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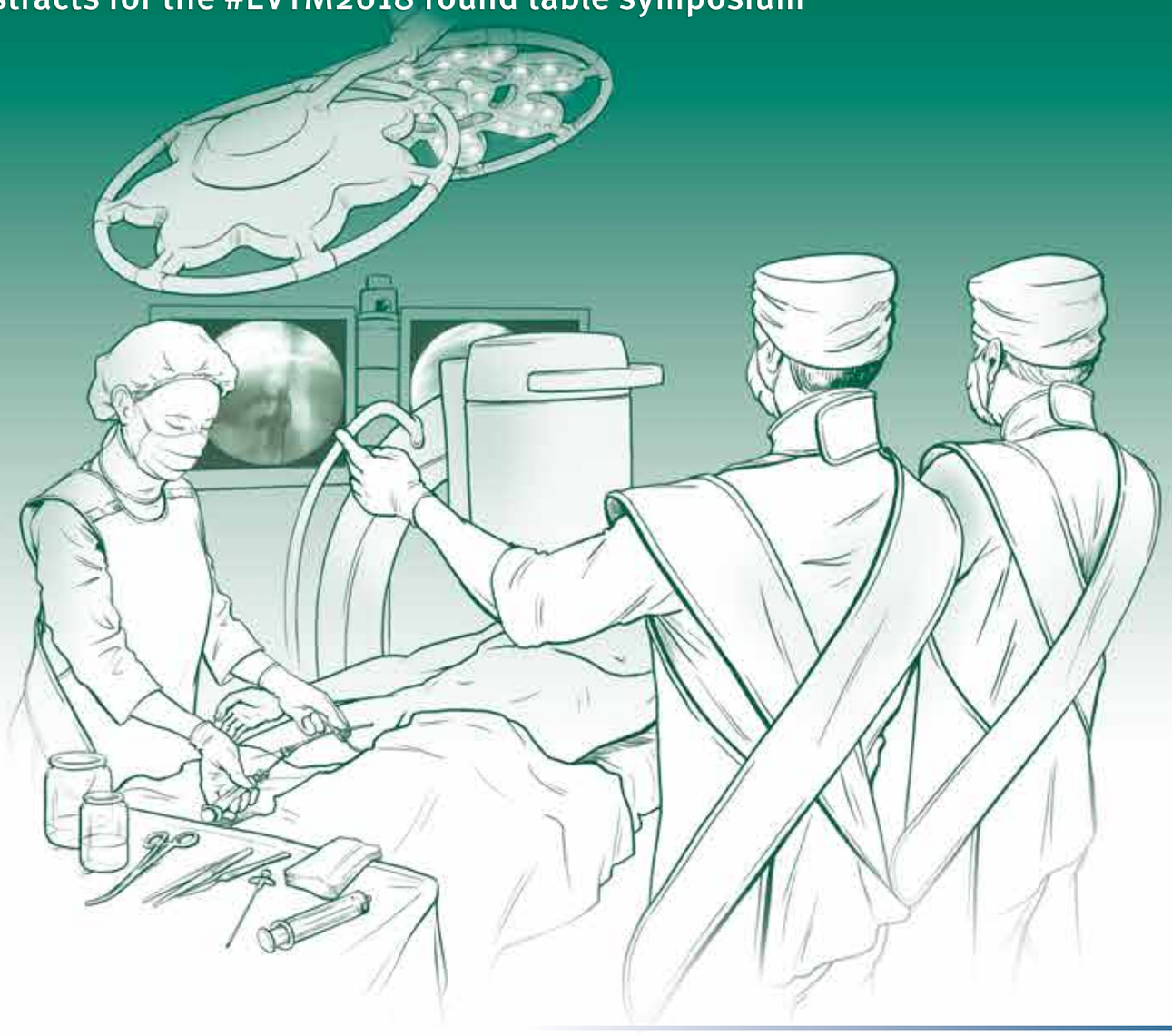
Issue Highlights

Liquid embolization agent to control peripheral bleeders
REBOA in austere combat casualty environment
Fascia Suture Technique for vascular closure after successful REBOA
Acute kidney injury following aortic occlusion
Hybrid approach to blunt abdominal aortic injury
Abstracts for the #EVTM2018 round table symposium



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This is the *Journal of Endovascular Resuscitation and Trauma Management*. We want to provide a truly Open Access platform for the dissemination of knowledge and peer-reviewed research in the field of endovascular and hybrid hemorrhage control.

To achieve this, we do not wish to be bound by medical discipline, country, resource or even the conventional rules of medical publishing. To achieve this goal, we have assembled an Editorial Board of clinicians and scientists who are experts within the field. This project is generously supported by a grant from Örebro University Hospital Research Unit.

We are keen to receive manuscript submissions that present new original findings, review important topics or educate our readers on any aspect of hemorrhage control, where an endovascular technique has been employed. This can either be in isolation or in combination with open surgical techniques (hybrid surgery). For further information for authors, please see *www.jevtm.com*.

As the subject of hemorrhage and resuscitation is a common problem across many medical disciplines, we encourage submissions from all specialties: vascular, trauma, acute care, obstetrics, emergency medicine, to mention a few.

The Journal will publish quarterly and will be truly Open Access. There will be no article processing charges or publishing fees. All articles will be published online and indexed using a digital object identifier. The Journal aims to be PubMed cited by 2019.

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EVTM Society

Join the Endovascular Resuscitation Platform

The EVTM society is a non profit organization that aims to share information on advanced methods for bleeding control and endovascular resuscitation, exchange of data, and cooperation and education. It is also designed to serve as a professional platform for the multidisciplinary approach.

EVTM Society is registered in Sweden, and works in collaboration with the EVTM program at Örebro University Hospital, the JEVTM journal and web platform, and some other institutes.

Vision and Mission:
Our mission is to promote optimal treatment and new methods for bleeding control in trauma and non-trauma patients, and state-of-the-art endovascular resuscitation. This will be achieved by a joint international body that will support the following:

- A web-based free platform for EVTM issues (jevtm.com).
- JEVTM – the Journal of EndoVascular and hybrid Trauma and bleeding Management, which promotes high quality research. It is an open access peer-reviewed journal.
- The EVTM round table symposium, which offers a platform for continuous debate and data exchange.
- Educational opportunities in the form of manuals (Top Stent), courses, workshops, and web seminars.
- Promoting open dialogue and cooperation between societies and organizations, and with the industry.
- Promoting new guidelines and recommendations for EVTM-related issues and protocols.
- Promoting research in EVTM-related areas, both human and animal.
- Promoting PR for EVTM issues, grants, and collaboration with industry.
- Encouraging residents and young colleagues to carry out research on EVTM issues.
- Promoting cooperation and data exchange with other medical instances.

Structure:
The EVTM council, led by the society chair will change membership periodically (i.e., after two years). The council aims to have one or two representatives from each participating country and discipline.

The EVTM society is supported at this stage by Örebro University Hospital in all financial respects (as part of EVTM research group support). This support has been granted for the forthcoming two years.

The main task of the council is to pave the way for the EVTM venture, and promote the JEVTM/EVTM symposium, EVTM-related courses, cooperation, and free exchange of information.

Members will obtain free information, and access to all JEVTM material. Members will also be offered a reduced fee for the EVTM round table symposium. A further benefit of society membership is receipt of regular updates on EVTM-related activities, education, and developments.

Members will be able to contribute in different ways, and create a professional discussion forum for this new movement. Information will be directed at members via JEVTM.com and different social media platforms.

Since the society is registered in Sweden, it will follow the rules and guidelines of the Swedish government and the EU. Expansion to other countries is welcome, but should follow our ethical guidelines and the EVTM society should be named in all documents appropriately.

Call for collaboration: We call out to physicians with an interest in endovascular resuscitation, trauma and bleeding management. We need the contributions of the medical professionals who want to be a part of our venture.

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Narrative Review Article

The Onyx Liquid Embolic System: Another Chance in the Management of Peripheral Bleeding

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Ethylene vinyl alcohol or Onyx copolymer (Medtronic) is an embolization agent increasingly used in peripheral interventional radiology. The Onyx Liquid Embolic System (LES) offers a liquid, non-adhesive, non-absorbable, injectable and permanent embolic agent with an indication for neuro-interventional procedures. Due to its physical properties, Onyx has more embolic predictability than other currently available liquid agents and seems to have good potential in endovascular bleeding management, especially for patients with coagulopathies or anti-coagulation therapy. The aim of this brief review is to analyze the advantages of Onyx in the emergency setting on the basis of evidence in the current literature.

Keywords: *Embolization; Hemorrhage; Endovascular; Onyx*

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INTRODUCTION

The use of the Onyx Liquid Embolic System (LES) is increasing. Onyx is a peripheral embolic agent that has been described for different indications [1]. In recent years, it has been used increasingly as a bleeding control embolization agent. The aim of this paper is briefly to discuss the role of Onyx in the management of peripheral bleeding according to the current literature. We will not discuss here the usage of Onyx for aortic intervention.

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General Technical Aspects of Onyx and How to Use It

The Onyx LES consists of an elastic polymer comprising an ethylene-vinyl alcohol copolymer (EVOH), dissolved in dimethyl sulfoxide (DMSO), and provided with x-ray radiopacity by adding micronized tantalum powder [1]. Onyx is available in two different viscosities: Onyx 18 (with 6% EVOH) and Onyx 34 (with 8% EVOH), and in two different formulations (1.5 ml and 6 ml). Onyx is a liquid, non-adhesive, non-absorbable, injectable and permanent embolic agent. Owing to its non-adhesive physical property, it is easy to deliver due to a low risk of sticking to a microcatheter tip. Its viscosity helps to achieve a correct delivery, although a risk of distal embolization is still present [1]. Potential advantages of Onyx are that it has high vascular penetration and that a small quantity of the agent is enough to obtain hemostasis [2,3].

Moreover, with other embolization agents, such as particles or cyanoacrylate, free flow is necessary, but Onyx works equally well with or without flow, which is an advantage when vasospasm is present. Onyx is known to have only a weak inflammatory effect on the endothelium, and its action is independent of underlying coagulopathies or low platelet count. By forming a cast of the vessel (Figure 1), the development of a blood clot is less important than with other embolic agents, indeed it was

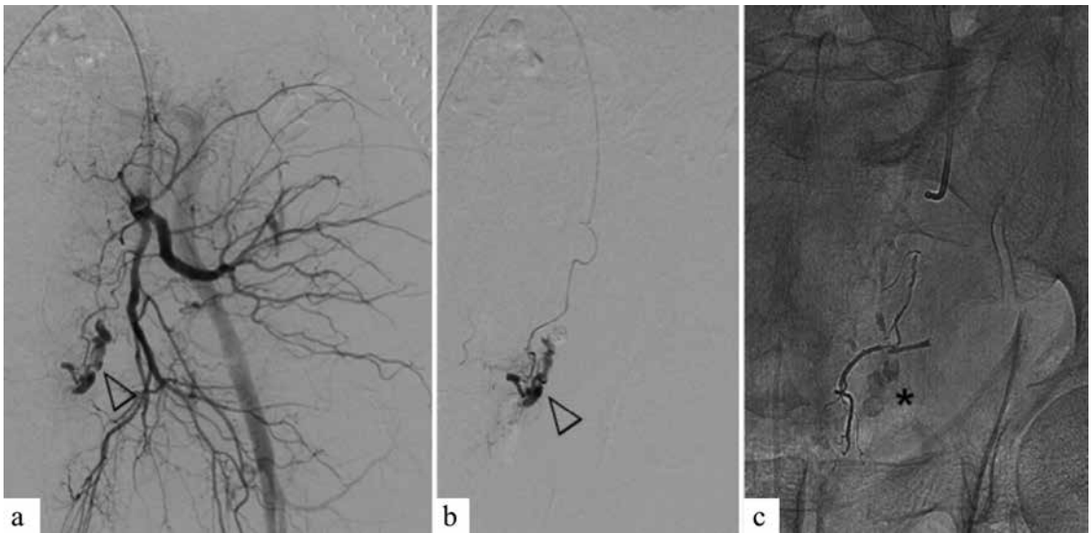

Figure 1 A multi-trauma patient with (**a**) active pelvic bleeding (arrowhead), (**b**) successfully catheterized (arrowhead), (**c**) and embolized with Onyx (asterisk).

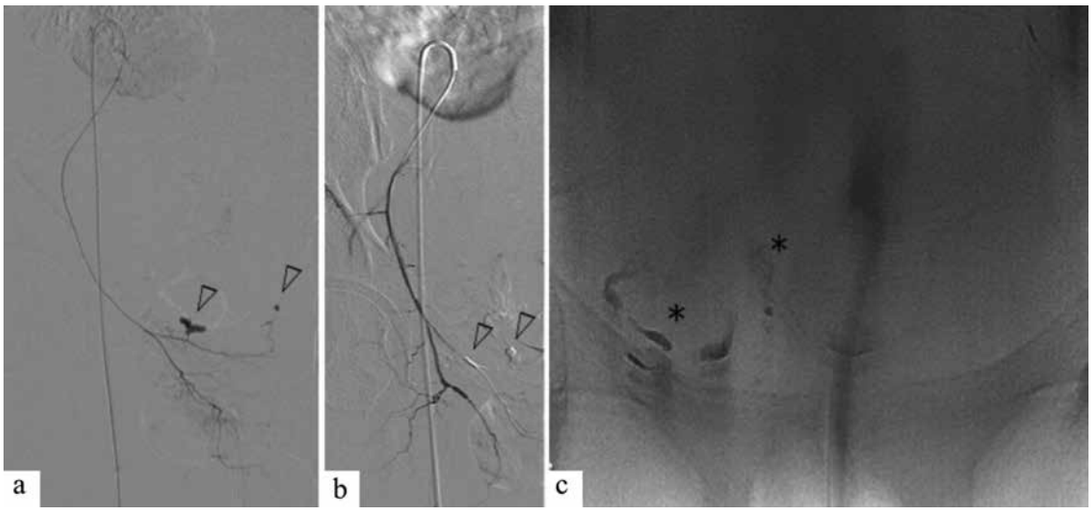

Figure 2 Traumatic bleeding in an uncoagulated patient (**a**) originating from a branch of the hypogastric artery (arrowhead), (**b**) successfully embolized with Onyx (arrowhead). (**c**) A single shot confirms the presence of Onyx (asterisk).

used with success in such settings (Figures 2 and 3) [2–5]. Controlled and slow injection is possible, permitting a relatively low risk of non-target embolization compared with the use of cyanoacrylate or particles which require a quicker injection and an indirect visualization of the embolizing material path, respectively [6]. A known drawback of Onyx lies in the artifacts seen after embolization on computed tomography (CT) images, but magnetic resonance (MR) shows fewer artifacts than is the case for coils [2–4]. No artifacts are observed on ultrasound examinations.

The manufacturer recommends placing the ready-to-use vials of Onyx on a mixer, shaking them for at least 20 minutes until a homogenous solution is created with the tantalum powder. DMSO-compatible devices (microcatheters, syringes, etc.) must be used as recommended by the manufacturer (Table 1). The microcatheter should be positioned as close as possible to the target vessel/bleeding, even though embolization can be performed when the microcatheter tip is far away from the target area due to high downstream penetration [1,7].

Before use, the microcatheter must be flushed with saline solution and then with DMSO, which prevents copolymerization within the microcatheter activated by contact with an ionic solution such as blood

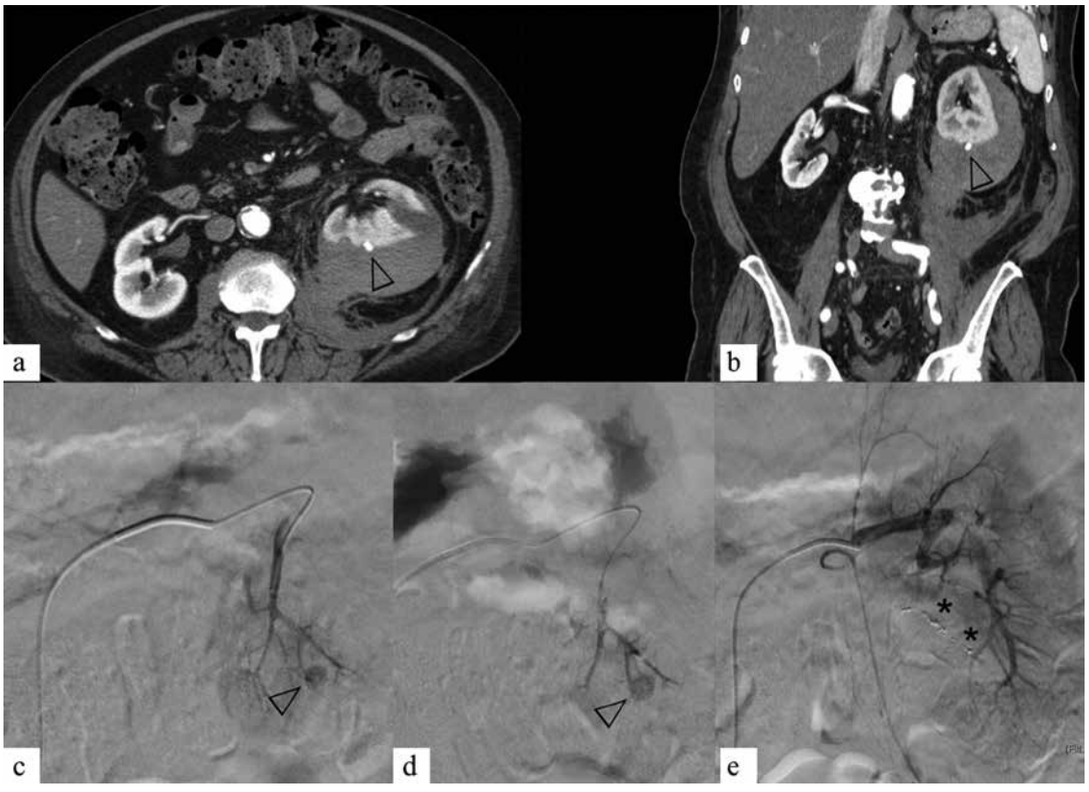

Figure 3 (**a**, **b**) Axial and coronal MPR CT images showing active spontaneous bleeding in an uncoagulated patient originating from a small pseudoaneurysm located between interlobular and arcuate renal arteries (arrowhead). (**c**, **d**) The same bleeding is clearly shown after superselective catheterization using a 2.8F DMSO-compatible coaxial microcatheter system (arrowhead; Progreat, Terumo Interventional Systems). (**e**) After successful embolization, a single shot confirms the presence of Onyx (asterisk).

or saline solution. Once the microcatheter dead space is filled with DMSO, Onyx must be injected very slowly and carefully with constant pressure under fluoroscopic guidance. Indeed, a quick injection of Onyx, leading to a fast displacement of DMSO in the bloodstream with local high concentrations of the solvent, can lead to strong pain. This is why the presence of an anesthesiologist could be useful to both stabilize the patient, when necessary, and manage the possible development of pain. Pain is due to DMSO angiotoxicity caused by endothelial irritation which potentially leads to the development of endothelial necrosis and the inflammatory response of the artery wall. However, a slow injection showed no untoward endothelial effects [1,4,8]. Onyx, after its solidification, typically forms a plug, which is fundamental in preventing the backflow of the embolic agent, with a lower risk of non-target embolization. Onyx solidification takes about five minutes, achieving a foam-like consistency [1,7]. The day after the procedure, the patient may complain about a garlic-like smell; this is due to the DMSO and should disappear within two days [1]. The required shaking time (20 minutes) may limit the use of Onyx in emergency settings. However, a well-coordinated procedure and promptly available Onyx embolization-related material can certainly be used in emergency procedures, such as with trauma patients (Figure 2) [1]. It is advisable to start shaking the Onyx as soon as it is suspected that it might be necessary during the preparation of the patient at arrival in the angiographic suite. If vials are not used, they can be returned to storage [4]. Specific training in the use of Onyx is required since it might migrate, and experienced hands are demanded during injection [4].

Since 2005, Onyx has been approved by the Food and Drugs Administration (FDA) for the treatment of brain arteriovenous malformations (AVMs), and since 2007 for the treatment of intracranial, saccular, sidewall aneurysms with a wide neck (≥4 mm) or with a dome-to-neck ratio <2, which are aneurysms that are not easily managed by surgical treatment [9]. Although Onyx is approved just for brain procedures, it has also been used both in the extracranial central nervous system (e.g., spinal cord) and in peripheral vascular, and even non-vascular (e.g., bile leakage) locations [4,10,11]. There are now several papers about peripheral applications of Onyx that demonstrate its safe and effective use [2–4,6,10–12].

Table 1 Known catheters approved for Onyx usage. In addition to these, there are now new catheters, e.g., Tokai microcatheters, that are compatible with DMSO and Onyx.

Catheter Name	*Manufacturer*	*Total Length (cm)*	*Proximal/Distal Diameter (F)*	*Dead Space Volume (ml)*
Rebar 14	Medtronic	153	2.4/1.9	0.49
Rebar 18	Medtronic	153	2.7/2.4	0.49
Rebar 27	Medtronic	130	2.8/2.8	0.49
Echelon 10	Medtronic	150	21/1.7	0.34
Echelon 14	Medtronic	150	2.4/1.9	0.34
Apollo	Medtronic	165 165	2.7/1.5	0.23
Progreat	Terumo	110;130;150	2.9/2.4	0.48;0.53;0.58
Progreat	Terumo	110;130	2.9/2.7	0.57;0.64
Progreat	Terumo	110;130;150	3.0/2.8	0.61;0.68;0.75
Renegade	Boston Scientific	105;130;150	3.0/2.4	Not specified
Renegade HI-FLO	Boston Scientific	105;130;150	3.0/2.8	Not specified
Direxion	Boston Scientific	105;130;155	–/2.4	0.40;0.46;0.56
Direxion HI-FLO	Boston Scientific	105;130;155	–/2.8	0.55;0.64;0.73

Other Embolization Agents Used in Bleeders Differ from Onyx

There are several agents used for embolization without universally accepted guidelines for the choice of which to use, which depends heavily on the operator's experience and confidence level. The efficacy of particles (e.g., PVA), coils and gelfoam is highly dependent on the patient's coagulation status, and the rate of clinical failure after embolization is high when the patient has a coagulopathy, for example, in a trauma setting [13–16]. N-butyl-2-cyanoacrylate (NBCA), which is a glue, has a high hemostasis effect with a low recurrent bleeding rate, but control of vascular glue penetration can be difficult and requires considerable experience [17].

One of the advantages of Onyx over NBCA or PVA particles is that Onyx permits a controlled injection capable of reducing the risk of non-target embolization and allowing stop-and-restart administration, whereas the quick polymerization of NBCA requires faster administration to reduce the risk of microcatheter gluing. Another advantage of Onyx compared with PVA particles is that Onyx is radiopaque and can, therefore, be seen at fluoroscopy, whereas a reflux of PVA particles can potentially be missed [14]. As with PVA particles, pure NBCA can be mixed with iodized-oil. However, the more oil is added, the longer will be the polymerization time, giving a higher risk of non-target embolization since the mixture can be washed away with the blood flow before it polymerizes [18,19]. The major disadvantage of Onyx over the other embolization agents is a higher cost compared to both PVA particles and NBCA and this cost is not always justifiable because, according to the clinical situation, the same results can be achieved by other embolic agents. However, an ideal embolic agent should have rapid and effective embolization potential so that it can reach and fill the distal vasculature targeted for embolization, be easy to prepare and use, have a high radiopacity, be well controllable during administration, and be biocompatible and cost-effective [20]. Onyx meets some of these major criteria well.

Published Series with use of Onyx for Peripheral Bleedings (Table 2)

The much-appreciated results of Onyx usage in the embolization of intracranial aneurysms [22–24] and AVMs have encouraged Onyx interventions also in a peripheral setting (Table 2) [2,4,5,15,16,21,25–31]. So far, there are only a few series of publications on Onyx embolization in peripheral bleeding, and most studies have a small sample size. These series are heterogeneous since the patients have presented different types of bleeding (e.g., as a consequence of trauma, or gastrointestinal (GI), uterine, AVM bleeding, etc.).

The first paper about the use of Onyx in peripheral bleedings was published in 2002 by Cantasdemir et al. [27]. It reported on the embolization of deep femoral artery branch pseudoaneurysms in three patients with massive hemorrhage, two for a penetrating injury, and one at the site of a fixation pin (an iatrogenic injury). In all cases, a successful closure of the pseudoaneurysm was obtained without re-bleeding during the follow-up period [27]. GI bleedings are very common and can have many causes, such as angiodysplasia, ulcers, tumors, diverticulas, varices, pancreatitis, etc.; however, their management is usually endoscopic, sometimes requiring an endovascular procedure [32].

A rare, but tricky and potentially life-threatening, condition is an arterio-enteric fistula; in this setting, the treatment of a saccular aneurysm of the right internal iliac artery was successfully treated with a combination of coils and Onyx [2]. Two series, published by

Table 2 Published series where Onyx was used for urgent bleeding control.

Study	*n° Patients*	*n° Lesions*	*Bleeding Site*	*Mean Follow-Up Time*	*Outcome*
Barral et al. 2017 [25]	12	16	uterus	29	1 technical failure
Bommart et al. 2012 [26]	15	28	lung in patients with hemoptysis	43.5 d	2 recurrences
Cantasdemir et al. 2002 [27]	3	3	thigh	4.3 mo	No recurrence
Ierardi et al. 2015 [4]	15	15	multiple	minimum f.u. time 4 mo	No recurrence
Khalil et al. 2010 [28]	15	15	lung in patients with hemoptysis	9.7 mo	1 technical failure
Khalil et al. 2012 [29]	12	12	lung in patients with hemoptysis	6.4 mo	2 recurrences, 1 technical failure
Klamroth et al. 2009 [5]	7	8	joints	16 mo	3 recurrences
Lenhart et al. 2010 [21]	16	16	GI	13.1 mo	No recurrence
Müller-Wille et al. 2012 [15]	13	13	multiple	27 d	1 erectile dysfunction possibly related to embolization, no recurrence
Regine et al. 2015 [16]	26	26	multiple	6 mo	No recurrence
Thulasidasan et al. 2016 [30]	7	10	angiomyolipoma of the kidney	284.2 d	1 retreatment (for new feeding vessels)
Urbano et al. 2014 [31]	31	31	GI	23.7 mo	4 recurrences, 2 technical failures
Vanninen et al. 2007 [2]	4	4	multiple	2.7 mo	No recurrence

**List of major case series; isolated case reports not included. GI: gastrointestinal.*

Lenhart et al. and Urbano et al. [21,31], investigated the potential role of Onyx, alone or combined with coils, in the treatment of GI bleeding in an emergency setting. For a retrospective double-center study, Lenhart et al. enrolled 15 patients (16 procedures in total, with one patient being treated on two of the sites) with GI tract acute arterial bleeding, untreatable solely by endoscopy, and therefore treated with trans-catheter arterial embolization. All patients were treated with Onyx only, except for two who received a combination of Onyx and coils. In combination with Onyx, coils are often used to prevent excessive distal migration of the embolic agent. The technical success rate was 100% with angiographic demonstration of bleeding cessation. Neither procedure-related complications, such as non-target embolization and signs and symptoms of bowel ischemia, nor re-bleeding during follow-up were registered [21].

A slightly different experience was reported by Urbano, who used Onyx, both alone and with coils, for the treatment of GI bleeding. In their cohort, 31 patients were retrospectively enrolled, and super-selective embolization was performed in 30 vessels. One patient underwent surgical resection due to severe atherosclerosis and failure of super-selective catheterization of the target vessel. One technical failure was registered due to reflux of Onyx in a marginal artery, without signs of intestinal ischemia during the follow-up period [31].

Klamroth et al. used Onyx in seven patients, six with hemophilia A and one with hemophilia B. All had elbow or knee bleedings that were not responsive to the administration of concentrated coagulation factors (fVIII/fIX). Eight joints were treated, each presenting two/three bleeding sites, all successfully embolized [5].

The ability to embolize regardless of the patient's coagulation status was the key to choosing Onyx for the management of hemoptysis by Khalil et al. Two re-bleedings (16.6%) were registered and attributed to an infection [29]. The Khalil team's experience of hemoptysis management with vascular embolization procedures includes not only pulmonary artery embolization but also the treatment of systemic vessels, such as the bronchial artery, inferior diaphragmatic artery and left internal thoracic artery [28,29]. The team identified two major groups of indications requiring the use of Onyx: anatomical and relapses of the previously occluded artery (e.g., re-bleeding). The anatomical indications for the use of Onyx were as follows: false aneurysms of a systemic artery, opacification of the bronchial artery causing bleeding through small anastomosis, unstable catheter position, spasm or dissection of the bronchial artery, and complete and definitive occlusion of the so-called dangerous artery, the embolization of which can be risky [28].

A paper on a more homogenous group was published by Bommart et al., who described a series of patients, including some affected by hemoptysis due to bronchial artery bleeding. Similar results to those obtained by Khalil and colleagues were achieved, with two failures out of 28 procedures [26].

Barral et al. studied the feasibility and effectiveness of Onyx as a single embolic agent for the treatment of uterine bleedings in both stable and unstable patients.

They enrolled 12 patients with uterine bleeding due to AVMs. Nine of the 12 were hemodynamically stable, and three hemodynamically unstable. Eight single procedures and four double embolizations were performed according to the size of the AVMs. In the patients undergoing a double procedure, the second was performed 15–21 days after the first to avoid uterine necrosis. Clinical success was defined as the absence of recurrent uterine bleeding within a month of the procedure. Neither uterine necrosis nor off-target embolization and other types of complications were registered [25].

Some good results have been reported on the employment of Onyx for the treatment of patients with renal bleeding angiomyolipomas (AMLs), or for other patients at high risk of bleeding. In a recent study, Thulasidasan et al. [30] treated AMLs >4 cm in diameter or bleeding AMLs of any size and obtained successful hemostasis and a statistically significant reduction in maximum lesion diameter. It is interesting to note that no statistically significant difference in glomerular filtration rate was observed. This is of basic importance because patients with tuberous sclerosis are at high risk of developing new AMLs, and therefore have an elevated risk of further kidney injuries. According to this study, to reduce recurrences, embolization should be selective but not as distal as possible in each case. Indeed, the closure of the proximal feeding vessels may prevent further regrowth.

The most common complication observed in some series was pain. However, it was short-lasting, successfully managed with analgesic drugs, and prevented by a reduction in the DMSO injection rate [2–4]. A rare, but tricky, situation was experienced by Vanninen and Manninen, who had a patient with an iatrogenic pseudoaneurysm of a side branch of the second lumbar artery as a consequence of a renal biopsy for sarcoidosis, rheumatoid arthritis, and suspected nephropathy. Although it was an urgent situation, as the patient developed hypotension, the pseudoaneurysm was successfully treated with the deployment of Onyx, and he recovered uneventfully [2].

DISCUSSION

Onyx has been used successfully to stop acute peripheral bleedings in several series. On the basis of our literature review, the properties of Onyx make it a useful and safe embolic agent, since some situations require a controlled injection and an opportunity to reach the most distal, thin, bleeding vessels. GI bleeding seems to respond particularly well to the embolizing properties of Onyx [4,15,16,21,31].

We agree with Khalil and colleagues that an unstable catheter might speak for the use of Onyx, since difficult catheterization of an artery prevents safe and effective coil deployment, and the use of NBCA or PVA particles may be risky in terms of non-target embolization. Moreover, the occlusion of a vital artery is a good indication for choosing Onyx since controlled injection allows the operator to check constantly where the embolic material is and, unlike NBCA, to interrupt the injection in case of undesired embolization without the risk of catheter gluing (thereby permitting injection restart at any time).

The need for embolization of bleeding AMLs (or AMLs at high risk of bleeding) is also an indication for Onyx use. Indeed, in these cases, very careful deployment of the embolic agent is required to be more selective, thereby preserving kidney function in both healthy patients with isolated AMLs and patients with tuberous sclerosis at high risk of further kidney injuries.

However, AML treatment not only requires selectivity but also embolization of the proximal feeding artery from its origin so as to prevent future regrowth. Here, the importance of Onyx features since the agent can enter the most distal vessels, and also embolize the feeding vessel from its origin, thanks to backflow during the controlled injection. No other embolic agent has this property [30].

In addition, Onyx's hemostasis power, which is not influenced by the patient's coagulation status, makes it helpful in the primary control of bleeding as well as in the prevention of re-bleeding in patients with coagulation disorders (Figure 3) [5].

It should be noted that the re-bleeding rate is often overestimated since new bleeding episodes are registered sometimes although they are not at the site of the embolization. This was the case in the series by Urbano and colleagues, in which four minor recurrences, over the 30 procedures performed effectively, were registered, but just one had occurred on the site of the previous embolization. This means that the re-bleeding rate requires careful analysis [31].

One of the most common drawbacks of Onyx use is pain. In our experience, patients with muscle hematomas experience more pain after DMSO injection than others with parenchymal bleeding [4]. The injection rate of the solvent may be responsible for the onset of pain, and we have corrected the rate during operation, resulting in symptom improvement [4]. Morphine i.v. significantly reduces patient discomfort, but it must be used very carefully, especially in patients with hemoptysis, as its central antitussive action reduces airway reflex, which can be life-saving in this case [28,29].

Nevertheless, as shown in Table 2, all the papers included in this review demonstrate high efficacy and a low complication rate. One severe complication registered was that of erectile dysfunction in a patient who had had a car accident and showed bleeding from the internal pudendal artery treated with Onyx embolization. However, this is not really a complication of the embolic agent but of the procedure itself. The embolization necessary to stop the bleeding was responsible for disruption of the blood flow within the dorsal and the deep artery of the penis, the latter supplying the corpus cavernosum. Probably, the same problem would have been registered using any other embolic agent.

Unfortunately, given the uncommon use of Onyx in peripheral applications, only case reports and small case series appear in the published literature. No multi-institutional studies, prospective studies, or randomized controlled studies are available. Accordingly, the use of Onyx copolymer in peripheral embolization cannot yet be standardized. Therefore, more liberal use of Onyx in academic institutions is recommended.

CONCLUSIONS

Onyx seems to be a potentially useful, safe and effective tool in the management of peripheral bleeding. Onyx use should now be increased in academic institutions within a non-industry funded blinded comparative multicenter randomized controlled trial with cost analysis in order to extend its use in peripheral bleeding from off-label employment to standard clinical practice.

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Acute Kidney Injury Following Resuscitative Endovascular Balloon Occlusion of the Aorta: A Systematic Review

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Background: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is an emergent technology for the treatment of non-compressible torso hemorrhage (NCTH). While aortic occlusion (AO) above the site of hemorrhage provides hemostasis and time for surgical intervention, ischemia-reperfusion injury to the kidneys is a known complication.

We aimed to report the incidence and factors associated with acute kidney injury (AKI) following AO in patients with NCTH or in similar porcine models.

Methods: We searched Pubmed (MEDLINE), Embase, Scopus, and ProQuest Dissertations & Theses from inception to July 2017. We included original studies of trauma patients with NCTH treated with REBOA, or similar porcine studies that included renal parameters, excluding case reports and case series. After duplicate removal, full texts of studies retrieved via the search strategy were evaluated by two authors. Renal parameters (e.g., creatinine concentration, urine output, histopathology) were extracted. Quality of the evidence and risk of bias were assessed.

Results: Twelve out of 2,100 records were included (three trauma patients, nine porcine studies). While one out of three human reports described AO in Zone 1, all swine publications reported Zone 1. All human studies reported renal damage. There were nonetheless inconsistencies in definitions used. Evidence of AKI was reported in three out of nine swine studies.

Conclusions: Consistent reporting of AKI incidence is lacking from human clinical studies of AO in NCTH trauma patients. While comorbidities in trauma patients may contribute to AKI, animal models support the association between AO and AKI. As REBOA is growing in popularity as a therapy for NCTH, further studies determining factors associated with the AKI are needed.

Keywords: *Intra-Aortic Balloon; Trauma; Hemorrhagic Shock; Non-Compressible Torso Hemorrhage; Resuscitation*

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INTRODUCTION

Hemorrhage is the leading cause of preventable deaths in combat theaters [1,2] and is responsible for 33–56% of prehospital deaths and over 80% of deaths that occur in the operating room [3]. Resuscitative endovascular balloon occlusion of the aorta (REBOA) has gained in popularity for the treatment of non-compressible torso hemorrhage (NCTH) owing to its potential benefits over resuscitative thoracotomy (RT) [4–7]. Complete aortic occlusion, with either REBOA or RT, results in profound distal ischemia, which in addition to the original insult further increases the risk of acute kidney injury (AKI) in trauma patients. To minimize ischemia-reperfusion injury, the concept of REBOA has evolved from complete to partial REBOA (pREBOA) to permit a small amount of distal flow to mitigate ischemia while maintaining adequate proximal blood pressure. Little is known about the renal consequences of aortic flow control in trauma patients with NCTH. Specifically, the effects of REBOA and pREBOA on AKI incidence or severity remains unknown.

AKI is a serious sequela in trauma patients. The incidence of AKI range from <0.1% up to 34% and post-traumatic AKI is associated with longer ICU and hospital stays [8–10]. Additionally, after adjusted analysis, both civilian and military studies demonstrate increased mortality in trauma patients who develop AKI with mortality rates ranging from 25 to 34% and acute mortality rates ranging from 18 to 22% [9,10].

The main objective of this systematic review was to report the incidence of AKI in trauma patients with NCTH treated with REBOA or pREBOA. Additionally, we aimed to analyze data from included studies to correlate localization and duration of aortic occlusion with AKI incidence. Our secondary objective was to report details of REBOA- or pREBOA-associated AKI in porcine trauma studies as a significant fraction of the REBOA literature has been based on this species.

MATERIALS AND METHODS

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations to conduct the search, select the articles, grade the evidence, and report the results [11]. PRISMA recommendations also satisfied guidelines for the reporting of the systematic review of animal data [12]. A health and life sciences librarian was consulted for process validation.

Protocol and Registration

We selected studies using human subjects or pigs. The trauma patients search was registered with the Prospero database (CRD42017067755).

Eligibility Criteria

The patient–exposure–outcome (PEO) question was: P – in trauma patients, E – treated with REBOA or pREBOA, O – what is the incidence of AKI? We had a similar PEO question for porcine studies of traumatic hemorrhagic shock.

Information Sources

We searched Pubmed (MEDLINE), Embase, and Scopus from inception to July 2017. We also screened the ProQuest Dissertations & Theses Database and proceedings from the American Association for the Surgery of Trauma meetings (2004–2016). Reference lists were evaluated for additional articles. Authors of relevant reports were contacted to determine if pertinent unreported data had been gathered.

Search Strategy

The Pubmed (MEDLINE) search strategy was developed and adapted for the other databases with a librarian (Figure 1).

Study Selection Process

Title and abstracts were reviewed. Studies of non-target species (e.g., dogs, or mice) or in a language other than English, Spanish, or French were excluded. We excluded publications non-related to trauma patients (e.g., aortic aneurysm, obstetric patients), case reports, case-series (with ≤5 patients enrolled), reviews, and letters to the editor (Reference lists of those publications were still screened). When available, full-text was then assessed for renal function information: serum creatinine and potassium concentrations, urine output, renal replacement therapy requirement, histopathologic evaluation of renal tissue, and other biomarkers (e.g., neutrophil-gelatinase associated lipocalin, NGAL).

Data Collection Process

Quality of the evidence and risk of bias were evaluated by two authors (GLH, PAC). In case of disagreement, a third author (AMJ) was consulted.

Data Items

Whenever available for human subjects, we recorded population age (adult versus pediatric), introducer sheath size, balloon catheter size, study type (e.g., retrospective study, randomized control trial), comparisons with other resuscitative procedures (i.e., RT), occlusion Zone (Zone 1, proximal to the coeliac artery; Zone 2, between the coeliac and the renal artery; Zone 3, below the renal artery), complete and partial aortic occlusion time.

((((((((failure[All Fields]) OR injury[All Fields])) AND ((kidney[All Fields]) OR renal[All Fields]))) OR (("acute kidney injury"[MeSH Terms] OR "acute kidney injury"[All Fields] OR "acute renal failure"[All Fields]))) AND ((((((((resuscitative[All Fields] OR "resuscitation"[MeSH Terms] OR resuscitation[All Fields]))) OR ((haemorrhage[All Fields] OR "hemorrhage"[MeSH Terms] OR hemorrhage[All Fields]))) OR (("Non-compressible torso hemorrhage"[All Fields] OR "Noncompressible torso hemorrhage"[All Fields] OR "Noncompressible truncal hemorrhage"[All Fields]))) OR trauma[All Fields])) AND ((endovascular[All Fields]) OR (occlusion[All Fields] OR "balloon occlusion"[MeSH Terms]))) AND ("aorta"[MeSH Terms] OR aorta[All Fields] OR aortic[All Fields]))) OR ((REBOA) OR "resuscitative endovascular balloon occlusion of the aorta")

Figure 1 Pubmed (Medline) search strategy.

Table 1 Kidney Disease Improving Global Outcomes (KDIGO) criteria based for the diagnosis of acute kidney injury [16].

Stage	*Serum Creatinine*	*Urine Output*
1	1.5–1.9 times baseline OR ≥0.3 mg/dL (≥26.5 µmol/L) increase	<0.5 mL/kg/hour for 6–12 hours
2	2.0–2.9 times baseline	<0.5 mL/kg/hour for ≥12 hours
3	3.0 times baseline OR Increase in serum creatinine to ≥4.0 mg/dL (≥353.6 µmol/L) OR Initiation of renal replacement therapy OR In patients <18 years, decrease in eGFR to <35 mL/min per 1.73 m^2	<0.3 mL/kg/hour for ≥24 hours OR Anuria for ≥12 hours

For porcine studies, we also recorded whether tissue trauma (beyond surgical preparation, e.g., liver or spleen laceration) was induced in addition to hemorrhagic shock.

Outcomes and Prioritization

The main outcome was AKI incidence based on the Kidney Disease Improving Global Outcomes (KDIGO) criteria (Table 1) [13].

Risk of Bias in Individual Studies

For trauma patient and porcine studies, the risk of bias was rated with the Modified Cochrane Risk of Bias Tool for randomized controlled trials [14] and the SYRCLE's risk of bias tool, respectively [15].

Metabias

Most reports originate from centers with extensive research and clinical experience with the procedure, which may alter publication bias.

Confidence in Cumulative Evidence

For trauma patients, the quality of the evidence was graded with the National Institutes of Health Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [16]. Composite forms were used for porcine experiments.

Summary Measures and Synthesis of Results

Preliminary literature searches retrieved a limited number of studies. We did not aim to report statistical inference (meta-analysis); rather, we reported descriptive statistics.

RESULTS

Study Selection

The search strategy identified 2017 records; 83 additional records were found from non-database resources (Figure 2). Three full-text manuscripts were included for final evaluation of trauma patients (Table 2) and nine were analyzed from porcine experiments (Table 3). Additionally, three abstracts were evaluated; one in trauma patients and two in porcine models.

All three reports of trauma patients were retrospective studies. One of the three reports described Zone 1 REBOA [17]. Occlusion in another study was reported in Zones 1, 2, and 3 in 79%, 2%, and 19% of patients, respectively [7]. The last study did not specifically report the occlusion site [18]. While there were inconsistencies in the definitions used, all three studies in humans reported some degree of AKI. The use of dialysis was reported in 4.3% of patients treated with REBOA and 2.9% of patients treated with open aortic occlusion, a difference that was not statistically significant and there was no data reporting the duration of occlusion resulting

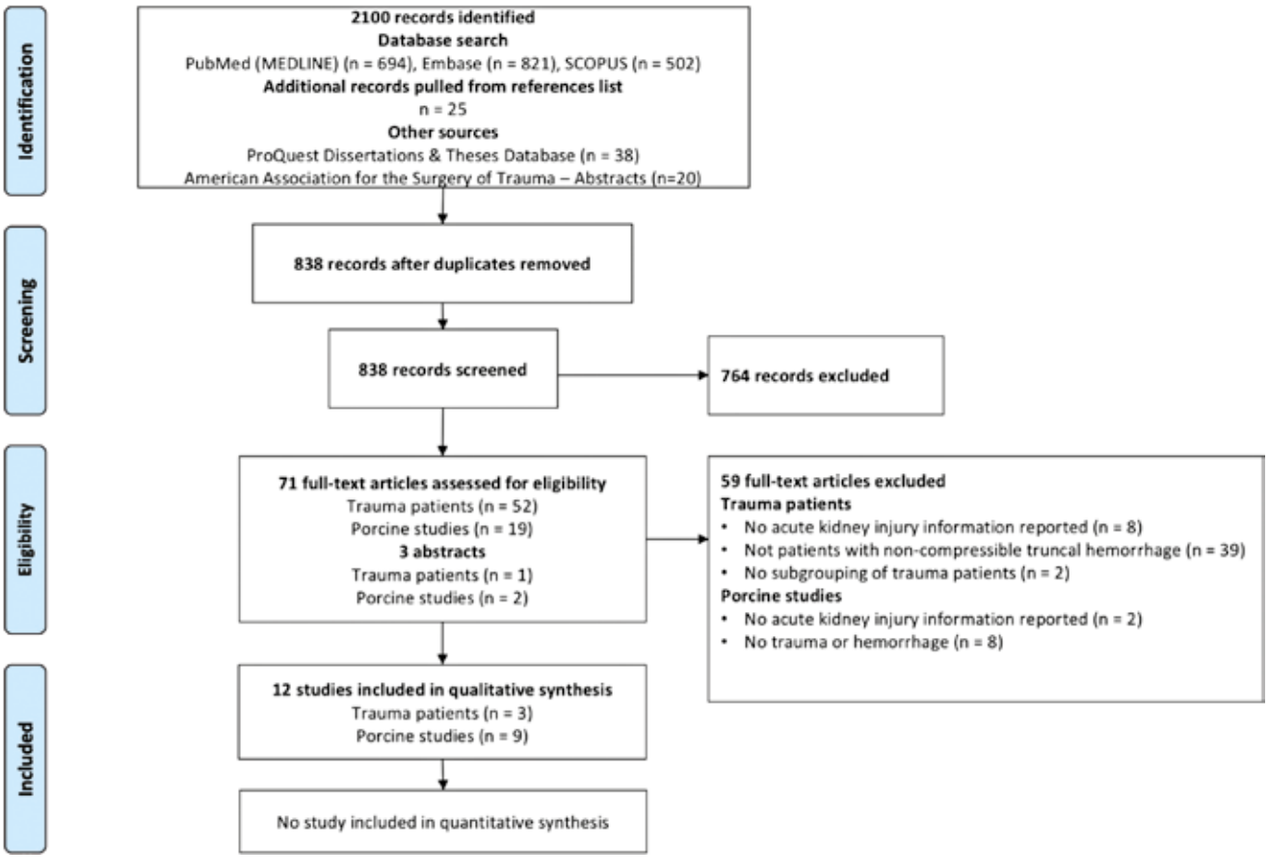

Figure 2 Systematic review process.

in dialysis dependence [7]. In another report [17], 9/24 patients had evidence of AKI according to the Risk Injury Failure Loss End-stage (RIFLE) criteria; 5/9 of those patients were classified in the failure category, but again there was no correlation between duration of occlusion and incidence of AKI. In the third study [18], evidence of AKI was reported in one patient based on an elevation in serum potassium and creatinine concentrations following 37 minutes of partial occlusion, which resolved following fluid therapy. No baseline serum creatinine concentration was reported for this patient. Quality of the evidence was poor in 2/3 reports [17,18] and fair in 1/3 report [7]. The risk of bias was rated as high in all three reports.

One report in abstract form was identified in trauma patients [19]. In this cohort, 26/43 patients were successfully resuscitated with either intermittent REBOA or pREBOA (11/26 patients). There was no difference in the incidence of hyperkalemia, which could be used as a partial proxy for renal injury, between the two groups [4/15 (27%) versus 4/11 (36%), respectively].

Reporting of AKI was more consistent in swine studies with nine studies meeting our inclusion criteria. All publications in swine reported Zone 1 REBOA. Definitive evidence of AKI was reported in 3/9 studies [6,20,21]. Park et al. as well as Russo et al. reported AKI from histopathological data. Morrison et al. reported AKI based on an increase in serum creatinine concentration. In the remaining six studies, two studies reported elevation in serum potassium concentrations [4,5]. One study reported no change in serum creatinine concentration [22]. One study did not report creatinine or potassium concentrations [23]. One study reported a urine output of 0.5 mL/kg/hour in an extracorporeal model of pREBOA [24]. Another study reported improved urine output in pigs undergoing a model of pREBOA compared to REBOA [25]. Histopathologic evaluation of renal tissue was reported in 5/9 studies. Park et al. demonstrated worse renal injury with 60 minutes of occlusion when compared to 30 minutes of occlusion [20]. Russo et al. reported a higher incidence of acute tubular necrosis in pigs treated with pREBOA when compared to animals treated with REBOA [21]. The minimum aortic occlusion time associated with AKI was 30 minutes [20], although similar occlusion times were not associated with renal damage in a separate study [22]. Quality of the evidence was graded as good, fair, and poor in 6/9, 2/9, and 1/9 reports. The risk of bias was low in all porcine studies.

Two reports in abstract form were identified in swine studies [26,27]. One report demonstrated lower renal thiobarbituric acid reactive substances, a by-product of lipid peroxidation, levels in pigs treated with REBOA

Table 2 Data summary for trauma patients with non-compressible truncal hemorrhage.

Authors Year	*Population*	*Number of Patients*	*Introducer Sheath Size (Fr)*	*Aortic Occlusion Catheter Size (Fr)*	*Study Type*	*REBOA compared with*	*Aortic Zone Occluded*	*Complete Occlusion Time (minutes)*	*Partial Occlusion Time (minutes)*	*AKI Information*	*QOE*	*ROB*
Saito 2015	Adults	24	10	NR	Retrospective	NA	1 initially	S: 21 NS: 35	NA	S: 9/14 patients (RIFLE criteria) R (KDIGO stage 1): 3 I (KDIGO stage 2): 1 F (KDIGO stage 3): 5	Poor	High
Irahara 2015	Adults	14	10	NR	Retrospective	NA	NR	S: 46 NS: 224	NR	Rise in [K^+] and [Creatinine] in 1 patient	Poor	High
Dubose 2016	Adults	114	NR	4-18	Retrospective	Open AO	1 (79%) 2 (2%) 3 (19%)	EAO: 20 AO: 25	NA	Dialysis requirement (KDIGO stage 3) EAO: 4.3% AO: 2.9%	Fair	High

AKI, acute kidney injury; AO, aortic occlusion; EAO, endovascular aortic occlusion; NA, not applicable; NR, not reported; NS, non-survivors; QOE, quality of the evidence; REBOA, resuscitative endovascular balloon occlusion of the aorta; RIFLE, risk, injury, failure, loss, end-stage renal failure; ROB, risk of bias; S, survivors.

after 90 minutes of hemorrhagic shock when compared to control (no intervention) [26]. In the other report, following hemorrhagic shock, animals treated with REBOA for 60 minutes had lower renal glutathione concentrations and higher manganese superoxide dismutase activity than pigs immediately transfused with shed blood [27]. The occlusion zone was not specified for either report.

DISCUSSION

REBOA is a promising therapy for the care of trauma patients. Currently, Zone 1 REBOA is limited by a relatively short therapeutic window that has been estimated to be 30 minutes due to the profound distal ischemia that occurs with complete aortic occlusion. We undertook this systematic review of the literature to better understand the effect of duration of occlusion on renal function. We have demonstrated that consistent reporting of AKI incidence is lacking from human clinical studies of REBOA in trauma patients with NCTH. No REBOA-associated risk factors for AKI (such as occlusion Zone or duration) were identified in trauma patients treated with REBOA. Our results also highlight the lack of long-term follow-up of renal function assessment. While confounding factors such as hemorrhagic shock and direct tissue damage contribute to the development of AKI [28], animal models support the strong association between REBOA and AKI but fail to determine maximal occlusion times prior to the onset of measurable AKI.

There is a paucity of studies comparing the effects of occlusion Zone on renal function. Zone 1 occlusion for REBOA, or aortic cross-clamping during surgical interventions, carries the highest ischemia burden. Importantly, the development of renal injury in these patient populations is not solely the result of ischemia from the intervention. Prior to any aortic occlusion, trauma patients are at a high risk of AKI, with an incidence ranging from <0.1% up to 34% [8–10]. The development of AKI is of critical importance as post-traumatic renal failure is associated with longer ICU and hospital stays [8]. Additionally, after adjusted analysis, both civilian and military studies demonstrated an increased risk of mortality in trauma patients who develop AKI with absolute mortality rates ranging from 25 to 34% and acute mortality rates ranging from 18 to 22% [9,10]. In those patients, post-traumatic renal failure has been attributed to direct renal damage, the need for emergent surgical intervention, and renal ischemia overall [8]. Studies evaluating the incidence of AKI in trauma patients treated with REBOA should adjust for the predisposition of this patient population to AKI.

In addition to blood loss and direct tissue damage, trauma-associated decreased oxygen delivery to the kidney can be potentiated by aortic occlusion. As the use of REBOA is still at early stages in clinical use, most the literature regarding the mechanisms behind AKI induced by aortic occlusion stems from studies of open surgical

Table 3 Data summary for porcine studies.

Authors	*Introducer Sheath Size (Fr)*	*Aortic Occlusion Catheter Size (Fr)*	*Hemorrhage*	*Trauma*[*]	*Aortic Zone Occluded*	*Complete Occlusion Time (minutes)*	*Partial occlusion Time (minutes)*	*AKI Information*	*QOE*	*ROB*
Avaro 2011	NR	7	Yes	Yes	1	40 versus 60	NA	Rise in [K^+] No change on renal histopathology	Fair	Low
Markov 2013	15	NR	Yes	No	1	30 versus 90	NA	No change in serum [Creatinine] No change on histopathology	Good	Low
Scott 2013	8 and 14	NR	Yes	No	1	60	NA	No baseline [Creatinine] reported Rise in [K^+]	Good	Low
Morrison 2014	NR	14	Yes	Yes	1	60	1 minute at 20 and 40 minutes	Rise in [K^+] and [Creatinine]	Good	Low
Park 2015	7	7	Yes	No	1	30 versus 60	NA	Damage on renal histopathology	Good	Low
Russo 2016	12	NR	Yes	Yes	1	90	10 minutes of complete then 80 minutes of partial occlusion	No change on renal histopathology	Good	Low
Russo 2016	12	NR	Yes	No	1	90	90	Acute tubular necrosis in 80% of pigs with C-REBOA No change in P-REBOA or control	Fair	Low
Williams[**] 2016	12	NR	Yes	Yes	1	NA	20 complete then 70 of partial	Mean UOP 0.5mL/kg/hour No control group	Poor	Low
Williams[**] 2017	NA	NA	Yes	Yes	1	20	70	UOP higher with permissive regional hypotension than complete aortic occlusion	Good	Low

AKI, acute kidney injury; C-REBOA, complete resuscitative endovascular balloon occlusion of the aorta; NA, not applicable; NR, not reported; P-REBOA, partial resuscitative endovascular balloon occlusion of the aorta; QOE, quality of the evidence; ROB, risk of bias; UOP, urine output. [*]: beyond surgical preparation. [**]: studies in which extracorporeal circulation was utilized.

repair of abdominal aortic aneurysms and open heart surgery. In both settings, aortic cross-clamp time is a predictor for the development of AKI [29,30]. With as little as 40 minutes of total clamp time, a significant decrease in glomerular filtration rate, renal blood flow, and urine output are seen when compared to infrarenal occlusion. Surprisingly, these hemodynamic changes persist even after clamp removal for up to 60 minutes [31]. Additionally, animal studies have demonstrated that following a 45-minute period of aortic occlusion, renal oxygen delivery and cortical tissue oxygen tension remain decreased although other visceral organs demonstrate normal perfusion [32]. These findings suggest that ongoing renal damage may occur despite appropriate systemic oxygen delivery (DO_2) after perfusion is reinstated. There are several potential trauma-related processes that may worsen renal function. Activation of the sympathetic nervous system is associated with worsening of renal function following renal vein and artery occlusion in rats [33], and renin release following aortic occlusion contributes to AKI in dogs following transient suprarenal aortic occlusion [34,35], both of which occur in the setting of significant trauma. Oxidative stress is another important pathologic process in the reperfusion phase. In a non-traumatic porcine model of aortic cross-clamping, 30 minutes of complete supra-coeliac aortic occlusion followed by reperfusion led to a significant increase in serum creatinine and NGAL concentrations in parallel with an increase in serum malondialdehyde (a biomarker of lipid peroxidation) concentration [36]. Our study identified two reports [26,27] demonstrating oxidative imbalances following REBOA therapy in porcine models of traumatic exsanguination however only the abstracts were available. Future studies should, therefore, investigate the effects of REBOA on oxidative stress.

Although considered to be protective of renal function during REBOA, studies of infrarenal aortic cross-clamping have demonstrated conflicting effects on renal function. There is opposing information regarding the association between occlusion in Zone 3 of the aorta and renal damage [37]. While the exact mechanisms remain unclear, alteration in blood flow distribution within the renal parenchyma and inflammatory responses have been proposed as possible causes of renal damages induced by infrarenal aortic clamping [37]. It has also been questioned whether microvascular shunting may be a contributor to AKI following reperfusion during Zone 1 as well as Zone 3 occlusion [38,39]. Additionally, since renal oxygen consumption (VO_2) is driven by sodium reabsorption, the potential increase in renal blood flow and glomerular filtration rate associated with Zone 3 occlusion could increase renal VO_2, which can be detrimental if DO_2 remains constant [40]. Earlier studies have also established the potential for shunting of blood within the renal parenchyma possibly leading to an imbalance between DO_2 and VO_2 [38]. Further studies are needed to elucidate these mechanisms.

To date, there is still a paucity of data comparing the effects of REBOA to aortic cross-clamping. Although animal studies have compared REBOA to RT in trauma models, there have been no renal function comparisons within these studies. Furthermore, although a single study in trauma patients demonstrated no difference in the need for renal replacement, this observational work has limitations secondary to inclusion bias and lack of randomization [7].

The recognition of the profound distal ischemia to the kidneys and other visceral organs that occurs during even brief periods of complete REBOA has driven the development of strategies to mitigate these potential complications. Although intermittent REBOA, in which the balloon is intermittently deflated and then re-inflated to allow a period of distal perfusion, has been suggested as a strategy to mitigate distal ischemia, there are no animal or human studies that assess the impact of this therapy on AKI. Partial REBOA is a technique whereby a small amount of distal flow is allowed past the point of occlusion [41]. Although only minimally studied in animals and not supported by clinical data at this time, a single study has reported reduced AKI risk based upon creatinine with pREBOA when compared to complete REBOA [25]. Histopathologic analysis of renal injury in porcine models of hemorrhagic shock have been less definitive with studies demonstrating both no difference as well as an increase in acute tubular necrosis with pREBOA when compared to complete occlusion [21,23]. Differences between animal studies of pREBOA may be the result of differences in how the therapy is applied, as pREBOA has undergone significant development and improvements in distal flow control since the publication of these manuscripts.

Consistent reporting has long been a source of debate when describing AKI with a multitude of grading systems. Inconsistency in renal function reporting made it often impossible to use commonly accepted guidelines such as Kidney Disease: Improving Global Outcomes (KDIGO) or the Acute Kidney Injury Network (AKIN). One study included in this review, Saito et al., [17] used the RIFLE criteria and reported an AKI incidence of 64%. In another report, Irahara et al., one patient had an elevated creatinine level after 37 minutes of partial occlusion but no baseline serum creatinine concentration was reported [18]. It was therefore impossible to determine whether it was the consequence of AKI, chronic renal failure, or chronic kidney disease with an acute injury. Finally, in the study by Dubose et al., 3.5% of patients undergoing aortic occlusion (open or endovascular) required renal replacement therapy, which would place those patients at stage 3 of the KDIGO guidelines [7]. Moving forward, it is imperative for a common grading system to be used so that the effects of REBOA on renal function can be understood.

The present study carries several limitations. First, similar to other systematic reviews of REBOA use, we

excluded a large number of reports from final inclusion [42,43]. A recent systematic review of the literature [43] identified 15 reports of patients with traumatic abdominopelvic hemorrhage, which included nine case reports or case series (with ≤5 patients). Of the remaining nine studies, only two were eligible for enrollment in our report [17,18]. Similarly, only one [7] in three studies included in a recent meta-analysis [44] were included in the present study. Additionally, systematic reviews and meta-analyses of the use of REBOA in trauma patients with NCTH are limited by the paucity of large reports [44]. Our findings also outline the inconsistent reporting of renal function information. In two of the porcine studies [4,5], serum potassium concentration was used as a surrogate for AKI. While hyperkalemia in trauma patients is multifactorial, sustained hyperkalemia in such patients occurs due to some degree of renal dysfunction. In those two studies, aortic occlusion lasted 45 to 60 minutes, yet hyperkalemia was sustained. Serum creatinine was not reported in one [4] and baseline serum creatinine concentration was not reported in the other [5], making AKI confirmation difficult. Systematic reporting guidelines have been proposed to improve consistency and evidence quality in the future [45].

CONCLUSIONS

In conclusion, consistent reporting of AKI incidence, severity, and outcomes is lacking from human clinical studies of REBOA in trauma patients with NCTH. While comorbidities in trauma patients may contribute to AKI, animal models support the association between REBOA and AKI. As REBOA is growing in popularity, future studies determining risk factors for AKI, as well as its effect on short- and long-term patient outcomes, are needed.

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Commentary

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Endovascular Resuscitation: The Emergency Physician has a Key Role to Play

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Endovascular resuscitative techniques in the critically hemorrhaging or otherwise ill patient are evolving at a phenomenal pace. One can review the articles appearing on a month-to-month basis in journals like this and others to see evidence of this.

From the onset, there has been much debate about who would and should be best placed to perform procedures such as resuscitative endovascular balloon occlusion of the aorta (REBOA) or extracorporeal membrane oxygenation (ECMO). Is it primarily the domain of the surgeon, and if so the trauma surgeon, cardiothoracic surgeon, or vascular surgeon? Should the surgeons defer to the interventional radiologist?

These arguments miss a very important point – the reality is that effective management of these critically ill and injured patients requires a collaborative team approach. Everyone involved, from the emergency physician to the intensivist, interventionalist, and surgeon, not to mention our nursing and paramedical colleagues, have "skin in the game" as we say in the USA. The goal of this team sport is clearly reaching the appropriate endpoint of restoration of normal physiology, be it by stopping bleeding or restoring circulation.

Let's talk more about the role of the emergency physician. Emergency medicine (EM) as a specialty has similarly developed at a faster pace than others in the house of medicine. EM has established itself as a specialty with a unique skillset: specialists able to manage the undifferentiated critically ill patient. Advanced airway management, ultrasound techniques, and invasive procedures including vascular access are built into the current curriculum of most EM training programs worldwide [1]. These were procedures and techniques traditionally in another specialty's realm, learnt and adapted to the EM environment with great success. Many were brought on by an understanding that critically unwell patients would need these interventions in the moment. These patients do not have the luxury of time available to them (especially when presenting out of hours or at a facility with limited support services) for another specialist to provide said intervention.

A similar principle applies to EM involvement in endovascular resuscitative techniques, which often need to be initiated in a time-critical fashion. Sometimes the emergency physician is the sole physician at the facility where the patient presents – a large part of the USA, for example, lies over 60 minutes away from access to a level 1 or level 2 trauma center [2]. Even in a busy academic center, the surgeon may be scrubbed in the operating room at the time of patient arrival or be busy with the care of another patient should there be multiple simultaneous patient attendances. As the other available senior physician, the emergency physician is then best placed to undertake the advanced open or endovascular intervention required to buy time to get the patient to definitive care.

In some countries, emergency physicians are intimately involved in providing care in the prehospital environment. We have already seen successful use of prehospital REBOA by the London Air Ambulance service, led primarily by

emergency physicians as part of a robust trauma system [3]. Similar capabilities are being adopted by the Japanese and more recently French prehospital systems, both of which integrate physician prehospital response. This capability also extends to other endovascular techniques such as ECMO [4].

In the military, close collaboration between emergency physicians and surgeons, working as part of far-forward specialist surgical teams, has successfully allowed for the use of endovascular techniques like REBOA by either type of physician [5,6]. Cross-training of skills can allow maximal utilization of limited resources and temporizing of patients in, for example, mass casualty incidents [7].

We are facing an increasing burden of potentially salvageable critically ill and injured patients [8]. Rather than isolating skills within silos of specific proceduralists, enlightened systems should focus on learning from those that have integrated all resuscitation team members in these evolving techniques. Emergency physicians remain a critical part of the resuscitation team, from the prehospital environment, the small community hospital, or at the academic trauma center, military or civilian. They possess a unique skillset that can be built upon to successfully train in the safe implementation of endovascular techniques [9]. Incorporating them into training and sharing knowledge will empower those working within appropriate systems to implement these techniques in the right scenario.

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Case Report

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Be Aware: REBOA May Increase Liver Bleeding

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INTRODUCTION

Severe liver injuries are rarely encountered, however, they are associated with a high mortality rate [1]. Regardless of grade severity, most liver injuries are treated non-operatively. The single indication for surgery, in the absence of other injuries requiring explorative laparotomy, is hemodynamic instability [2]. Surgery in these patients is complicated due to a rapid development of traumatic coagulopathy, followed by hypothermia and acidosis. The opening of the abdominal cavity is often associated with deterioration of hemodynamic status, with a decrease in blood pressure and even hemodynamic collapse. The mechanism is multifactorial but mostly results from the use of anesthetic drugs that have vasodilatory effects [3]. The decrease in systemic blood pressure in massive bleeding might, at times, force the trauma surgeon to perform procedures such as thoracotomy and aortic clumping, which would not have been considered in more favorable situations. With the introduction of resuscitative endovascular balloon occlusion of the aorta (REBOA) and the immediate availability of this technique in some hospitals, in selective cases, REBOA is performed simultaneously with explorative laparotomy as part of the EndoVascular Trauma and Bleeding Management (EVTM) concept [4,5]. In this way, it is possible to obtain a reasonable blood pressure and to "buy" time for more planning and less extensive procedures. We hereby report a case of a patient with a severe blunt liver injury who required a non-anatomical right hepatectomy, where inflation of the intra-aortic balloon would certainly worsen bleeding. The clinical course and therapeutic dilemmas are discussed.

Case Description

A 19-year-old previously healthy male was brought to our trauma unit after a bicycle accident. At the scene, he was stable and had a Glasgow Coma Score of 15. On admission, his blood pressure was 120/78 mmHg, heart rate was 90 beats per min, and he had a pulse oximetry of 95%. Respiration, as well as heart sounds, were normal. On physical examination, multiple abrasions on the anterior chest and abdominal wall were noted. The abdomen was distended and tense. The remainder of the physical examination was unremarkable. Focused assessment with sonography for trauma (FAST) did not reveal any sign of pericardial fluid but did present with a large amount of abdominal fluid. Portable chest x-ray was interpreted as normal. Head, spine, and chest computed tomography (CT) were without findings. Abdominal CT angiography demonstrated right lobe liver laceration grade 5, reaching the hepatic hilum with no signs of arterial or venous extravasation (Figure 1). In addition, a grade 3 spleen laceration was noted, as well as a significant amount of intraperitoneal fluid. Due to his stability, a decision for non-operative management was made, and the patient was admitted to the ICU. Within the next two hours, laboratory results showed a

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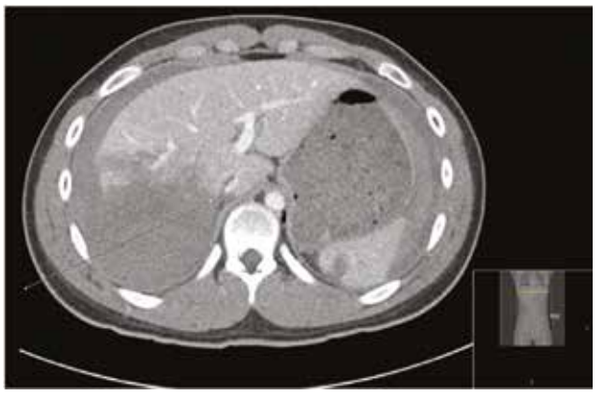

Figure 1 Demonstrating grade V liver laceration. The white arrow shows the tear reaching the liver hilum.

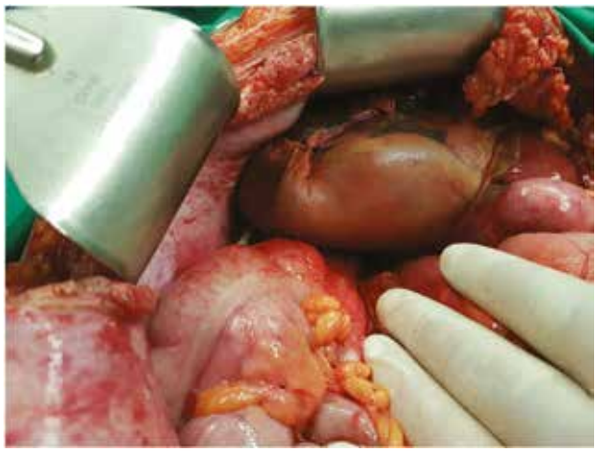

Figure 2 This figure shows the remaining liver after non-anatomical right keratectomy, wrapped with absorbable Vicryl mesh 30 × 30 cm.

drop in his hemoglobin from 11.9 g% to 8.3 g%. Immediate blood transfusion of two units of PC was initiated, and the plan was to refer the patient to hepatic angioembolization. Suddenly, a few hours later, his blood pressure dropped to 80 mmHg, and the patient did not respond to massive blood and fluid resuscitation. The patient was immediately brought to the operating room and the REBOA protocol was activated. Simultaneously, with the initiation of explorative laparotomy, right groin femoral access was achieved by an interventional radiologist using a femoral sheath 8 Fr 10 cm Radifocus Introducer II (Terumo Medical Corp. Ethicon, MD, USA) and an intra-aortic balloon (Rescue Balloon, Tokai, Japan) was inserted and placed according to a catheter 40 cm external marker. In surgery, more than 2.5 liters of blood were evacuated from the abdominal cavity and the abdomen was initially packed. Exploration of the abdomen revealed a large right lobe liver laceration and a grade 3 spleen laceration. Splenectomy was performed as well as peri-hepatic packing. At this point, the patient's blood pressure dropped to 48 mmHg and the balloon was inflated approximately 7 minutes afterward. Immediately after this procedure the blood pressure rose to 155/84 mmHg but bleeding from the liver worsened. This required suture of the liver using local hemostat and additional liver repacking. Total balloon occlusion time was about 15 minutes and then the balloon was deflated. After completion of the procedure, the surgeon's perception was that the peri-hepatic packing itself might be insufficient and that the patient needed additional surgery with on-table angiography and hepatic embolization. During the angiography, several attempts to catheterize the celiac trunk failed and the patient's blood pressure decreased again, to 50 mmHg. A re-laparotomy and immediate Pringle maneuver was performed. This procedure did not improve the situation and under these circumstances, it was decided to perform a non-anatomical right hepatectomy, followed by liver wrapping, using absorbable Vicryl mesh (Figure 2). Due to critical hemodynamic instability, the aortic balloon was fully inflated several times to achieve a reasonable blood pressure. Each time a systolic blood pressure of 90 mmHg was reached, a partial balloon deflation (pREBOA) was done. When blood pressure dropped below the targeted level, the balloon was once again fully inflated. However, each attempt at balloon inflation led to worsening of the liver hemorrhage. After completion of hepatectomy and liver wrapping, the blood pressure became progressively stable; therefore, the balloon was deflated. The total intermittent REBOA (iREBOA) time was one hour. The remaining liver was repacked again, and the abdomen was left open using a Bogota bag. During the procedure, the patient received 22 units of packed red blood cells, 8 units of FFP, and other replacement products. The patient's condition improved gradually and the femoral artery sheath was removed the following day. After 48 hours the abdominal packs were removed, however, the abdomen was left open. On post-operative day 7, the patient underwent definitive abdominal closure using absorbable Vicryl mesh. On post-operative day 10, the patient was successfully extubated and started oral feeding.

DISCUSSION

Surgical treatment of severe liver injuries remains very challenging despite advances in surgical techniques, development of local hemostats, and different devices for hemostasis, such as the cavitational ultrasonic surgical aspirator (CUSA) and the argon coagulator. One of the major problems is that the hemostasis must be achieved quickly. Bleeding from the liver lowers the amount of coagulation factors and causes rapid development of traumatic coagulopathy.

The most acceptable and rapid maneuver for liver hemostasis is peri-hepatic packing [5]. However, in some cases, the packing may be ineffective and there is

an urgent need to perform more sophisticated procedures in patients who are unable to tolerate extensive surgery [6]. REBOA enables a rapid increase in systemic blood pressure. The indications for REBOA usage are still not well defined, however, a recent EVTM Society consensus has clearly indicated the use of this technique in hypotensive trauma patients suffering from massive bleeding [7]. Limited data suggest that the use of pREBOA (or iREBOA) might be beneficial with a higher survival rate [8]. It has been shown that in cases where there is a sudden deterioration of the trauma victim, a resuscitation strategy by the inflation of a previously inserted REBOA, may achieve an increase in systemic blood pressure and can prevent the extension of surgery for thoracotomy with above/below the diaphragm aortic clumping [9]. In our opinion, it is very important to achieve arterial access at an early stage of trauma management, in order to prepare for the worst scenario. Confirmation of the balloon placement may be done in several ways, such as fluoroscopy, ultrasound or even CT scan. In most emergency situations, the balloon is inserted blindly using external catheter markers. The accurate distance for reaching different zones of occlusion is not clear. In a cadaver study, Linnebur et al. [10] found that the average distance from the common femoral artery puncture sites to the mid-sternum and xiphoid was a measured mean (SD) of 41.8 (3.3) and 31.8 (3.9) cm, respectively. However, results of this study are limited and cannot be extrapolated to clinical practice, because cadavers are typically representative of older patients and may also exhibit precise morphological differences from living humans [10]. Another study performed on 25 living trauma patients, based on multiplanar CT angiography, showed that the distance from the femoral artery to the celiac trunk ranged from 30–35.2 cm [11]. The proper placement of the balloon is crucial in order to prevent zone II aortic occlusion, since this may expose the patient to the risks of visceral ischemia, without providing significant benefits compared with a zone III occlusion [12]. Based on the literature, a distance of 40 cm should be appropriate for achieving the correct anatomic location. However, without radiologic confirmation, this is not a simple procedure in urgent settings, when height, habitus, and BMI may be inaccurately assessed.

In our case, the decision to perform explorative laparotomy was made when a hemodynamically stable patient, selected for non-operative management, suddenly deteriorated with a dramatic drop in blood pressure and lack of response to blood resuscitation. In this situation, the inflation of the balloon significantly improved the patient's condition. However, after the inflation, we noted a distinct increase in arterial bleeding from the liver. A similar observation was noticed several times when we needed to re-inflate the balloon due to a significant decrease in blood pressure during the hepatectomy and wrapping. Theoretically, closure of the aorta should decrease any arterial bleeding below the occlusion level. This did not happen in our case. We have several explanations for this fact. The balloon was inserted according to a 40 cm catheter marker in a patient with a height of 165 cm. Therefore, it may have been located between the renal arteries and the celiac trunk. Being open from the celiac part and closed below it, this may certainly worsen the bleeding from the hepatic artery and the whole liver surface. Moreover, exacerbation of the hemorrhage may be associated with increased return pressure via the portal vein. However, after the surgery, we performed a reconstruction of the patient's CT imaging and found that the balloon was located in zone 1. In this case, the worsening of bleeding may be explained by a potential increase in collateral perfusion to the liver. Another theoretical option is misplacing of the balloon into the venous system. In such a situation, occlusion of the inferior vena cava will only decrease the systemic blood pressure. We assume that our case observation is important for trauma teams. In such a situation, when the liver hemorrhage worsens despite balloon inflation, immediate replacement of the balloon at a distance further than the accepted 40 cm marker to ensure zone 1 aortic occlusion should be considered. Even then, the balloon inflation may worsen the bleeding resulting from an increased blood flow via collateral perfusion to the liver. Unfortunately, at the time of surgery, we did not clearly understand and did not consider that the worsening of bleeding may be directly associated with REBOA inflation.

CONCLUSIONS

REBOA may worsen liver bleeding in selected cases. This may be explained by improper zone II balloon placement requiring rapid repositioning of the balloon, positioning of the balloon into the inferior vena cava system or an increase of collateral perfusion to the liver. We believe that future research should be performed to confirm our clinical observations.

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Case Report

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Femoral Arterial Closure After REBOA using the Fascia Suture Technique: First Experiences in a Military Setting

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Femoral vascular closure after REBOA can be challenging, and large-caliber sheaths combined with acute traumatic coagulopathy may lead to serious bleeding complications. The Fascia Suture Technique (FST) has been proposed as a safe easy-to-use and cheap method for reliable vascular closure. We present two cases of critically unstable patients for whom this technique was successfully used after REBOA placement through 8 Fr and 10 Fr sheaths at a Role 2 medical treatment facility. In one case, the FST was used for closure of both the femoral artery and vein. The femoral vascular closure took 6–7 minutes for each procedure (in both cases). No additional sutures were needed before reliable hemostasis was achieved. No hematoma or any other complication was noted during air transportation or afterward during a 6-month follow-up period. This report demonstrates the feasibility and effectiveness of using the FST in austere environments.

Keywords: *Arterial Trauma; REBOA; Vascular Closure; Fascia; Suture; Fascial Closure; Endovascular Trauma Management*

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INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is an effective tool for hemorrhage control in exsanguinating patients [1,2]. In addition to trauma resuscitation, REBOA can act as a bridge to definitive surgery in a variety of clinical settings, such as postpartum and gastrointestinal hemorrhage, ruptured abdominal aortic aneurysm, intraoperative uncontrolled hemorrhage, and non-traumatic cardiac arrest [3–8]. With increased adoption worldwide, the clinical use of REBOA has advanced into pre-hospital and combat casualty care [9,10].

Expedient removal of the sheath after REBOA is an important part of this therapeutic modality and should be done as soon as clinically possible to prevent complications [11,12]. However, sheath removal poses challenges in cases where there is primary insertion of a large sheath, severe coagulopathy, patients with a high body mass index, poor knowledge of vascular anatomy, and a lack of basic endovascular skills. It is obvious that the larger the inserted sheath, the more challenging its removal might be [13]. Since the renaissance of REBOA in modern clinical practice, there has been an evolution in the size of the balloons used. Although modern small-caliber (7 Fr) balloons are now registered in America and Europe, large-caliber balloons (Coda® Cook, Reliant® Medtronic, Boston Scientific) that are compatible with 11-12-14 Fr sheaths are still actively used in some countries [13,14].

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Some alternate solutions like vascular closure devices (VCDs) and the Fascia Suture Technique (FST) can reduce the number of possible complications during sheath removal [15]. Yet, most VCDs have been designed for sheaths ≤8 Fr, and the devices that can be used for large sheath removal are quite expensive and often unavailable. Alternately, the FST is an inexpensive and simple technique that has been employed for femoral arterial closure after endovascular aortic repair [15,16].

Fascia Suture Technique Description

We used the following technique based on a previously described procedure [16,17]. When a balloon catheter is withdrawn, a short starting 0.035″ guidewire is advanced via the sheath inside the lumen for a stable arterial access line allowing rapid back sheath insertion in case of any kind of emergency situation (ligature rupture while making a knot, extensive bleeding after tying a knot, etc.). A short transverse 1.5-cm incision to the lateral and medial site of the leg is made at the entry site for a sheath into the skin to explore the deep fascia (Fig. 1A). When the fascia around the sheath is blindly dissected (Fig. 1B), two 0.5-cm deep bites are performed along the femoral artery, and a 3-0 silk mattress suture is positioned around the entry site for a sheath into the vessel (Fig. 1C). This is followed by tying a knot during sheath withdrawal (Fig. 1D). If there is no continuous bleeding, then the guidewire is removed and skin sutures are applied thereafter, followed by careful distal pulse examination of the treated body part.

Case Descriptions

We present two cases where FST is used after successful REBOA for femoral arterial closure performed to prevent puncture-site bleeding due to coagulopathy and before transportation to the next echelon of care at a Role 2 medical treatment facility (MTF). A Role 2 MTF is a far forward facility mostly deployed in tents and aiming to provide basic resuscitative and emergency surgery [18–20]. Surgical operations are usually performed by a forward surgical team consisting of a few surgeons, nurses, and other staff [20]. At this level of care, only limited equipment, armamentarium and diagnostic tools, such as X-Ray and ultrasound are available.

Patient #1 sustained injuries to his chest and right leg by fragments from an explosion. He had a systolic blood pressure (BP) of 60 mm Hg and a heart rate of 120 beats per minute on admission to a Role 2 MTF 4 hours after injury. Primary assessment revealed a tangential injury to the left chest with entry and exit wounds located at the level of the VI and XI left ribs, respectively. Ultrasound showed free fluid in the abdomen, and the patient was immediately taken to the operation room. Alongside aggressive resuscitation, REBOA was performed for temporary hemorrhage control. A primary right femoral artery puncture failed, and the femoral vein was accidentally cannulated instead via a 10-Fr sheath (MIT, Russia). This line was then used for fluid resuscitation. A second blind attempt was successful and the femoral artery was catheterized via an 8 Fr sheath (Cordis Endovascular, USA). A Rescue balloon® (Tokai Medical Products Inc., Japan) was used for blind zone I aortic occlusion without either ultrasound or fluoroscopy navigation. Immediate inflation of the balloon resulted in an increase and stabilization of systolic BP at the level of 100–110 mm Hg. Immediate laparotomy revealed 1500 ml of blood in the abdomen due to severe splenic injury from fractured rib fragments, and the spleen was removed, followed by slow balloon deflation. Total occlusion time was 25 minutes.

In this case, the FST was applied for removal of both arterial and vein sheaths. Taken sequentially, arterial and venous closure took 15 minutes from skin incision to skin closure (6–7 minutes per each vascular closure). Interrupted 4-0 Prolene skin sutures were applied at the end of the procedure. No further bleeding was noted from either the arterial or venous puncture site during the early post-operative period, medical evacuation by air, and up to discharge from hospital. Two months later, the patient had only a small cosmetic scar in the right femoral region.

Patient #2 suffered a direct blow to his pelvis after a combat-vehicle blast injury. The 25-year-old man was injured while sitting on top of the vehicle but was primarily hemodynamically stable. During evacuation, his condition deteriorated, and he was admitted to a Role 2 MTF with non-measurable BP 3 hours after injury. A pelvic belt was fitted due to mechanical pelvis instability, and ultrasound revealed free fluid in the abdomen. He was immediately taken to the operation room and underwent primary REBOA. A first blind attempt at pulseless femoral artery puncture was successful, and a 10 Fr MIT® balloon catheter (MIT, Russia) was inserted into the aortic zone I and inflated. The patient's BP instantly increased and stabilized at the level of 100–110 mm Hg up to the end of treatment. Immediate explorative laparotomy revealed no injuries in the abdomen, and preperitoneal pelvic packing was performed via a separate incision, followed by pelvic external fixation and pelvic belt removal alongside slow balloon deflation. Total occlusion time for the whole procedure was 16 minutes. As in the first case, the FST was used for femoral artery closure after balloon removal. The whole procedure from skin incision to skin closure took 6 minutes. No bleeding occurred after sheath removal, and a running intradermal Prolene® suture was put in place (Fig. 2). The patient was evacuated to the next echelon of care and underwent pelvic pack removal 3 days after, which was followed by elective internal fixation of bone fractures. No REBOA- and access-related complications were recorded before discharge.

Both procedures were performed by a trauma surgeon trained in vascular and endovascular surgery who

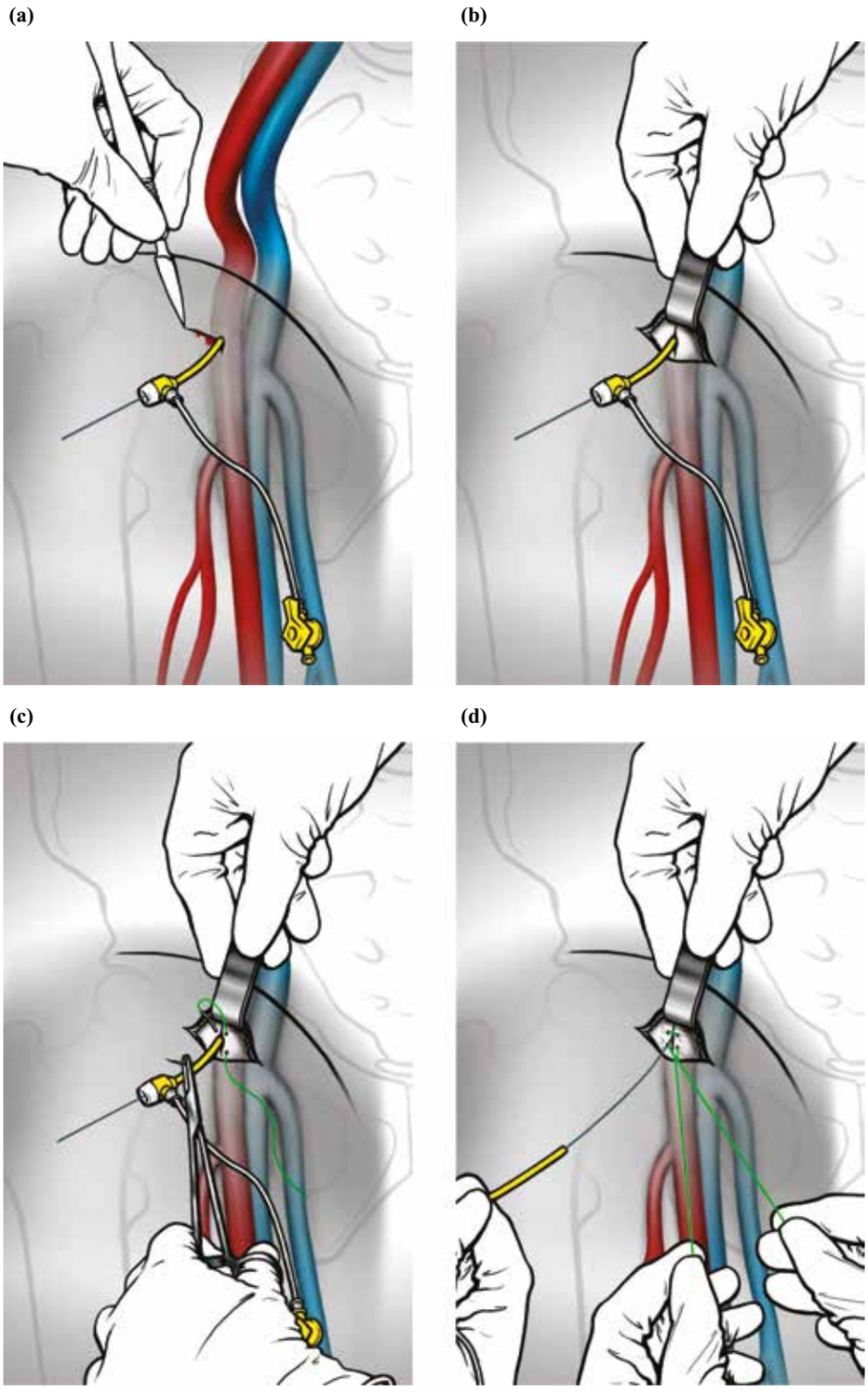

Figure 1 Schematic illustrations demonstrating the Fascia Suture Technique. (**a**) A transverse skin incision to explore the deep fascia. (**b**) The deep fascia is exposed around the sheath. (**c**) One mattress suture is applied around the sheath. (**d**) Sheath removal while tying a knot.

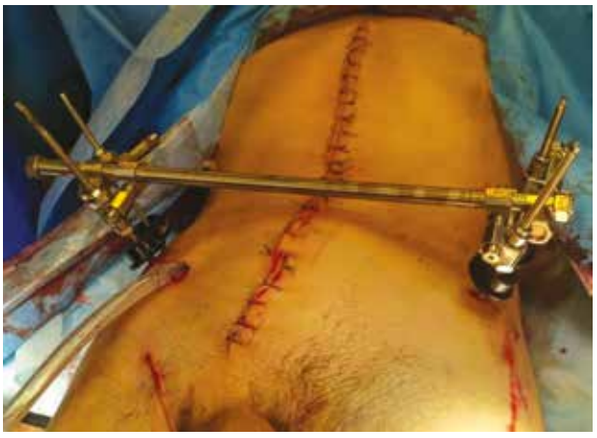

Figure 2 Postoperative view of Patient #2 after REBOA, explorative laparotomy, external pelvic fixation, preperitoneal pelvic packing, and application of the Fascia Suture Technique for femoral vascular closure.

had completed several Endovascular Trauma Management workshops at Örebro University, Sweden, and who had no additional expertise in the FST.

DISCUSSION

REBOA is important for a severely injured patient as a bridge to definitive or even damage-control surgery. At a Role 2 MTF, the most seriously wounded casualties usually go through life-saving damage-control procedures prior to evacuation to the next echelon of care [18–20]. The most reliable procedures should be performed to prepare a casualty for strategic evacuation in such a way as to minimize the risk of recurrent bleeding. In this regard, a method for femoral vascular closure is of importance in modern military settings during frontline surgery.

This report clearly demonstrates the possibility of using the FST, and its effectiveness in austere environments. It shows that the method is simple, fast and safe. No complications were recorded during the bail-out procedures, and both patients survived with good cosmetic results.

The FST was first described for vascular closure by Diethrich et al. in 1997 [15], but the idea of using a simple technique for closing a defect in the arterial wall was born earlier. In 1971, Kornilov proposed a new sutureless method for traumatic lateral arterial injury closure, and successfully investigated it in a canine model [21]. He wrapped an injured artery with a surrounding fascia, creating a compressing cuff impeding extravasation. This method was designed for general surgeons, especially military surgeons, with poor experience of vascular suturing, but it never became regular practice.

The method of Fascia Suture was later developed and investigated by Larzon et al. [16, 22], Montan et al. [17], and Harrison et al. [23], where it was used after endovascular aortic repair. The technical success rate for 18–24 Fr sheath removal using the FST was 88–95% in different studies [17, 22–24]. A recent RCT comparing a VCD for femoral artery closure and the FST has shown that the latter is a faster and cheaper method [22]. The median access closure time for the FST in that study was 12.4 minutes, which correlates with the timing in our study. The total complication rate in the FST group was twice as low as in the VCD group ($p = 0.18$) [22]. It should be noted that the FST envisages putting one or more suture over the artery. Almost every third patient in the recent study had two, three, or even four (1 case) sutures for 16-Fr puncture site closure [22]. In our short series, one suture was enough to completely close 10-Fr and 8-Fr holes.

Removal of a large-caliber sheath is often challenging as it can result in complications, such as a puncture-site bleeding, occlusion or pseudoaneurysm formation. Mathisen et al. describe five adverse events (bleeding, arterial occlusion, a pseudoaneurysm) after removal of ≥18-Fr sheaths by using the FST in a cohort of 50 patients (10% complication rate) [24]. In a recent study by Larzon et al., only one puncture-site hematoma and one pseudoaneurysm developed in a group of 48 patients (4%) after removal of ≥16-Fr sheaths [22]. Although there is a potential risk of failure, in our cases, no complications were noted after removal of relatively small-caliber sheaths during the 6-month follow-up.

Methods for vascular closure after 8-Fr sheath removal can be controversial. It is common to use manual compression [13], or at least small-caliber VCDs (ExoSeal®, AngioSeal®, etc). Although these techniques are reliable and effective in "ideal" settings when a patient can be closely monitored on a continuum of care, no-one has investigated different vascular closure techniques in combat operations when a patient can undergo long transportation by air. Spontaneous re-bleeding from a 3–4-mm hole in the femoral artery can have devastating effects, especially if it occurs during transportation. Thus, we regard the simplest and the most reliable maneuver, i.e., the use of the FST, to be the method of choice in military settings.

Since vascular surgeons do not typically work at a Role 2 MTF, REBOA, if indicated, has to be performed by a general or trauma surgeon. The same is for balloon and sheath removal. The vascular closure technique required is a question answered by the medical, tactical, organizational issues related to a certain military conflict. If the delivery time to the next echelon of care is short and a vascular surgeon is available there, and no immediate strategic evacuation is planned, then a standard lateral suture would be an option of choice and there is no need to remove the sheath early. When, however, there is a need for sheath removal, the FST may be optimal for general surgeons less experienced in vascular procedures because no vascular exploration or lateral vascular suture is needed. Once REBOA is performed, the FST can be easily used by a trained general surgeon.

Sheath removal necessitates appropriate training as an important part of the whole REBOA procedure.

When pre-hospital REBOA is done, vascular closure becomes the only procedure a surgeon at a Role 2 MTF should be prepared for. Special cadaver and live tissue training in performing this procedure may be recommended as a part of different educational courses and REBOA workshops aimed at pre-deployment preparation of military surgeons.

CONCLUSION

The FST is a safe and effective femoral vascular closure procedure after REBOA and is feasible in military settings. Employing the FST may be particularly useful during aeromedical evacuation to minimize the risk of puncture-site bleeding. A certain level of expertise is needed to perform the procedure; hence military surgeons should be trained in the vascular closure techniques following successful REBOA.

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Case Report

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A Case Report of Simultaneous Hypotensive Patients Managed with Concurrent REBOA in a Single-Surgeon Austere Combat Casualty Environment

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Current trends in combat damage control resuscitation (DCR) and damage control surgery (DCS) are moving toward increased support and utilization of resuscitative endovascular balloon occlusion of the aorta (REBOA). The initial reports of successful utilization in combat casualty care, spearheaded by the development of the smaller Prytime ER-REBOA™ catheter, have helped to drive further investment into expanding the use of REBOA. We present a case report that highlights the multiple benefits of REBOA in DCR and DCS. This case report involves the simultaneous management of two combat casualties with non-compressible torso hemorrhage (NCTH) and hypotension. Concurrent use of REBOA in this situation, where both patients required immediate surgery with only one surgeon and operating room table available, emphasizes that REBOA use provides temporization of immediately life-threatening NCTH, a relatively dry operative field, reduced time to operative hemorrhage control, and decreased use of blood products.

Keywords: *REBOA; Austere; Combat*

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INTRODUCTION

Non-compressible torso hemorrhage (NCTH) has been shown to be a leading cause of death on the battlefield [1, 2]. The use of resuscitative endovascular balloon occlusion of the aorta (REBOA) in the management of trauma patients with NCTH is an emerging practice that continues to gain momentum in civilian trauma centers as well as in the far-forward combat casualty care environment [3-5]. Advancements in equipment (e.g. Prytime ER-REBOA™ catheter) and increased training opportunities have further facilitated the progression of this technology [6, 7]. Examples of the combat use of REBOA include recent reports by Manley et al. and Glaser et al., which describe the use of the Prytime ER-REBOA™ catheter [4, 5]. The US Air Force Special Operations Surgical Team (SOST) currently have the most experience with combat utilization of REBOA, this was a total of 20 cases at the time of writing [8].

The US Air Force SOST is a mobile six-person surgical team typically including a surgeon, emergency physician, anesthesia provider, critical care/emergency nurse, respiratory therapist, and scrub technician. SOST members undergo extensive medical and tactical training to provide care to combat casualties in austere environments on opportune air, land or sea platforms in various threat environments [9]. SOST surgeons, emergency physicians, and anesthesiologists are trained in REBOA use at the Basic Endovascular Skills for Trauma (BEST) course prior to deployment [4, 8].

Case Description

Forward resuscitation team care

Two partner force soldiers suffered dismounted blast and fragmentation injuries from an improvised explosive device (IED). They were transported by non-medics in the bed of a pick-up truck to a forward damage control resuscitation (DCR) team within 30 minutes of injury. The forward DCR team included a physician and combat medics from the US Army. They were positioned in a building of opportunity approximately 20 km from the front line of troops. No pre-hospital field interventions had been performed by the local partner forces prior to transport.

Patient Alpha arrived hypotensive with extensive fragmentation wounds and a mangled right lower extremity with a partial amputation at the level of the mid-tibia. During resuscitation, an extended focused assessment with sonography for trauma (eFAST) was positive in the abdomen. After the transfusion of one unit of low-titer type O whole blood (LTOWB), one unit of packed red blood cells (PRBC) and one unit of liquid plasma (LP), the patient's blood pressure improved to 96/56.

Patient Bravo was initially normotensive and tachycardic and suffered a right open tibia-fibula fracture, left femur fracture and extensive fragmentation injuries. An eFAST exam was similarly positive in the abdomen. He received one unit of LTOWB and was normotensive (BP 114/67) just prior to transfer.

From receipt-to-transfer, this care took about 30 minutes. A partner force ambulance, with limited medical resources and training, transported both patients to a DCS team located 45 minutes away.

Surgical facility care

The surgical facility was a makeshift building with a small three-bed resuscitation area and single bed operating room (OR). The only imaging modality available was handheld ultrasound. There were no laboratory capabilities. Blood products were limited. Post-operative patients were generally transferred by local partner force ground ambulance to a hospital with surgical and critical care capability about four hours away.

Both patients arrived at the surgical facility simultaneously approximately 1 hour 45 minutes from injury. Patient Alpha was found to be confused with a BP of 80/50 and HR 110. It was noted that Patient Bravo was also confused with an initial BP of 90/60 and HR 120. A right-sided chest tube was placed in Patient Bravo for pneumothorax without any significant blood output. At this time, it was recognized that both patients required immediate surgery with only one surgeon and OR available. The decision was made by the surgeon to place REBOA catheters in both patients. Both patient's chests were cleared for hemothorax with ultrasound.

Patient Bravo was resuscitated with LTOWB while the right common femoral artery (CFA) was accessed under ultrasound guidance with a 21 G micro-introducer needle, 0.018″ wire and 5 Fr sheath. This was upsized to a 7 Fr sheath using a 0.035″ wire. The REBOA catheter was placed in zone 1 (to 46 cm as measured by external landmarks) and inflated to full occlusion with 8 ml normal saline. The procedure was completed by an emergency physician. Patient Alpha also underwent ongoing resuscitation with LTOWB while the surgeon placed a REBOA catheter in the left CFA using the technique described above. Our standard practice at this point would be to place either a 5 Fr micropuncture sheath or 7 Fr arterial sheath to establish CFA access. This allows for arterial pressure monitoring while facilitating subsequent REBOA catheter placement. In this case, the surgeon planned for preoperative partial and/or intermittent inflation techniques while the other patient underwent surgery, and therefore opted to proceed with REBOA catheter insertion.

Our experience with REBOA has shown that external landmarks are reliable for marking the depth of insertion. Our practice is to verify placement manually at the time of surgery. We have found ultrasound to be unreliable in verifying balloon placement.

Both patients' arterial pressure was monitored with the Centurion Compass UniversalHg™ in-line pressure monitor. This device allows for easily maintainable and transportable invasive arterial pressure monitoring. SOST has refined the use of this device with REBOA for both verification of adequate balloon inflation as well as monitoring of central mean arterial pressure above the balloon. This is achieved by placing the in-line pressure monitor on the arterial port of the Prytime ER-REBOA™ catheter. We believe this device should only be used for short-term monitoring of arterial pressure such as during REBOA use.

Patient Bravo was taken to the OR first. The patient had abdominal scars and deformities from previous surgeries that indicated a hostile abdomen. He also demonstrated the more immediate need for surgery given his transient response to resuscitation. Exploratory laparotomy was performed with extensive lysis of adhesions (LOA), mesenteric hemorrhage control, multiple enterotomy repairs, ascending colon resection, and abdominal

washout and packing. After LOA, exploration was performed for major sources of bleeding beginning with the retroperitoneal zones and solid organs. No retroperitoneal or solid organ sources were identified. Clamps were then placed on all areas of mesenteric injury. The balloon was deflated once bleeding was controlled with clamps. Aortic occlusion (AO) time was 28 minutes followed by 5 minutes of partial occlusion. Partial occlusion was used as an adjunct during balloon deflation to allow anesthesia to "catch-up" with resuscitation efforts. Partial occlusion was achieved by removing half of the balloon volume (approximately 4 ml). The balloon was completely deflated once anesthesia confirmed that the patient was tolerating partial deflation. Total OR time was approximately 1.5 hours.

While awaiting surgery, the resuscitation team maintained Patient Alpha's SBP at about 100 mmHg with transfusion of four units of LTOWB. As there was no formally established SOST protocol, the resuscitation team did not utilize preoperative partial or intermittent AO. After transfer to the OR, the patient's SBP dropped to 90 mmHg and the REBOA catheter was inflated with 8 ml saline in zone 1 (measured at 49 cm). The decision to inflate the balloon at this point was to counter the hemodynamic effects of induction as well as give the surgeon a relatively dry operative field. He underwent exploratory laparotomy with mesenteric bleeding control, ileocecectomy and multiple small bowel resections. Major intraabdominal bleeding was controlled in a similar manner as stated above. Mesenteric injury was the only major source of bleeding identified. AO time was 12 minutes. Partial occlusion was not performed given the short duration of total AO.

Postoperatively, both patients maintained SBP >100 and were noted to be making urine. The REBOA catheters and sheaths were removed as the local national hospital was reportedly unfamiliar with the use of endovascular arterial devices. Manual pressure was held for 30 minutes at the CFA insertion sites. Our practice for sheath removal is manual pressure vs open arteriotomy repair. We do not currently utilize arterial closure devices due to lack of training and concern for infection in the austere environment. Distal arterial flow was demonstrated by ultrasound in both cases prior to transfer to the hospital.

Both patients survived the four-hour transport to the next level of care. Further outcomes were unable to be obtained from the local partner forces. This was due to operational limitations in an active war zone and the significant distance between our site and the local national hospital necessitating multiple patient handoffs during transfer.

DISCUSSION

This case report exemplifies the multiple benefits of REBOA for far-forward surgical assets and augments the growing body of evidence supporting its use. AO via resuscitative thoracotomy is reserved for patients in near arrest or in cardiac arrest. REBOA provides an alternative for AO in the patient who is a transient responder or non-responder with NCTH [10]. In our case, the decision for REBOA placement was multifactorial. Patient Bravo presented as a transient responder with extensive abdominal scars that indicated a difficult dissection. Patient Alpha presented with hypotension and the surgeon made the decision to place the REBOA catheter due to his concern for potential decompensation during Patient Bravo's surgery. The surgeon also intended for Patient Alpha to be treated with partial and intermittent AO while awaiting surgery. This could have resulted in clot formation/stabilization and conserved blood products. Inadequate communication of intent as well as lack of established protocols utilizing these techniques resulted in Patient Alpha's continued resuscitation utilizing permissive hypotension. REBOA use with the simultaneous presentation of hypotensive patients allowed the surgeon to focus efforts on the more demanding patient and provided a temporization to the other patient's ongoing hemorrhage, both in a "proactive" strategy.

In times of extreme resource limitations and mass-casualty scenarios (MASCAL), our situation could have resulted in the triage of one of the patients to "expectant" care. REBOA can potentially alleviate or postpone the need for "expectant" triage practices during MASCAL events.

The technique of hemorrhage control during laparotomy described above is our standard practice. We have found this to decrease the time of AO and overall operative time. Decreased time to control hemorrhage results in less blood product utilization as well as potentially reduced morbidity and mortality. AO provides the surgeon with a relatively dry operative field which speeds identification and control of hemorrhage. In this case report, it also provided time for extensive LOA. This resulted in less operative morbidity such as iatrogenic enterotomies.

Once initial hemorrhage sources are identified and controlled with clamps or packing, the balloon may be deflated to reveal sites of continued bleeding. This decreases the negative effects of an ischemia-reperfusion injury caused by AO. Intermittent occlusion, as well as partial occlusion, are additional techniques to reduce total AO times [11]. Further study is needed to better define how and when to use these techniques. In our case, these techniques could have resulted in decreased blood transfusion requirements and stabilization of blood pressure.

Balloon AO has been shown to decrease overall blood loss and subsequent transfusion requirements in complex surgical oncology cases [12, 13]. This is expected to be an added advantage with REBOA use in trauma over the relatively controlled situation of elective surgery. This is due to more rapid identification/control of hemorrhage as well as limiting the amount of transfused product lost to ongoing bleeding.

CONCLUSION

REBOA continues to show great promise in both civilian and military trauma settings. This case report adds to the growing body of evidence supporting the far-forward use of REBOA. It shows the multiple benefits of REBOA that are magnified in an austere resource-limited combat environment that is often met with unique challenges imposed by MASCAL events. Further study is required to define partial and intermittent inflation techniques which will broaden the scope of application for REBOA in both military and civilian practice.

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Case Report

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Blunt Abdominal Aortic Injury: A Hybrid Approach to Combined Injuries

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Blunt abdominal aortic injury (BAAI) is a relatively rare pathology, usually the result of a seat belt injury in motor vehicle accidents (MVAs), mostly combined with other injuries. Time is a crucial factor for the successful early management of these cases. Hybrid operating theaters, which support the integration of surgical treatment and interventional radiology, provide opportunities to reduce the time-to-surgery for life-threatening conditions. We report the case of a 24-year-old female who was involved in a high-kinematics MVA. On presentation, she was hemodynamically stable but had a prominent seat belt sign and peritoneal signs. A computerized tomography (CT) scan revealed an intimal flap of the infra-renal aorta and a peri-aortic hematoma together with a suspected laceration of the small bowel. The patient was operated with a hybrid approach; emergent endovascular repair of the aortic injury with stent deployment immediately followed by an explorative laparotomy for the intestinal injury. Her postoperative course was uneventful. The hybrid staged approach allowed a clean and efficient repair of a potentially lethal aortic injury and addressed a contaminated injury in the same compartment, hence preventing redundant morbidity. With the advances and growing availability of endovascular techniques, the hybrid approach has to be an important component of trauma management in the modern era.

Keywords: *Blunt Aortic Injury; Abdominal Aortic Injury; Hybrid Approach; Interventional Radiology; Endovascular Graft Stent*

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INTRODUCTION

Time is a crucial factor for successful outcome in the early management of traumatic critical situations. The complexity of poly-traumatized patients requires different approaches in order to cope with the different injuries. This sometimes requires transferring the patient between different locations in the hospital such as the operating room and the angiographic suite. Transferring an injured patient, especially if hemodynamically unstable and is subjected to damage control strategy, is cumbersome, time-costly, and doomed to complications. Hybrid operating theaters, integrating fixed high-quality angiography equipment within the surgical environment, eliminate the need to transfer unstable patients from one location to another. As such, hybrid operating theaters are increasingly becoming available worldwide and could improve the survival rate of severe multi-trauma victims. In this case report, we describe the use and the sequence of a hybrid approach in the management of a 24-year-old female who presented with a BAAI combined with a hollow viscus injury. The case demonstrates the dilemmas of treatment prioritizations and of choosing the right operative approach from those available in the management of complicated injuries.

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Case Report

A generally healthy 24-year-old woman arrived at the emergency department after being involved in a head-on collision as a front passenger. The driver who suffered from multi-organ injuries was evacuated in a helicopter to

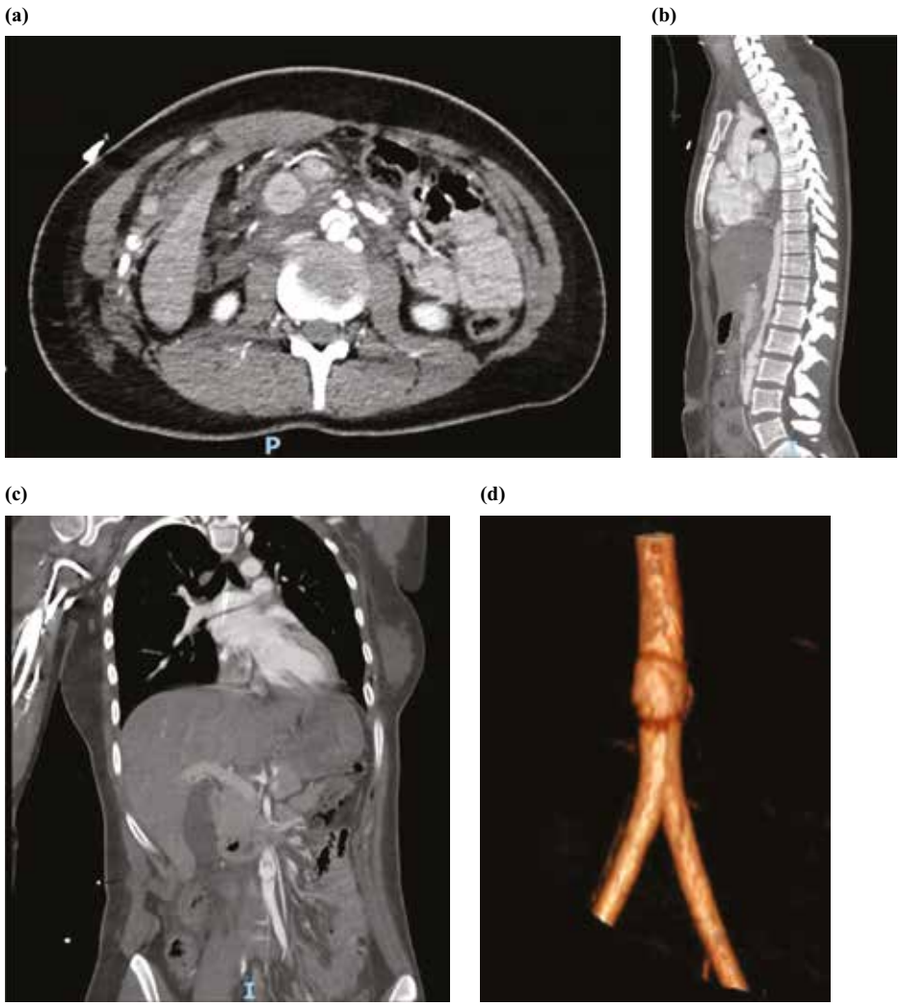

Figure 1 (**a**) Abdominal CT scan, axial view. (**b**) Abdominal CT scan, sagittal view. (**c**) Abdominal CT scan, coronal view. (**d**) 3D reconstruction of the infra-renal aorta.

another trauma center but succumbed within a few hours. On arrival, the presented patient had hemodynamic and respiratory indices within the normal range and was fully alert (HR 81, BP 115/55, Saturation 97%, and Glasgow coma scale 15). The patient complained of hypogastric abdominal pain and low back pain. On physical examination, she had a seat belt sign – abraded cutaneous bands with ecchymosis and diffuse abdominal tenderness. Bilateral femoral and radial pulses were normal. A FAST examination was performed and fluid was observed in the Morrison pouch. As she was stable, the patient was transferred to a total body computerized tomography (CT) scan that showed free fluid in the pelvis, an infrarenal intimal flap 17 mm in length with a hematoma adjacent to it (Figure 1*a–d*), and a hematoma of the small bowel mesentery with a suspected perforation in a mid-jejunal loop.

A multidisciplinary team, including trauma and vascular surgeons, was involved in the surgery of the patient. In the hybrid operating room, an intra-aortic access was gained through the right common femoral artery under general anesthesia. The angiography depicted the infrarenal intimal flap (Figure 2). A BeGraft Aortic Stent Graft System (Bentley™, Hechingen, Germany) with a 12 mm diameter and 39 mm length was placed and lodged with balloon inflation (Figure 3). Subsequently, an explorative laparotomy was performed. There was a small amount of enteric fluid in the peritoneal cavity that was cleansed and a perforation in the mid-jejunum was identified and primarily repaired. The operative time of the combined procedures was 68 minutes. After the operation, the patient was transferred to the ICU for observation. The patient awoke within a few hours. Intravenous antibiotic therapy was given for 24 hours and prophylaxis anticoagulation for prevention of venous thromboembolism was given. After 2 days in the ICU, the patient was transferred to the surgical ward for further observation and 11 days from her admission she was discharged home after an uneventful course.

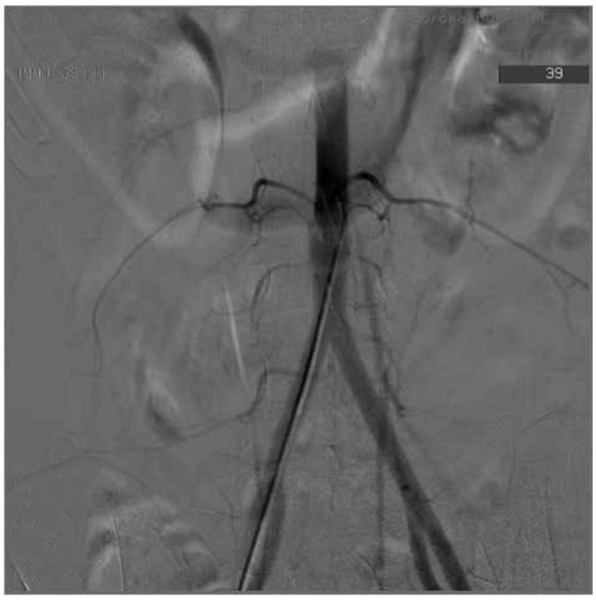

Figure 2 On-table pre-graft insertion angiogram.

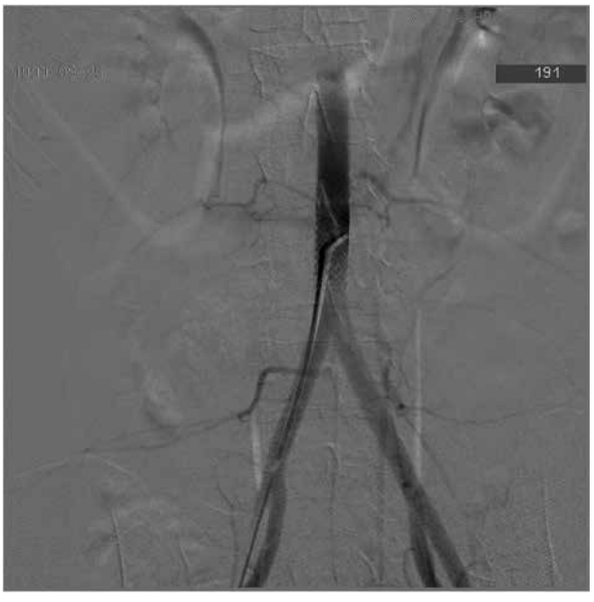

Figure 3 On-table post-intervention angiogram.

DISCUSSION

Incidence

Traumatic blunt abdominal aortic injury (BAAI) is rare and sparsely reported. In an autopsy series of 8,710 injured patients, there were 400 aortic injuries, only 4% of them involved the abdominal aorta [1]. In some series, the incidence of abdominal aortic injury was 0.05%–0.12% [2–5]. In a literature review on BAAI from 1996 to 2012, motor vehicle crashes accounted for more than 60% of the reported causes [6].

Pathophysiology and Clinical Manifestation

Most BAAIs are located infra-renal or below the inferior mesenteric artery [7], as in the current case. On admission, the most common presentation is abdominal pain and signs of acute abdomen usually associated with a seat belt sign. In addition, the patient may complain about different symptoms including lower limb symptoms such as dysesthesias and/or painful paresthesia, painless paralysis, and back pain. Vertebral fractures and hemorrhagic shock may accompany this type of injury. But more importantly, the patient may be asymptomatic and only high suspicion may lead the team to diagnose the injury. The aortic injury is probably the result of the compression and shear forces that are created between the seat belt and the vertebral column. BAAIs to the aorta between T5 and L1 were described with complete obstruction of the Adamkiewicz artery, leading to irreversible lower spinal cord ischemia. In cases of mesenteric vessel involvement, a bowel ischemia can occur either by direct occlusion or by thromboembolism. The presentation may be either acute or slowly advance over a few days. Other common concomitant injuries in the presence of BAAI are spinal fractures (Chance-like fracture) and visceral involvement. Hollow viscus injury is more frequent than the injury of solid organs, with lesions varying from contusion or serosal tear, to transection and avulsion of the vascular pedicles leading to necrotic ischemia. Extra-aortic vascular injuries, notably inferior vena cava laceration and superior mesenteric vein tear, were reported as well [8–12]. Regarding the aortic injury itself, the injury can be an intimal tear associated with disruption of the vasa vasorum that can be asymptomatic. However, subsequent progression to subintimal fibrosis and stenosis may lead to chronic limb ischemia. Full-thickness disruption of the intima and media, with sparing of the adventitia, results in the development of a false aneurysm over hours to weeks. A full-thickness transection will result in massive hemorrhage with a high probability of death due to exsanguination. When no thrombosis or dissection of the aortic lumen is detected, atheromatous plaque fracture with distal embolization is the most likely mechanism of peripheral limb ischemia, either acute or chronic [13,14].

Diagnosis

The diagnosis of a BAAI may be challenging. In an unstable patient, the high-resolution imaging that a CT scan can offer is usually not available pre-operatively. Aortic injuries, especially intimal lesions, may be missed. BAAI can be revealed when retroperitoneal hematoma in Zone I is explored during the emergent explorative laparotomy. CT angiography has a very high sensitivity and specificity for identifying aortic injuries. Due to its high accuracy in identifying most of the vascular lesions

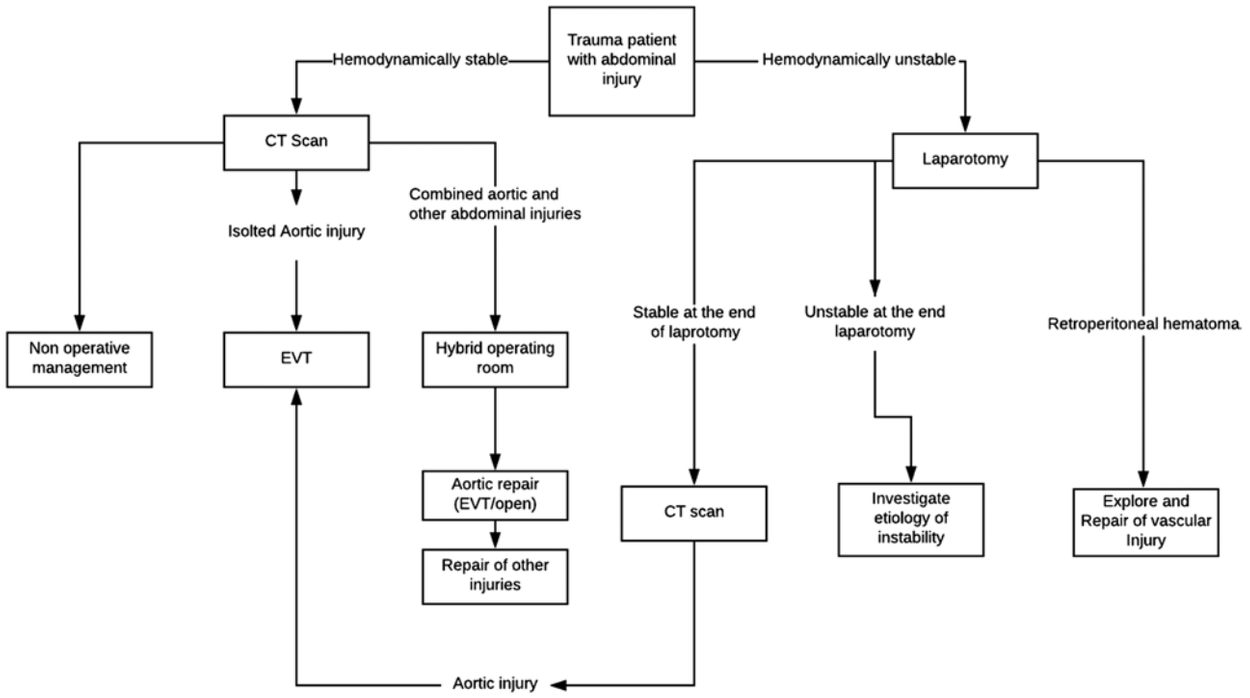

Diagram 1 Proposed use of EVT in abdominal trauma cases.

such as double channel, intimal flap, dilation of the aortic lumen, dissection, thrombosis, pseudoaneurysm, and aortic rupture, it has replaced angiography as the modality-of-choice [15].

Treatment

In the past, laparotomy was used to manage BAAI. In the last few decades, sporadic reports about successful endovascular treatment (EVT) for the acute treatment of blunt abdominal aortic injuries have been published and have revolutionized the treatment of BAAI [3,16–19]. In the present case, it was clear that there was no need for rapid hemorrhage control so a decision had to be made about which of the two injuries identified should be addressed first. In order to manage the patient in the most efficient, rapid and safe way, we decided to treat the patient in a hybrid operating room with angiography capabilities. Although laparotomy was planned in any case and could include a trans-abdominal aortic repair, it was decided that it would be performed using EVT. This approach prevents the contact of a synthetic graft with intestinal contents. The aortic repair preceded the laparotomy due to the potential risk of exsanguination from the transected vessel, which overcomes the risk of further contamination due to the intestinal injury. Today, all cases of poly-traumatized patients are operated in our center on a carbon fiber surgical table with a portable C-arm x-ray machine which enables intraoperative imaging and treatment of suspected orthopedic and vascular injuries. The approach of emergent EVT represents a beneficial solution in the case of abdominal contamination and may be particularly advantageous to patients requiring either damage control surgery or non-operative management of associated lesions. In damage control surgery, the seriously injured patient has physiological derangements and the open procedure which includes entering into a retroperitoneal hematoma, getting proximal and distal control of the injured aorta, and repairing or replacing it with a graft is time-consuming and associated with more blood loss and further physiological deterioration. EVT is an elegant, minimally invasive, rapid option. In non-operative management of abdominal injuries, this approach prevents an unnecessary laparotomy. The method and sequence of managing such injuries are dictated by a few factors including patient hemodynamics, concomitant injuries, and the availability of modalities such as EVT and the necessary setup. For an aortic injury discovered during an urgent laparotomy in unstable patients, a repair, replacement or exclusion with extra-anatomic bypass are options. However, after bleeding control is achieved it is possible to perform an endovascular repair. This approach should be considered especially if there is contamination of the abdominal cavity. In cases where there are concomitant injuries that require laparotomy but the patient is hemodynamically stable, the laparotomy may be preceded by EVT of the aorta. In our opinion, an endovascular approach is preferred because it can save further dissection of abdominal viscera, bleeding, and contamination. This superiority over the conventional open approach justifies transferring patients with BAAI

to trauma centers with EVT ability. In Diagram 1 we propose an algorithm for the integration of EVT in a trauma patient.

CONCLUSION

BAAI is uncommon but should always be considered especially in incidents of high energy mechanism and in the presence of a seat belt sign. Missed or delayed diagnosis may lead to devastating complications. Therefore, for investigation of the vascular involvement peripheral signs of acute ischemia must be assessed, followed by a CT angiography. Once a diagnosis is made, prompt treatment has to be taken. The presented case and other recent reports convince us that the advantages of EVT will make it the preferred approach in the future, even in cases of planned laparotomy, although open surgical repair is still considered state-of-the-art. Nevertheless, the long-term results of such therapy are yet to be evaluated. Hybrid operating rooms are a necessity to enable the implementation of this management strategy.

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2nd EVTM Symposium - Örebro, Sweden, 7-9 June 2018

ABSTRACTS

The Abstracts on the following pages have been approved for publication by the authors. Abstract Committee: Joe DuBose, Kristofer Nilsson, Tal Hörer.

1162-A-1821

Splenectomy versus hilar splenic vessel ligation (animal model)

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Introduction: the most prevalent method of treating splenic injury is splenectomy. This method is followed by many major postoperative complications. Therefore, less invasive procedures such as splenic angioembolization are introduced. This technique needs appropriate training and a high-tech setting, which is followed by some complications therefore not all surgeons agree to do this procedure for patients with splenic injury. Splenic artery ligation is another method with not fully understood results. Splenic hilar ligation of main vessels is a non-invasive procedure with similarity to splenectomy with unknown results as well. We aim to evaluate hematologic and immunologic changes and functional state of spleen before and after ligating its main vessels and compare it to splenectomy.

Materials & methods: 30 rats divided into splenectomy and splenic hilar ligation groups. Identical grade 3-spleen injury performed on all rats. Main vessels ligation performed by silk sutures. After 6 weeks blood samples were obtained and various hematologic and immunologic aspects were measured in their serum. Giemsa stained peripheral blood smears obtained from ligation group and investigated with light microscope. Scintigraphy performed by injecting technetium 99m in normal and ligated groups.

Results: comparing above-mentioned variables before and after the surgery in splenectomy and ligation group showed statistical significance in all aspects except IgM, C4 and platelets levels in ligation group (P value: 0.213, 0.059 and 0.649 respectively). Analysis revealed significant deference in postoperative WBC, IgM and C4 levels between splenectomy and ligation group (P value: <0.001, <0.001 and 0.026 respectively).

Conclusion: splenic hilar ligation of main vessels is an easy way of treating splenic injury in hemodynamically stable patients with less postoperative complications therefore, it can be performed by all surgeons in all kind of medical centers. Spleen remains viable and continues its role although some aspects of its function become erupted.

1453-A-1821

Retrievable RESCUE Stent Maintains Distal Perfusion during Rapid Control of Noncompressible Hemorrhage

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Introduction: Limitations of current methods for control of noncompressible hemorrhage are ischemic injury and continued retrograde hemorrhage. A RESCUE stent is a retrievable stent that offers rapid placement while preserving branch perfusion and was examined for control of caval and aortic hemorrhage in a porcine model.

Methods: RESCUE stents were constructed with a retrievable “petal and stem” design from nitinol wire and a sleeve of polytetrafluoroethylene. Single section stents were sized at 23 mm for venous injuries. Alternately, for aortic injuries a three section stent included covered regions at the top and bottom while the middle is bare to offer continued visceral perfusion. Anesthetized pigs underwent 22-French injury of either the vena cava or thoracic aorta followed by deployment of the respective RESCUE stent by sheath withdrawal from a femoral access. Hemorrhage control and distal perfusion were imaged. At one hour, the stents were retrieved by simple sheath advancement during permanent repair.

Results: Deployment of the 9 French venous RESCUE stent took less than 2 minutes under fluoroscopy. The stent immediately conferred caval hemorrhage control and allowed rapid correction of hypotension. The stent was retrieved easily with sheath advancement at the time of permanent vascular repair. Postoperative labs revealed no statistically significant change compared to baseline. In addition, an 8 French, three section aortic stent provided immediate aortic hemorrhage control while preserving flow to the visceral vessels and lower extremities.

Conclusions: A RESCUE stent provided rapidly-deployed control of hemorrhage in porcine models of both caval and aortic injury without interruption of distal or visceral perfusion. Contrasting to intensive sizing of permanent stents, the RESCUE stent accommodates different diameters and allows removal at the time of permanent repair. In summary, the RESCUE stent may have valuable application for “minimally invasive damage control” of hemorrhage while minimizing ischemic injury and retrograde hemorrhage.

ABSTRACTS

1454-A-1821

Beyond REBOA: Military Priorities for Translational Research in Endovascular Hemorrhage Control and Resuscitation

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Uniformed Services University of the Health Sciences
United States Army Institute of Surgical Research
Madigan Army Medical Center

Background: Delays in surgical hemostasis make non-compressible torso hemorrhage (NCTH) an increasing threat to life on the modern battlefield. The US military has identified endovascular hemorrhage control and resuscitation (EHCR) as a research area to mitigate this threat.

Methods: Following a call to produce endovascular solutions for prolonged battlefield hemorrhage control and resuscitation from NCTH, a literature search was performed to identify details of military NCTH and relevant animal models of EHCR for these injury patterns. Gaps in translational research were synthesized into areas for future study and short, mid, and long-term objectives identified.

Results: Solid organ, major arterial, and pulmonary vascular injuries are the most common sources of NCTH, with major arterial and pulmonary injuries strongly associated with mortality. Few relevant large animal translational models of EHCR to definitively address such injuries exist and minimal battlefield capable EHCR technologies have been studied. The physiologic effects of >60 minute aortic balloon occlusion have been minimally explored and aortic occlusion as a resuscitation adjunct has not been studied in conjunction with EHCR. Three priority areas for translational EHCR research are identified: 1) Endovascular Resuscitation (autonomous vascular access/guidance, advanced vascular occlusion/resuscitation techniques, mitigation of induced ischemia-reperfusion injury), 2) Management of Major Arterial Injury (non-angiographic identification, control, and exclusion of injuries), and 3) Management of Pulmonary and Solid Organ Injury (embolization and pulmonary vascular exclusion techniques). Meaningful research in each area will require the development of novel large animal models and new endovascular technologies and devices suitable for use under battlefield conditions. EHCR training must progress along with translational research such that advances can be fielded.

Conclusion: Large knowledge and technology gaps are present in the EHCR management of battlefield NCTH. Appropriately focused translational endovascular research programs should be developed to address these gaps, especially at the intersection of resuscitation and hemorrhage control.

1461-A-1821

Endovascular management in severely traumatized patients: Experience at a Level 1 Trauma Center in an Upper-Middle Income Country

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Introduction: Endovascular and hybrid therapy have emerged as a new treatment option for complex trauma. We describe a case series of trauma patients with endovascular management at a Level I Trauma Center in an upper-middle income country.

Methods: Retrospective study of traumatized patients who received endovascular therapy from 2010 to 2017. Patients were divided in two groups, patients with single endovascular therapy (SET) and those with hybrid therapy (HT). Demographic data, injury details and treatment were registered.

Results: This study included 74 patients. 21 patients with SEM and 44 with HT. In SET group, mean age was 35 (IQR 22-56), ISS 16(IQR 9-25). 63,3 % had penetrating trauma (53,3% by gunshot), 26,7% arrived in shock. 43,3% of the arterial injury was subclavia. 46,7% were managed with stent (GORER VIABAHN R). There were 2 endovascular complications (Endoleaks). There were no deaths. HT group mean age was 25 (IQR 20-42), ISS 25 (IQR 16-35). 56.8% of trauma mechanism was penetrating (51,4% by gunshot). 34 patients arrived in shock. In 84.1% of the cases, surgery was prior to endovascular procedure. 50% of the cases with hybrid treatment were due to vascular trauma in areas of complex surgical approach (25% subclavian, 18% hypogastric and 10,8% hepatic arteries). 5 patients with non-compressible torso hemhorrage needed REBOA as a bridge to the hemodynamics. 47.7% presented active hemorrhage at angiography. 39,2% underwent Gianturco Coil R embolization. 43.2% of these patients presented general complications (coagulopathy, pneumonia, infection). There were 4 endovascular complications (Endoleak, thrombosis). There were 6 deaths, none attributable to endovascular management.

Conclusion: Endovascular and hybrid trauma management are still evolving. They seem to be a feasible and safe option and may be able to reduce mortality in penetrating trauma.

ABSTRACTS

1464-A-1821

Resuscitative Endovascular Balloon Occlusion of the Aorta: A Single Trauma Center Experience in Korea

Dong Hun Kim, Seok Won Lee, Ye Rim Chang, Jeongseok Yun, Seokho Choi, Sung Wook Chang, Jung-Ho Yun

Dankook University Hospital

Purpose: Resuscitative endovascular balloon occlusion of the aorta (REBOA) as minimally invasive alternative to open aortic cross clamping to provide temporary aortic occlusion can be a bridging modality for damage control resuscitation. We present experiences of REBOA in patients with exsanguinating abdominal or pelvic injuries after multiple blunt trauma in Korea.

Methods: REBOA performed at a level I trauma center from August 2016 in which an institutional REBOA protocol was established. The level of aortic occlusion for REBOA was indicated as the aortic zone reported previously. Zone I consists of the thoracic aorta below left subclavian artery and zone III includes the infrarenal aorta. Balloon catheters were used with 7 or 12Fr.

Results: REBOA was performed in 20 patients, median age was 50 years (range, 7-89 years), and 65.0% were male. All patient sustained blunt trauma, and the median injury severity score was 32 (range, 16-75). Of them, aorta was occluded in zone I of 10 patients (50%) with abdominal organ injuries and zone III of 5 (25%) with unstable pelvic fracture, and the procedure was failed in 2 patients (10%). Among the 3 patients with a zone I insertion, 2 were identified with thoracic injury and 1 was upper cervical spine injury attributed to refractory shock. Three patients died with cardiopulmonary resuscitation in progress at the time of REBOA. Four patients (20%) survived with damage control procedure following REBOA (3 zone I, 1 zone III). In the successful REBOA, median door-to-puncture time was 23.5 minutes (range, 10-120), and median balloon duration was 48.5 minutes (range, 30-104). REOBA-related complication was presented with skin necrosis on foot dorsum in a zone III patient.

Conclusion: REBOA targets on achieving temporary aortic occlusion in trauma patients with exsanguinating abdominopelvic hemorrhage, and so that may be an effective resuscitative modality as a bridging procedure for definite bleeding control.

1487-A-1821

Isolated Aortic Abdominal Injury in Blunt Trauma: Two Case Reports and Review of the Literature

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Meir Medical Center

Injury to the abdominal aorta as part of a blunt injury is a rare event. A Western Trauma Association study reviewed 392,315 blunt injury cases and found blunt abdominal aortic injury in only 113 (0.3%) of cases. In many these cases, the aortic injury is associated with other abdominal injuries, such as solid organ injury, small bowel injury, mesenteric hematoma, colon injury etc. The increasing use of multi-detector CT scans has led to an increase in the detection of injuries to the abdominal aorta.

Blunt injuries to the aorta are classified by type and by location. The types of aortic injury include free rupture and pseudoaneurysm, in which the external contour of the aorta is abnormal, as well as intimal tears and large intimal flaps, in which the external contour of the aorta is unchanged. Zones of injury are classified based on possible endovascular approaches: Zone I injuries range from the diaphragmatic hiatus to the origin of the SMA, Zone II encompasses the SMA, IMA and renal arteries, and Zone III includes injuries below the renal arteries.

The management of blunt abdominal injury is highly variable, ranging from non-operative management to open aortic repair. In the past decades, endovascular techniques have emerged. As more and more experience is gained with abdominal aortic repair in the elective setting and with traumatic thoracic aortic injury on the other hand – the endovascular management of abdominal aortic repair is rapidly gaining momentum.

We present two cases where injury to the abdominal aorta was the sole abdominal injury. Details and on the management and outcome are described and a review of the available literature is presented.

ABSTRACTS

1488-A-1821

A case series of resuscitative endovascular balloon occlusion of the aorta (REBOA) for noncompressible torso hemorrhage.

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Gachon University Gil Medical Center

Introduction: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is using as an adjunctive management for profound shock in some trauma centers. We report our early experience of REBOA to describe implementation and possible indications of REBOA.

Methods: Descriptive case series of REBOA in profound shock due to noncompressible torso hemorrhage (NCTH) at a single Korean trauma center.

Results: All cases (n=12) were done for blunt mechanisms. Six cases (50%) were REBOA in zone 1 and six cases (50%) in zone 3. Mean pre-occlusion systolic blood pressure (SBP) was 54.7 and post-occlusion SBP was 95.3. Eleven patients (91.7%) survived at trauma bay and seven (58.3%) survived for 24 hours. Four patients (33.3%) survived and discharged without neurologic deficit and all of them were zone 3 occlusion.

Conclusion: REBOA can be effective method of aortic control in profound shock due to NCTH. In our series, especially zone 3 REBOA for pelvic hemorrhage showed better outcomes.

1490-A-1821

Ealry Experiece of Resuscitative Endovascular Balloon Occlusion of the Aorta in South Korea

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Gachon University Gil Medical Center

Objectives: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a relatively innovative procedure designed to control critical hemorrhage in trauma. In South Korea, trauma centers began to be built in 2012, and ten trauma centers are recently in operation. However, REBOA is currently in active use at only a small number of trauma centers. The purpose of this study was to describe a Korean trauma center's early experience with REBOA and to evaluate its outcome.

Methods: All patients treated by REBOA from three level I trauma centers in South Korea were included. Data were collected retrospectively.

Results: Thirty-eight patients (23 male, from 7 to 89 years) were included. All patients was admitted via emergency department due to blunt trauma. Mean of injury severity score was 36.5. 16 (42.1%) patients had unstable pelvic bone fracture and 21 (55.2%) had hemoperitoneum. Only one case had both leg open fracture with shock status. Zone I of REBOA was used in 24 (63.1%) patients. The remaining 14 (36.8%) patients received zone III of REBOA. All of patients were checked ballon position with plain X-ray but one case with ultrasonography. Procedure of REBOA was performed by trauma surgeon in all 38 (100%) patients. The mortality was 71% (27/38) and survival was 28.9% (11/38). During post REBOA, femoral artery occluded by sheath in one patients and cuased ischemia of leg.

Conclusions: Early data suggest that REBOA represent a feasible option for unstable trauma patient. Although beginning stage, we expect usefulness of REBOA and effectiveness for more positive results in unstable trauma patient.

1491-A-1821

Successful endovascular and staged surgical management in traumatic thoracic aorta dissection with impending rupture

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Gachon university Gil medical center

A 53-year-old male who presented to the trauma center with blunt trauma after a traffic accident while riding his bicycle. He suffered from traumatic brain injury, clavicle fracture, tibio-fibular open fracture and especially chest pain from aortic dissection. Aortic dissection progressed from distal aortic arch to celiac trunk, and The patient was treated by thoracic endovascular aortic repair(TEVAR). The origin of aortic dissection was an distal aortic arch and the stent graft blocked the left subclavian artery due to narrow landing zone. Fortunately, angiogram after TEVAR performed that showed The blood supply from the vertebral artery to the left arm was well maintained. We performed an scheduled operation for connect the carotid artery to the left subclavian artery with ring graft 7 days after TEVAR . The patient treated the other injuries and discharged without any complications.

1495-A-1821

Successful partial REBOA with solving the specific issue in extreme elderly patient

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Faculty of Medicine Siriraj Hospital

- Background: To demonstrate how to perform successful REBOA in extreme elderly patient

- Materials and methods: A case report

- Results:

A 86-year old male, he was struck by car and transferred to Level I Trauma center at Siriraj hospital. Arrival clinical signs were coma and hypotension, lowest SBP was 50 mmHg. Primary survey found unstable pelvic fracture and severe head injury. We did REBOA at Zone I via left common femoral artery which aim to do partial balloon technique by inflation with 15-18 mL and arterial line monitoring for goal SBP around 100-120 mmHg due to his extreme age and associated traumatic brain injury. After CT scan showed no intra-abdominal injury, we did reposition the balloon to zone III under fluoroscopy. Unexpectedly, during deflation the balloon before removal, we found fresh blood through the balloon port, then ruptured balloon was suspected and confirmed with aortography. We immediately converted to remove by open technique due to balloon was failed to shrinkage through 7-Fr sheath. We reviewed the CT scan was shown calcified plaque along aorta and arteries which could be the cause of ruptured balloon. Throughout all procedures to stop bleeding which are pelvic external fixation, preperitoneal pelvic packing and angioembolization, patient was given PRC only 4 units and no inotropic support to stabilizing patient. Total inflation time was 167 minutes with partial and intermittent REBOA technique. ICU Admission lab showed normal renal and liver function.

- Conclusion:

To perform REBOA in extreme elderly trauma patient, the partial balloon technique with goal SBP to balance between associated injury in polytrauma patient is very essential. The specific concern in this group would be related with the changing of reserve function and vascular access. Techniques for detection and solving uneventful conditions should be prepared and learnt to successfully save the elderly patient.

ABSTRACTS

1497-A-1821

Initial Experiece of Resuscitative Endovascular Balloon Occlusion of the Aorta in single regional trauma center of South Korea

Pil Young Jung, Seongyup Kim

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Background: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a relatively innovative procedure designed to control critical hemorrhage in trauma. We present initial experiences of REBOA in single Regional Trauma Center of South Korea.

Materials and Methods: From January 2017 to December 2017, patients who performed REBOA in our institution were collected and reviewed.

Results: Eight patients (6 female, from 17 to 72 years) were included. All patients was admitted via emergency department due to blunt trauma. Mean of injury severity score was 30 (from 9 to 41). 4 (50.0%) patients had unstable pelvic bone fracture and 3 (37.5%) had hemoperitoneum. Only one case had both leg open fracture with shock status. Zone I of REBOA was used in 4 (50.0%) patients. Except for 2 cases (RESCUE catheter), Reliant catheter was used. The remaining 4 (50.0%) patients received zone III of REBOA. All of patients were checked ballon position with plain X-ray but one case with ultrasonography. Procedure of REBOA was performed by trauma surgeon in all 8 (100%) patients. The mortality was 62.5% (5/8) and survival was 37.5% (3/8). During post REBOA, femoral artery occluded by sheath in one patients and cuased ischemia of leg.

Conclusions: Early data suggest that REBOA represent a feasible option for unstable trauma patient. Although beginning stage, we expect usefulness of REBOA and effectiveness for more positive results in unstable trauma patient.

1543-A-1821

REBOA for in-hospital cardiac arrest due to idiopathic retroperitoneal hemorrhage in a patient undergoing anticoagulation therapy

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Background: Recently many reports have shown that REBOA produces good results in patients with hemorrhagic shock due to both trauma and non-trauma. We present a case of in-hospital cardiac arrest from hemorrhagic shock caused by idiopathic retroperitoneal hemorrhage.

Case report: The case was an 87-year-old man hospitalized for the treatment of thrombotic cerebral and cerebellar multiple infarcts suffered six days before. He received anticoagulation therapy with heparin and warfarin in the stroke care unit. The latest PT-INR value was within the target range, 2.36. His condition suddenly deteriorated with a depression of mental status and a severe drop in blood pressure. His hemoglobin dropped to 3.6 mg/dl. A CT scan revealed a massive retro- and intraperitoneal hemorrhage with a focus on an iliopsoas muscle hematoma. After CT examination, he was referred to our department as he was going into cardiac arrest. When he arrived at the emergency room, he already had a pulseless electrical activity. We performed advanced cardiac life support, including uncross-matched type O packed red blood cell transfusion, and simultaneously established REBOA with a blind procedure. Finally, we achieved successful resuscitation. Subsequent angiography showed active bleeding from multiple lumbar arteries, which were managed by transcatheter arterial embolization with gelatin sponge particles. He remained hemodynamically stable after deflating the REBOA balloon. After seven days of intensive treatment, he went back to stroke care unit for further treatment and rehabilitation for the primary disease.

Conclusion: REBOA can be safe and effective in hemodynamically unstable hemorrhagic patients, even shortly after cardiac arrest.

ABSTRACTS

1553-A-1821

Look before you leap!; A classic but novel chest X-ray finding for aortic injury, “UGG®-ly” mediastinum.

N Shima, S Okuma, T Miyakawa, R Kumano, K Yagihashi, H Mimura, T Yamada, Yuri Kon, Takeshi Miura, Junichi Matsumoto

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Tokyo Women's Medical University Yachiyo Medical Center
St. Marianna University

In the setting we need to think of REBOA, the patient is hemodynamically unstable and we have to decide immediately if we use the aortic occlusion balloon. Suggested algorithms say not to use REBOA in the patient with suspected aortic, cardiac, or severe chest injury causing major chest bleeding. This means it is very important to detect “major” chest injuries with using chest X-ray, ultrasound, and/or chest tubes.
The purpose of this poster presentation is to show how to quickly evaluate “major” chest injuries with portable chest X-ray during primary survey with emphasis on the classic and useful radiographical sign for aortic injury, which we named it “UGG®ly” mediastinum after its unique shape mimicking the very popular sheep skin boots of UGG®, by an American brand.
Other findings explained in this presentation will be those for various amounts of pleural fluid collection, cardiac, and lung injuries. Corresponding CT images will be shown to share the mechanisms of these signs. Clinical significance and management of these radiographical findings during primary survey will be also discussed.
It is essential for you to get able to evaluate these findings if you need to think of REBOA. Look before you leap!

1600-A-1821

REBOA in Hybrid-ER

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Background: The algorithm of the resuscitative endovascular balloon occlusion of the aorta (REBOA) in trauma care is being established. In case of a blunt trauma with hemorrhagic shock, REBOA will be deployed with chest radiography to assess the possibility of aortic injury. However, it is impossible to exclude aortic injury only by chest radiography. In hybrid emergency room (Hybrid-ER), computed tomography (CT) can be easily performed, and it is possible to exclude aortic injury. Case: A 40-year-old male was transferred to our hospital with abdominal pain after a traffic accident. Vital signs at the scene were as follows: GCS14 (E4V4M6); respiratory rate, 30/min; pulse rate, 98/min; blood pressure, 57/28mmHg; and oxygen saturation, 97%. After assessment of airway and breathing, CT was performed. It showed no intracranial injury or massive intra-abdominal hemorrhage. Hence, open surgery was performed. Tracheal intubation under sedation and REBOA were performed; laparotomy was thus started 30 minutes after arrival. Gallbladder injury and hepatic injury (AAST Grade 2) was recognized; cholecystectomy and liver suture were performed as an abbreviated surgery (DC1). Discussion: In Hybrid-ER, CT can be performed easily. The more accessories (intravenous lines, intubation tube, respirator, and chest tube) the patient has, more difficult it is to perform CT. Therefore, CT should be performed only after assessment that the patient is not indicated for emergency intubation. CT should be performed within 10 min after arrival. CT can reveal the presence of aortic injury making it easier to share treatment strategies. In this case, active intra-abdominal bleeding was observed, and urgent laparotomy was required. Aortic injury was not observed, and REBOA was indicated. We believe that this is a typical case of the algorithm of REBOA in Hybrid-ER.

ABSTRACTS

1592-A-1821

A case of traumatic shock in which hepatic hemorrhaging was controlled and the patient's life was saved using an Intra-Aortic Balloon Occlusion catheter.

Toru NASU, Shuji KAWASHIMA, Naoaki SHIBATA, Kentaro UERDA, Tsuyoshi NAKASHIMA, Masaoh TANAKA, Yuko OKISHIO, Kosei KUNITATSU, Takafumi YONEMITSU, Seiya KATO

Wakayama Medical University Hospital

We use the intra−aortic balloon occlusion (IABO) procedure to temporarily control abdominal bleeding at the prehospital accident scene and in the emergency room (ER) based on the individual circumstances.

The patient was a 25-year-old man, who was injured in a head-on collision with a telephone pole while driving a small car. The patient was transported to our ER suffering from high-energy trauma. When he arrived at the emergency clinic, he had GCS of 14 points (E4V4M6), his blood pressure was 66/60 mmHg, his pulse was 132 beats/min, his respiratory rate was 20 breaths/min, and his SpO2 value was 95% with 6L of oxygen per minute by mask. FAST was positive (Morison's pouch and perisplenic region). X-p revealed no findings. He was unresponsive to the initial transfusion. IABO through the right femoral artery was performed in the ER. Emergency laparotomy was performed 60 minutes after admission. The intraoperative findings showed hepatic injury of the VI segment with hemorrhage. Accurate artery ligation and perihepatic packing with gaze were successfully employed to control liver hemorrhage. Temporary abdominal closure, followed by hepatic arteriography and embolization of a branch of the common hepatic artery, completed the damage control. Re-exploration laparotomy confirmed definitive hemostasis and the packing material was removed without complications.

In the present case, we were able to temporarily control the bleeding, carry out surgical treatment in a bloodless field, and identify the site of bleeding by inflating/deflating the balloon. On the other hand, we believe that emergency thoracotomy should be quickly performed when it is not possible to safely insert an IABO device.

1596-A-1821

Successful use of resuscitative endovascular balloon occlusion of the aorta in the management of ruptured right gastric artery aneurysms

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Mie prefectural general medical center

Background

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a life-saving procedure used to control bleeding and maintain blood pressure temporarily in hemorrhagic shock.

Materials and methods

A 75-year-old man was transferred to the emergency department with sudden abdominal pain. Radiographically, we diagnosed intra-abdominal bleeding due to a ruptured aneurysm of the right gastric artery. Endovascular therapy of coil embolization was chosen to treat the aneurysm. Because of refractory hypotension despite maximal conventional therapy, we used REBOA before patient transfer to the angiography suite for endovascular treatment.

Results:

Coil embolization was performed proximal to the aneurysm with successful vascular occlusion. The patient's postoperative course was uneventful and was discharged on the 14th day after embolization.

Conclusion

REBOA might be a minimally invasive technique that can be used as an adjunct to massive transfusion resuscitation and endovascular therapy for life-threatening intraperitoneal hemorrhage.

1591-A-1821

Blood pressure targeting by partial REBOA is possible in severe hemorrhagic shock in pigs and produces less circulatory, metabolic and inflammatory sequelae than total REBOA

Mitra Sadeghi

Västmanlandssjukhus

Blood pressure targeting by partial REBOA is possible in severe hemorrhagic shock in pigs and produces less circulatory, metabolic and inflammatory sequelae than total REBOA

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Abstract

Background: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is an effective adjunct in exsanguinating torso hemorrhage, but causes ischemic injury to distal organs. The aim was to investigate whether blood pressure targeting by partial REBOA (pREBOA) is possible in porcine severe hemorrhagic shock and to compare pREBOA and total REBOA (tREBOA) regarding hemodynamic, metabolic and inflammatory effects.

Methods: Eighteen anesthetized pigs were exposed to induced controlled hemorrhage to a systolic blood pressure (SBP) of 50 mmHg and randomized into three groups of thoracic REBOA: 30 min of pREBOA (target SBP 80-100 mmHg), tREBOA, and control. They were then resuscitated by autologous transfusion and monitored for 3 h. Hemodynamics, blood gases, mesenteric blood flow, intraperitoneal metabolites, organ damage markers, histopathology from the small bowel, and inflammatory markers were analyzed.

Results: Severe hemorrhagic shock was induced in all groups. In pREBOA the targeted blood pressure was reached. The mesenteric blood flow was sustained in pREBOA, while it was completely obstructed in tREBOA. Arterial pH was lower, and lactate and troponin levels were significantly higher in tREBOA than in pREBOA and controls during the reperfusion period. Intraperitoneal metabolites, the cytokine response and histological analyses from the small bowel were mostly affected in the tREBOA compared to the pREBOA and control groups.

Conclusion: Partial REBOA allows blood pressure titration while maintaining perfusion to distal organs, and reduces the ischemic burden in a state of severe hemorrhagic chock. Partial REBOA may lower the risks of post-resuscitation metabolic and inflammatory impacts, and organ dysfunction.

1598-A-1821

An optimal length for the zone-1 placement by Resuscitative Endovascular Balloon Occlusion of the Aorta

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Purpose: To identify an optimal length in zone-1 placement for the use of Resuscitative Endovascular Balloon Occlusion of the Aorta, REBOA.

Materials and methods: We conducted a prospective observational study at two hospitals in Kanagawa, Japan. We included patients with trauma transported by an ambulance to the hospitals and received an insertion of an arterial sheath at the right thigh, followed by a contrast-enhanced computed tomography. We measured distances from the tip of an arterial sheath to the zones-1 to -3 in aorta, using a medical image processing software, and finally analyzed 72 patients' data. We categorized patients based on patient's height into following three groups: smaller than 160 cm as a lower, taller than or equal to 160 cm and smaller than 170 cm as a middle, and taller than or equal to 170 cm as a higher group. We defined the optimal range as an interval between the lower end of zone-1 placement in a higher group and the upper end in a lower group.

Results: Among 72 patients, 51 were male. The mean and the range of age were 49 and 15-94 years old, respectively. There were significant differences in the zone-1 placements of each group (ps < 0.05). The mean and 95% confidence interval of the measured length to the lower and the upper end of zone-1 placement were 36.7 cm (35.2 to 38.1), 60.3 cm (58.4 to 62.2) in the lower group, and 36.9 cm (37.9 to 40.3) and 64.2 cm (62.5 to 65.9) in the higher group. In addition, we determined the optimal range would be between 40.3 and 58.4 cm.

Conclusion: The optimal range obtained from this study could be applied to a clinical setting, when treating a patient with trauma, for an adequate placement of REBOA.

1605-A-1821

An Observational Study to assess Follow Up in patients with Blunt Thoracic Aortic Injury treated by Thoracic Endovascular Aortic Repair

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Background

Blunt traumatic thoracic aortic injuries (BTAI) are a surgical emergency with high mortality. Thoracic Endovascular Aortic Repair (TEVAR) has become the “de facto” intervention for treating blunt aortic injury. There is, however, little information about long term outcomes of TEVAR in a young, trauma cohort.

Methods

A cross-sectional, retrospective analysis of all cases of BTAI treated with TEVAR at St Mary’s Major Trauma Centre (SM-MTC) in London was performed. Data was extracted from the UK Trauma Audit & Research Network database and electronic patient record from 2010 onwards. Primary endpoints were inpatient and 1 year mortality, and follow up at annual intervals thereafter.

Results

22 patients presented to SM-MTC with BTAIs, of which 15 underwent TEVAR (figure 1 – baseline characteristics). Of the seven patients who did not undergo TEVAR, two died prior to intervention, one paediatric patient was transferred, and the remaining had conservatively managed injuries. All TEVAR patients survived to discharge and were alive at 1 year.

12 of the 15 patients were discharged from SM-MTC over a year ago. Loss to follow up was high; only 58% of patients attended for review at 1 year, and none attended follow up at 5 years. Given the centralised nature of trauma services, 14 patients were not from the immediate location surrounding SM-MTC, and 33% were transferred out prior to discharge.

Conclusion

There is high loss to follow up in patients undergoing TEVAR following trauma, due to patient and hospital causative factors. Whilst no clear consensus exists on how and when to follow up this cohort, given the lack of data on long term outcomes, institutions have a responsibility within clinical governance to conduct medium-long term follow up. This will ensure patients are appropriately managed, data about complications are recorded, and will guide the development of follow up protocols.

1633-A-1821

Use of REBOA before open and endovascular treatment for ruptured abdominal aortic aneurysms: experience from 35 consecutive patients

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Background

Ruptured abdominal aortic aneurysms (rAAAs) represent a surgical emergency, with an extremely high mortality rate. Limited data exist about the use of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) before treatment for rAAAs, in particular before open repair.

The aim of the study was to assess the effectiveness and safety of REBOA in patients who underwent surgical and endovascular treatment for a rAAA.

Materials and methods

We retrospectively analysed all consecutive cases of rAAA treated at the San Gerardo Hospital.

An aortic occlusion balloon (Numed PTX) could be placed from a 9Fr 45cm sheath using an extrastiff guidewire and inflated in zone 1 in order to stop the bleeding, if the patient was hemodynamically instable. The access to the femoral artery could be surgical or percutaneous.

Also in case of surgical repair of the aorta, the REBOA was positioned in local anaesthesia before induction of general anaesthesia, in order to counterbalance the rocuronium-induced muscle relaxant effect, eventually causing the sudden lack of the contained rupture.

Results

Patients were treated in the 61.1 % of cases with open repair and in the 38.9% with endovascular repair. The 30-day mortality rate was 43.2%, being 55,2% in open repair group and 24.3% in endovascular one.

Thirty-five patients were included in the REBOA study.

The REBOA was always positioned in local anaesthesia, both in case of surgical and percutaneous approach to the common femoral artery.

The REBOA was positioned in the supraceliac aorta in all patients, with a significant improve of hemodynamic stability. No complications were recorded, related to the use of REBOA.

Conclusions

We demonstrated that REBOA is effective and safe in patients who underwent surgical and endovascular treatment for rAAAs.

REBOA should be included in the protocol for the management of rAAAs, independently from the choice of treatment.

1637-A-1821

The establishment of vascular access and use of REBOA in profound hypotension with impending cardiac arrest: a 3-year report from the ABOTrauma Registry

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Purpose:

The use of resuscitative endovascular balloon occlusion of the aorta (REBOA) may have a positive effect on systolic blood pressure (SBP) in traumatic hypovolemic shock. There is, however, a considerable difference between establishing arterial access and deploying REBOA in patients with a SBP of 90 mm Hg compared to those with profound hypotension with impending cardiac arrest (ICA). The purpose of this study was to investigate the establishment of vascular access and use of REBOA in patients with profound hypotension with ICA using data from the ABOTrauma Registry.

Methods:

The ABOTrauma Registry has collected retrospective and prospective data on the use of REBOA from centers around the world. Hemodynamic, access, complication and survival data were reported. ICA has been defined as a SBP 40 mm Hg upon REBOA initiation and compared to No-ICA (NICA), defined as SBP >40 mm Hg upon REBOA initiation.

Results:

One hundred and forty patients were included between 2011 and 2018, 96 patients with NICA and 44 patients with ICA, of which 41% received cardiopulmonary resuscitation. Injury was due to blunt mechanisms in 87%, with median Injury Severity Score being significantly higher in ICA patients (42; IQR 34-53) compared to NICA patients (38; IQR 26-48). In 56% of ICA patients, femoral arterial access was established on first attempt, 66% through blind puncture and 82% upon admission to the emergency department. Substantial hemodynamic improvement (elevation of SBP to ≥80 mm Hg with REBOA) was achieved in 43%. Overall survival post 30-days was 43% (ICA 18%, NICA 54%; $p<0.05$).

Conclusions:

Femoral arterial vascular access and REBOA are feasible in traumatic patients with profound hypotension with ICA, SBP may be elevated and there are survivors.

2nd EVTM Symposium - Örebro, Sweden, 7-9 June 2018

PROGRAM

2nd EndoVascular resuscitation and Trauma Management round table symposium.

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THURSDAY June 7th	
07.30	**Registration opens / Coffee**
07.40	**Opening remarks** - *Tal Hörer & Kerstin Nilsson, Dean of medical school, University of Örebro*
Opening session EVTM round table 2018 7 min talk + 3 min discussion **Chairs: Joe DuBose and Lauri Handolin** Panel: *Session speakers*	
07.50	Endovascular Resuscitation current update - *T. Rasmussen (US)*
08.00	When do truncal hemorrhage patients die and what are we going to do about it - *L. Moore (US)*
08.10	Experience from EVAR in rAAA- adjunct techniques that can be used in bleeding patients- *T. Larzon (SE)*
08.20	Lessons learned from clinical experience and training perspectives over the last 5 years - *M. Brenner (US)*
08.30	Updates on open techniques for hemorrhage control - Role of Endo? Future? Changes in DSTC courses? - *K. Boffard (ZA)*
08.40	Optimizing endovascular resuscitation for trauma management : A senior trauma surgeon's perspective - *EE. Moore (US)*
08.50	First successful REBOA in mass casualty event and other experience at Role 2 MTF - *V. Reva (RU)*
09.00	Introducing a Trauma Hybrid OR to your trauma service - *A. Kirpatrick (CA)*
09.10	**Round table discussion 1:** EVTM; Endovascular rescucitation and REBOA - Where do we stand? Where do we go?
09.30	**Coffee in foyer**
Session 1: EVTM practical issues and multidisciplinary approach 7 min talk + 3 min discussion **Chairs: Viktor Reva and Thomas Vogl** Panel: *M Brenner (US), S Cacala (ZA), O Merin (IL), B Darvish (SE), S Mohseni (SE), EE Moore (US), S Spiliopoulos (GR)*	
10.00	REBOA in South Africa- update and short term lessons - is it really needed? - *F. Plani (ZA)*
10.10	IR/endovascular role in bleeding control - How to do? How to think? Examples - *M. Delle (SE)*
10.20	Multidisciplinary early bleeding control interventions in Japan. Who? How? Updates - *J. Matsumoto & Y. Matsamura (JP)*
10.30	Using endo (and hybrid) techniques in trauma - Evidance? Guidelines? Trauma surgeon thoughts - *L. Handolin (FI)*
10.40	Using endo techniques in non-trauma bleeders (PPH, spontaneous, iatrogenic) - Evidence? Guidelines? - *T. Vogl (DE)*
10.50	Practical aspects of EVTM implementation at your institution - What "stuff" do you need? - *M. Hoehn (US)*
11.00	Effect of EVTM with the Hybrid ER: Innovation in the field of severe trauma - *T. Kinoshita (JP)*
11.10	Is Multidisciplinary/EVTM concept applicable in the US? Who should do what? - *J. Duchesne (US)*
11.20	**Debate 2.0: EVTM in my hospital - Yes, we do!** - *B. Kessel & O. Galili (IL)*
11.30	**Debate 2.0: EVTM in my hospital - Dream on; Impossible!** - *G. Oosthuizen (ZA)*
11.40	**Panel and audience discussion**
12.00	**Lunch in the exhibition / REBOA workshop in room *Byggaren* / Nurses and pre-hospital workshop in room *Lodet***
Session 2: Vascular access in resuscitation, bleeding & trauma patients 7 min talk + 3 min discussion **Chairs: George Oosthuizen and Ernest Moore** Panel: *T Larzon (SE), A Pirouzram (SE), M Delle (SE), C M Wahlgren (SE), M Lerardi (IT), O Galili (IL), A Kirkpatrick (US), F Cocollini (IT)*	
13.00	When and for whom should we obtain emergent femoral vascular access on arrival? - *T. Williams (US)*
13.10	Vascular access in austere environment/on site/battlefield. Update/tips/problems - *V. Reva (RU)*
13.20	How to close a vascular access? Closure devices - What to use, when? - *Z. Rancic (CH)*

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13.30	Vascular access for non-vascular surgeons/non IR; Feasable? How to learn? Tips? - *T. Vogl (DE)*
13.40	What to use for access in the ER/Surgery/IR suite for access? New devices? Complications - *D. Eefting (NL)*
13.50	**PRO- vascular access on arrival/in the field - We should do it in selected cases** - *V. Reva (RU)*
14.00	**Debate 2.0: CON-Vascular access on arrival/in the field- Dangerous; Bad idea!** - *L. Moore (US)*
14.10	**Panel and audience discussion**
14.30	**Coffee / Industry Exhibitors**
Session 3: Updates on REBOA 7 min talk + 3 min discussion **Chairs: Lauri Handolin and Junichi Matsumoto** Panel: *K Boffard (ZA), C Montan (SE), L Moore (US), P Skoog (SE), V Reva (RU), F Plani (ZA), M Brenner (US), J Galante (US), M Martin (US)*	
15.00	Never do REBOA for chest or CNS injuries? True or myth? - *T. Williams (US)*
15.10	Should I start in Zone 1 first for every REBOA use? What can I use to confirm position now and in the near future? - *E. Benjamin (US)*
15.20	Never do REBOA - existing data and contra-indications - *J. Duchesne (US)*
15.30	Practical aspects of REBOA - Who do you need? What kind of team? Imaging? - *M. Hoehn (US)*
15.40	Why pREBOA and iREBOA? What does the data tell us? - *L. Neff (US)*
15.50	On the horizon for vascular access and REBOA - *T. Rasmussen (US)*
16.00	Clinical trials update - The ABOTrauma registry update - *D. McGreevy (SE)*
16.10	Clinical trials update - The AORTA study (US) - *J. DuBose (US)*
16.20	Clinical trials update - The DIRECT IABO study (JP) - *Y. Matsamura (JP)*
16.30	Israeli experience with REBOA. For trauma and non-trauma: two years experience - *B. Kessel (IL) & G. Shaked (IL)*
16.40	**Panel and audience discussion**
Session 4: Zone III REBOA embolization and pelvic bleeders 7 min talk + 3 min discussion **Chairs: Todd Rasmussen and Joe Galante** Panel: *T Vogl (DE), M Hohen (US), E Søvik (NO), K Boffard (ZA), E Moore (US), L Ansaloni (IT), G Wallin (SE), A Albäck (FI)*	
17.00	Animal SAAP models and REBOA data. Where do we go? - *J. Ross (US)*
17.10	Walkthrough the new pelvic fracture guidelines (Packing/embolization/REBOA) - *F. Coccolini (IT)*
17.20	Transitioning to a practice using zone 3 for REBOA - practical aspects and tips - *J. Ibrahim (US)*
17.30	Level 2-3 trauma REBOA - can you manipulate the "golden hour"? - *W. Teeter (US)*
17.40	What to do when things go wrong and it´s bleeding? Cases - *J. Tisnado (US)*
17.50	Liquid embolisation for the pelvic - data and how to do - *A M. Lerardi (IT)*
18.00	EVTM and REBOA for pediatric patients - A bridge to far? - *L. Neff (US)*
18.10	**Debate 2.0: PRO- REBOA should always be considered for pelvic bleeders** - *M. Brenner (US)*
18.20	**Debate 2.0: CON- REBOA only if pre-peritoneal packing failes** - *S. Cacala & G. Oosthuizen (ZA)*
18.30	**Panel and audience discussion**
18.45	**Get Together / Industry Exhibitors**
FRIDAY June 8th	
07.30	**Coffee / Industry Exhibitors**
Session 5: Training aspects of endo-rescucitation and residents point of view! 7 min talk + 3 min discussion **Chairs: Megan Brenner and Artai Pirouzram** Panel: *Y Matsumura (JP), O Merin (IL), S Cacala (ZA), L Qingsheng (CN), M Wikström (SE), L Lönn (DK), F Granholm (SE), R Lendum (UK)*	
08.00	The way to do it - Vascular surgeon or interventional radiologist - *M. Taudorf (DK)*
08.10	REBOA by EM physicians: US perspective and challenges - *W. Teeter (US)*
08.20	Military aspects of EVTM training and what is relevant in my experience. Training my residents? - *M. Metthew (US)*
08.30	EndoVascular Training and group for advanced endo treatment in trauma (Korean first experience) - *S. Chang (KR)*
08.40	Radial Artery Access for Angioembolization in Trauma and training aspects - *J. DuBose (US)*

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08.50	Training Courses in the USA - What's on the horizon and what is needed? To who? - *M. Brenner (US) & M. Hoehn (US)*
09.00	**Debate 2.0: We have to do EVTM/REBOA** - *K. Mani (Vascular) (SE)*
09.10	**Debate 2.0: No, We should do EVTM/REBOA** - *J. Galante (Trauma) (US)*
09.20	**Panel and audience discussion** on training aspects for EVTM - Who should do what?
09.35	**Coffee / Industry Exhibitors**
Session 6: Pre-hopsital and military REBOA and EVTM techniques 7 min talk + 3 min discussion **Chairs: Joe DuBose and Viktor Reva** Panel: *T Williams (US), L Handolin (FI), M Martin (US), R Lendrum (UK), O Merin (IL), G Shaked (IL), S Sadek (UK), P Rees (UK), Y Kon (JP)*	
10.00	Military EVTM experience. Data! US military update - *M. Northern (US)*
10.10	En route transfer REBOA on the battlefield - *J. Keränen & L. Handolin (FI)*
10.20	REBOA vs alternative minimally invasive techniques for massive pelvic hemorrhage on the battlefield - *M. Metthew (US)*
10.30	"Beating Heart" vs. "Non-Beating Heart" Traumatic Cardiac Arrest: Implications for Resuscitation - *J. Manning (US)*
10.40	Civilian pre-hospital REBOA; Update on current world status - *S. Sadek (UK) & Y. Matsamura (JP)*
11.00	Implementing the REBOA-protocol for non-vascular trauma surgeons - *F. Plani & G. Oosthuizen (ZA)*
11.10	Pre-hospital femoral access and REBOA use might become part of standard combat casualty care capability in the near future, realistic? - *L. Neff (US)*
11.20	REBOA afloat- an adjunct to military maritime damage control resuscitation and surgery - *P. Rees (UK)*
11.30	**Debate 2.0: PRO: Transfer vascular access and REBOA - is there a role for that in EVTM? Advantages and considerations YES** - *J. Galante (US)*
11.40	**Debate 2.0: CON: Transfer vascular access and REBOA - is there a role for that in EVTM? Disadvantages and considerations Don't** - *L. Moore (US)*
11.50	**Round tables discussion 2:** On pre-hospital and military EVTM/REBOA and EVTM methods in the field - what is possible? Should we push the limits?
12.05	**Lunch in the exhibition**
Session 7: Endovasucular and hybrid techniques for bleeding control 7 min talk + 3 min discussion **Chairs: Megan Brenner and Thomas Larzon** Panel: *L Qingsheng (CN), Z Rancic (CH), J DuBose (US), L Lönn (DK), M Hoehn (US), E Søvik (NO)*	
13.00	Sizing endografts for younger patients (Thorax, Abdomen, Iliac, Subclavian) - *S Fajer (IL)*
13.10	Onyx and mechanical embolic agents for bleeding control. Any rationale? - *A M. Lerardi (IT)*
13.20	Coils and/or plugs for bleeding control - What to use? Products? How to do and choice of agent - *T. Vogl (DE)*
13.30	TEVAR in trauma and bleeders - *L. Qingsheng (CN)*
13.40	Liver bleeding - how to manage; What to use in visceral bleeding? Optimal imaging? Tips - *M. Delle (DE)*
13.50	Subclavian, axillary and neck vessels - Technical aspects to hemostasis in the EVTM era - *J. Duschene (US)*
14.00	**Debate:** You have to have endografts for EVTM! What every major hospital should have on its shelf - *K. Mani (SE)*
14.10	**Debate:** Simple C-arm and some simple tools can make a different. What to use and what to have on the shelf (Europe) - *A. Priouzram & T. Hörer (SE)*
14.20	**Live debate "what to have in my EVTM kit" and how to use it.**
14.35	**Coffee / Industry Exhibitors**
Session 8: More on training and who should do EVTM - We want to do that! 7 min talk + 3 min discussion **Chairs: Joe DuBose and George Oosthuizen** Panel: *K Boffard (ZA), L Moore (US), J Manning (US), T Vogl (DE), Z Rancic (CE), R Lindgren (SE), L Lönn (DE), J Matsumoto (JP), S Fajer (IL), Y Kon (JP)*	
15.05	Training for fast vascular access - How fast, what is safe? What to consider and how to teach? - *D. Eefting (NL)*
15.15	**The great panel debate:** Trauma surgeons vs Emergency doctors v.s Vascular surgeons vs Interventional Radiologists. How should we use EVTM and when? Training.
15.40	Simulation and working with C Arm - What exist and what can be done? - *L. Lönn (DK)*
15.50	Perfused models - What exist and what can be done? How to get a good model? Limitations? - *E. Benjamin (US)*
16.00	Training modalities in EVTM. What's out there. Benefits and limitations - *T. Williams (US)*

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16.10	Resuscitative balloon occlusion of the aorta (REBOA): a population based analysis of potential trauma patients in Germany - *K. Elias (DE)*
16.20	**Debate 2.0: PRO - With proper training, anyone can do REBOA (and other procedures?)** - *J. Ibrahim (US)*
16.30	**Debate 2.0: CON - EVTM and REBOA procedures should be done by professionals!** - *C-M. Wahlgren & C Montan (SE)*
16.40	**Panel and audience discussion**
Session 9: Vascular injuries EVTM treatment - open and endo; viceral bleeding 7 min talk + 3 min discussion **Chairs: Todd Rasmussen and Carl M Wahlgren** Panel: *C Montan (SE), J Sahagoff (BR), J DuBose (US), J Duchesne (US), M Brenner (US), M Hoehn (US), S Fajer (IL), A Albäck (FI)*	
17.00	Chosing embolization agent - What, when and how? My favorite tools - *R. Lopez (CH)*
17.10	Vascular injuries in South Africa-data? Place for Endo? - *G. Oosthuizen (ZA)*
17.20	Vascular injuries in Brazil-data? First Brazilian EVTM workshop rapport - *J. Sahagoff, M. Steinman & B. Pereira (BR)*
17.30	Isolated Aortic Abdominal Injury in Blunt Trauma: Two Case Reports and Review of the Literature - *B. Raguan (IL)*
17.40	More on vascular injuries and strategies. How to do, what to consider? - *S. Spiliopoulos (GR)*
17.50	Vessels endograft repair for trauma beyond the thoracic aorta - current data & results - US data - *J. DuBose (US)*
18.00	Chosing embolization agent - What, when and how? These are my favorite tools! - *M. Delle (SE)*
18.10	*TEVAR – The solution for Thoracic Aortic Blunt and Penetrating Trauma- Guidelines and Indications* - *S. Fajer (IL)*
18.20-18.45	EVTM Society Meeting - *Open to all of interest*
19.30	**Dinner** - *Örebro Castle*
SATURDAY June 9th	
07.30	**Coffee / Industry Exhibitors**
Session 10: Endovascular Resuscitation; What do we know? Translational data and research 7 min talk + 3 min discussion **Chairs: Boris Kessel and Jim Manning** Panel: *L Qingsheng (CN), L Lamhault (FR), M Larsson (SE), J Manning (UK), A. Kirpatrick (CA) , F Granholm (SE), B Peirera (BR), C-M Wahlgren (SE), G Wallin (SE), G Oosthuizen (ZA)*	
07.50	REBOA (ABO) might be used for non-trauma cases - The physiology behind it and why it works?! REBOA should be in eCPR! - *K. Nilsson (SE)*
08.00	Indications for REBOA and embolization in PPH - when/how? - *E. Søvik (NO)*
08.10	Retrievable Stents as an Alternative to REBOA for Aortic and Caval Hemorrhage - *B. Tillman (US)*
08.20	How hybrid trauma management might change "classic surgery"? Role in cancer surgery? - *B. Kessel (IL)*
08.30	Thoracic injuries and intra-opeartive use of REBOA. Experience from Colombia - *Ordoñez (CO)*
08.40	Cardiac arrest and REBOA - myth or reality? Bridge to ECMO? - *A. Johnson (US)*
08.50	**Debate 2.0: PRO - REBOA has a role in hemodynamic unstable patients, not only trauma!** - *F. Plani (ZA)*
09.00	**Debate 2.0: CON - REBOA is dangerous and has no place in other bleeders!** - *J. Duchesne (US)*
09.30	**Coffee / Industry Exhibitors**
Session 11: Complications, anesthesiological and ICU aspects 1 7 min talk + 3 min discussion **Chairs: Joe DuBose and Lauri Handolin** Panel: *K Nilsson (SE), L Moore (US), E Moore (US), Z Kellet (UK), B Darvis (SE), G Wallin (SE), S Cacala (ZA)*	
10.00	What complications to expect after endovascular procedure? How to manage it? ICU aspects - *P. Skoog (SE)*
10.10	What can we learn on the ICU period in REBOA treated patients? Day 2-3-4? - *L. Moore (US)*
10.20	Endovascular major complications - How to avoid and how to solve. Post-operative considerations - *T. Larzon (SE)*
10.30	REBOA during CPR - experience/data - Is it effective? Any data? - *E. Dogan (SE)*
10.40	A new femoral access for REBOA and ECPR by a hybrid technique - *L. Lamhaut (FR)*
10.50	A place for balloons in the ICU? Endovascular approaches for profound shock states - *A. Johnson (US)*
11.00	Simulation for aortic occlusion balloon in RAAA – a protocol including all hybrid staff reduces door-to-balloon time - *A. Albäck (FI)*
11.10	**Round tables discussion 3:** Where do we stand and how to avoid complications? Optimal ICU care? Role of ICU staff?

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Session 12: Complications, anesthisiological and ICU aspects 2; Medical treatment and other adjuncts in bleeding? (Lunch to go) 7 min talk + 3 min discussion **Chairs: Boris Kessel and Laura Moore** Panel: *S Kellet (UK), J Duchesne (US), E Gamberini (IT), P Rees (UK), K Thörn (SE), D Eefting (NL), K Nilsson (SE), F Cocollini (IT)*	
11.40	Pressure, flow and inflammation: managing the patient undergoing balloon occlusion aorta - *S. Kellertt (UK)*
11.50	Intra-abdominal hypertension and abdominal compartment syndrome in bleeders - Lessons - *Z. Rancic (CH)*
12.00	ECMO - possible role for Endovascular Resuscitation; When? Who? - *M. Larsson (SE)*
12.10	ECMO in Endovascular Resuscitation. Data and let's speculate - *L. Lamhaut (FR)*
12.20	Antithrombotic treatment in the ICU after EVTM. You have an endograft in. What to do next? Evidence? - *P. Skoog (SE)*
12.30	Imaging: CT, angio and hybrid suite or semi-hybrid suites - what´s out there and what's on the horizon? - *M. Taudorf & L. Lönn (DK)*
12.40	**Debate: Supraceliac hematoma and severe hypotension at trauma laparotomy: left thoracotomy and X-clamp vs. REBOA? ICU care is way different!** - *K. Boffard (ZA)*
12.50	**Debate: Supraceliac hematoma and severe hypotension at trauma laparotomy: left thoracotomy and X-clamp vs. REBOA? ICU care is quite the same** - *M. Metthew (US)*
13.00	**Panel and audience discussion**
13.15	Update on the JEVTM. Where do we go? - *J. DuBose (US)*
13.25	EVTM Future aspects, the next EVTM symposium, JEVTM, the EVTM society and closing remarks - *T. Hörer (SE)*

Calendar

Forthcoming EVTM related events

ECTES 2019
May 5-7, 2019 Prague, Czech Republic

Critical Issues in Aortic Endografting 2018
June 29-30, 2018 Malmö, Sweden

CIRSE 2018
September 22-26, 2018 Lisbon, Portugal

ESVS 32nd Annual Meeting
September 25-28, 2018 Valencia, Spain

LINC 2019
January 22-25, 2019 Leipzig, Germany

Western Trauma Association (WTA)
March 3-8 Snowmass, CO

AAST
Sept 26-29, 2018 San Diego CA

Academic Surgical Congress
February 5-7, 2019 Houston, TX

Eastern Association for Surgery of Trauma (EAST)
January 15-19, 2019 Austin, TX

National Neurotrauma Society
Aug 11-16, 2018 Toronto, Canada

Society of Critical Care Medicine
Feb 17-20, 2019 San Diego, CA

Society of Thoracic Surgeons
Jan 26-30, 2019 San Diego, CA

Southeastern Surgical Congress
Feb 23-26, 2019 Charlotte, NC

Southern Surgical Association
December 2-5, 2018 Palm Beach, FL

Western Surgical Association
Nov 3-6, 2018 San Jose de Cabo, Mexico

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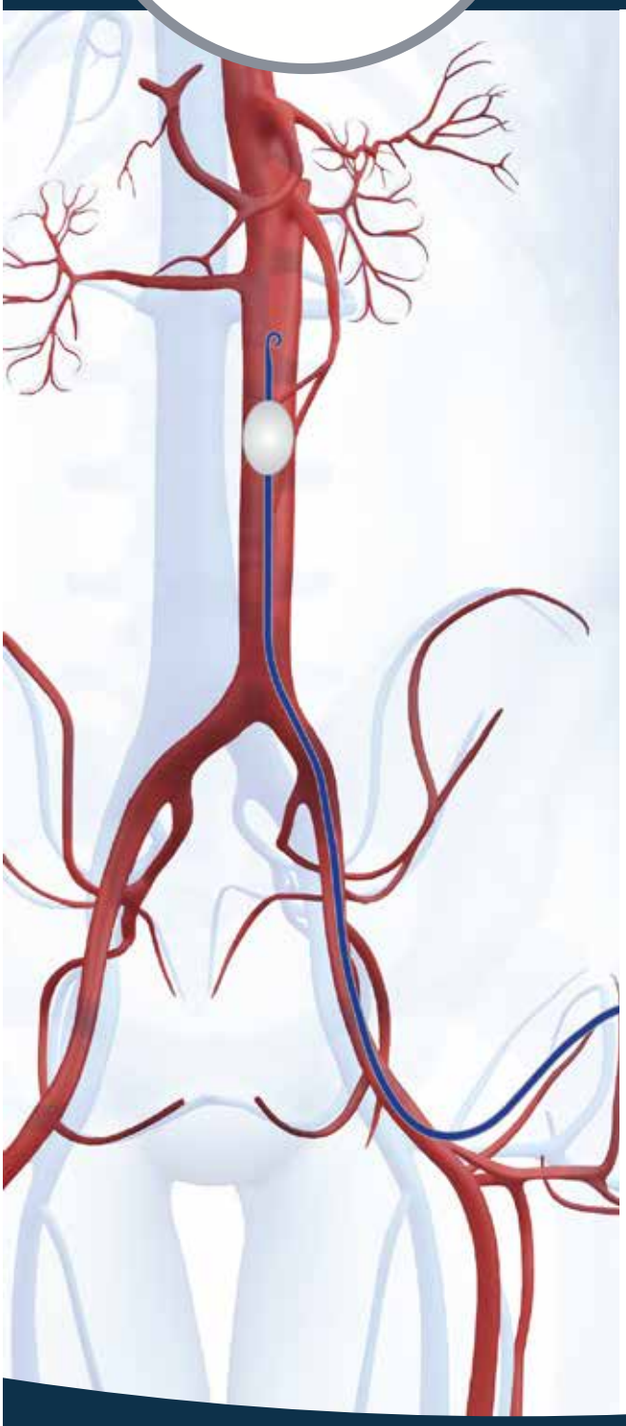

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