trauma setting you must consider “time”, “coagulopathy”, “difficulty of the material”, “your skill”, “catheter position” and “bleeding point”. You also have to know – what do you have? What is best for this patient? **What can you do?** As a general principle there is a balance between more proximal and “safe” embolization (plugs, coils), which lowers perfusion pressure in the bleeding area, and a more effective but risky distal embolization when using smaller particles. These might cause ischemic damage in the target area. Embolization in general may cause target organ ischemia and it is better to do super selective embolization if possible. We will discuss different products and possibilities. Their usage depends on experiences and availability as well as the situation.

**Gelatin sponge particle:** Gelatin sponge (GS) is probably the most common embolic material in embolization globally. Particularly in trauma patients, you can prepare and embolize quickly and it is cheap. GS is a kind of temporary embolic agent. It is easier and quicker to place than coils, and it is easier to control than liquid embolization agents such as NBCA or Onyx. GS is appropriate for pelvic fractures and liver injury (without AV shunt). Some example are Gelfoam, 20×60×7mm and Spongel 2.5cm×5cm×1cm. GS is “solved” in a contrast-saline mix of about 50/50. The volume depends on the amount of GS used.

There are two types of GS preparation: Cutting method and pumping method. With the cutting method, you can make GS fragments in any size you want but it takes time, up to around 5 minutes. Usually you slice the GS cube into 2 or 3 layers, and then cut into 0.5mm to 2mm squares. Using too small a particle size will require more GS injection volume, and the small particles migrate more distally, and might induce excessive ischemia like gluteal necrosis. With the pumping method, you can perform the task in a much shorter time, within a minute or so. 5-time pumped is used for a 4 or 5Fr catheter, and 20-time pumped is used for a microcatheter (one reciprocation is counted as two pumps). Is there any advanced evidence for this pumping time? No. But if you fix your pumping time constantly, you will recognize the appropriate injection amount more easily.
Remarks:
» If some of the tips here feel too advanced, your feeling is probably correct. Some of these methods need advanced training and experience.
**Coils:** In general, coil embolization takes longer to perform than when liquid material is used. You will deploy the coil to make sure it forms tightly in the vessel. Coils do not work well in coagulopathy, but you can embolize in an accurate vessel position. The method is usually considered good for gastro-intestinal bleedings, isolation of pseudo-aneurysm, and pinpoint embolization. If the coils do not occlude flow, small amounts of GS or liquid agents can be added, combined with the coils. In life-threatening condition, you will need to choose the fastest and most effective embolic method. There are now available micro coils that are pushable, detachable, and many different types with different characteristics.

**Tips:**

» Check what items are available within your institution and get to know how to use them.

New coils are constantly being designed and put on the market. Pushable coils have been standard, conventional and cheap. However, once you put the coil in the catheter, you can only push it forward. Even if your coil will not form tightly, or is not optimal (under or oversized for the vessel), or is placed in an undesired position, you cannot pull it back. A migrated or displaced coil can cause unwanted embolization and disaster. If you use a detachable coil, you can pull it back or remove it, and start over again. Selection of best coils size that fits target vessels is an art to be learned. Undersized coils lead to distal migration, and oversized coils will not form...
tightly in the vessel. A tip for determining coil size lies in the “+3 rule”. You can measure vessel size in the DSA image calibrated with the catheter size (or in the CTA you did before). You may have a wide variety of sizes, i.e. diameters and lengths. Adding “3” to the vessel diameter gives the proper diameter. If the diameter of the splenic artery is 5.2mm, choose an 8mm diameter. Even if you do make the wrong choice, retractable coils will give you and the patient safety and security. Device development is rapid, so speak to your friends in the IR department. It’s all about collaboration.

**Tips:**

- For selective and super selective coil embolization, use microcatheters. A coil-pusher is recommended.
- You have to choose coils of an appropriate size not only for the catheter but also for the vessel to be treated! Look at the package to find out what size of catheter is needed (or ask someone who knows!). Choose coils that are somewhat bigger than the vessel.
- If coil placement has to be accurate or the catheter is in an unstable position, use detachable coils.

**Vascular plugs**

A vascular plug consists of a tight nitinol mesh and its delivery mechanism is controllable. The plugs are suitable for large and high-flow arteries, like the splenic and the hypogastric arteries. In hemodynamically unstable, high grade splenic injury patients, proximal splenic embolization is acceptable. If you cannot use NBCA or Onyx for coagulopathic pelvic fracture, a plug might be helpful (practically, combined with GS). An Amplatzer vascular plug cannot be delivered through a micro catheter. If you fail to advance the catheter to the target region for any technical or anatomical reason, you cannot use it. Vascular plugs are delivered through a catheter or guiding catheter. The delivery sheath varies in size depending on the size of the plug. The effect of vascular plugs is, as with coils, dependent on whether the patient has coagulopathy. In a trauma setting, you have to consider procedure time. New micro-plugs (3-5-7mm, by Medtronic) can be delivered through micro catheters, and may be very useful as they can be inserted into smaller vessels and plug them fast and effectively.
**NBCA + lipiodol**

N-butyl-2-cyanoacrylate (NBCA) is a liquid and permanent embolic agent. This is the original “super glue”, approved for skin wounds and esophageal varices. Injected into the vessel mixed with lipiodol – lipid contrast – you can embolize even under coagulopathy since its embolization capacity is independent of coagulation status. You can extend the reactive time by increasing the lipiodol part of the mixture, then you will embolize more distally and slowly. So, in other words, this is a fluid to inject. It will go downstream and block the bleeding focus. This is a great tool for coagulopathic patients, and essential for damage control interventional radiology in some centers. However, it is difficult to control the embolized area and length. To visualize clearly, DSA images during fluoroscopy during injection helps to establish when to stop the injection. Your catheter tip might be dipped in the cast. An “NBCA package” will help you in urgent situations. The package would contain a 1mL locked syringe (for final injection), a 2.5mL locked syringe (for aspiration of NBCA first, and then for glucose injection), a 5mL locked syringe (for lipiodol and mixing), a 20mL locked syringe (for glucose), an 18 gauge needle (for glucose and lipiodol), a 3-way stopcock (for mixing and injection), and usually a syringe set for angioembolization (e.g., 10mL locked, 5mL locked, 2.5mL locked).

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**Figure 12.1**: An Amplatzer Vascular plug. There are different sizes to fit target vessels and sheaths. This information is on the package, which includes delivery system information (size).

**Figure 12-2**: A micro-vascular plug (Medtronic). May be useful for medium size vessels for complete occlusion.

**Figure 13**: A micro-vascular plug (Medtronic). May be useful for medium size vessels for complete occlusion.
Figure 14: N-butyl cyanoacrylate (NBCA) preparation. You need NBCA, lipiodol, and 5% glucose. Cut off the plastic tip of the NBCA bottle, then put it into a locked 2.5mL syringe, and aspirate the blue glue (0.5mL NBCA). Lipiodol sets in the 20mL syringe, and inject the appropriate volume needed (if you want to make 1:4 NBCA/Lipiodol, you inject 2mL lipiodol). Mix it by inversion or pumping with 3-way stopcocks.

**Tips:**

» Most of us would consider this is a rather more advanced product that you have to know well for safe usage, but if you know the product well, it is very effective.

» Under coagulopathy or in most urgent situations, NBCA is a fast and reliable embolic agent. But NBCA is difficult to handle. Be aware of distal embolization and complications!

» Onyx works as well in coagulopathic patients (see below).

» Follow IFU!

**Onyx**

Onyx is a polymer that stiffens in contact with an ionic solution, i.e., blood. It contains tantalum to become visible during fluoroscopy. The substance is injected through macro or micro catheters (2.7–2.8Fr, e.g., Progreat, Terumo). The catheter must be compatible with Onyx (e.g., Bernstein catheter). To prevent Onyx polymer getting stiff in the catheter during injection (as should happen when in contact with liquid), the catheter lumen is filled with DMSO solution once the catheter has reached the target area. After the Onyx has been shaken for 20 minutes it is slowly (around 0.3 ml/min as a recommended rate) injected using a 1 ml syringe. As Onyx comes into contact with the blood, when it leaves the catheter tip, it will stiffen and thereby gradually fill and occlude the vessel lumen or pseudo aneurysm. It is important that the injection is done slowly; otherwise Onyx will go with the flow in fragments.
to more distal vessels “downstream”. Onyx, like glue, occludes flow even if coagulopathic, but the drawback is that is time-consuming, compared with, for example, GS and coils in patients in severe hypovolemic shock. One advantage, however is that it gradually fills the vessel in a distal direction, so it might reach areas a few cm from the catheter tip that are not reached by the catheter itself.

**Tips:**

- Check which catheters you have; are they compatible with Onyx?
- Slow injection of DMSO in conscious patients is recommended but might cause spasm and pain.
- Inject the onyx slowly when you are beyond the dead space of the catheter! It might migrate.
- Always consider the risk of embolization when removing your catheter.
- You can do control angiography via the macro catheter during the procedure (you will need a Y-connector)!
- Liquid embolic agents are not easy to use and you should not use them if you are not very experienced with embolization.

**PHIL**

A new embolization liquid that can be injected directly after DMSO, which is similar in this regard to Onyx, but without preparation time. It is currently being evaluated for bleeding control, so it is hard to give more information at the moment.
Balloon catheter and micro-balloon catheters

Balloon catheters might give you strong support in bleeding control. Of course, you can use an aortic balloon occlusion catheter (REBOA) in refractory hemorrhagic shock patients. But long occlusion at Zone 1 might impose a catastrophic metabolic burden: Excessive ischemia and subsequent ischemic-reperfusion injury. If you can identify the bleeding point, change to a more selective balloon catheter (or micro balloon catheter). It will be safer and more effective. In patients with a hemodynamically stable high grade splenic injury, proximal embolization with a vascular plug is standard in some centers. At times, you cannot get as distal as you want and, while considering what to use or to do, you might have other solutions. Temporary balloon occlusion of the splenic artery may be an option. This may allow you to do open surgical repair with balloon bleeding control. Combined with REBOA or a balloon catheter, intraoperative bleeding might be reduced if patient requires surgery. If your patient has an abdominal blunt injury and catastrophic hemodynamics, emergency laparotomy under hemorrhage control with REBOA will reduce the bleeding amount and transfusion, and you can keep the surgical field dry. You may meet a patient with a subclavian artery injury. If you are familiar with catheterization of the subclavian artery, proximal control by balloon catheter might be useful during surgical repair. However, care must

Figure 16 1-2: Iliac balloon for proximal control in a bleeding femoral artery. A PTA (Cordis 16mm) balloon was used and for this an 8Fr sheath was inserted from the Left side. The balloon was inflated just some atmosphere to get bleeding control and open surgery performed (hybrid concept).
be taken regarding potential cerebral ischemic effects due to the subclavian supply to vertebral arteries and the right carotid artery. Balloon catheters can also be used to occlude a vessel during injection of an embolization agent and decrease distal migration as well. These are advanced methods that we will not be able to discuss in this manual. We will discuss balloons in non-aortic locations in a separate chapter.

So, in this chapter we tried to cover the issues of what to use and how in a basic matter. We do not recommend to use any of these methods without proper training and suggest good cooperation with your IR or vascular colleagues. We should also mention here again that you should follow the IFU (Instructions for use). There are probably more tools to use, in different ways.

Think before using endovascular and hybrid tools, and be careful out there!
Notes