Case Report

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

Viktor A Reva MD PhD[1], Tal M Hörer MD PhD[2], Igor M Samokhvalov MD PhD[1] and Thomas Larzon MD PhD[2]

[1] *Department of War Surgery, Kirov Military Medical Academy, Saint-Petersburg, Russian Federation*
[2] *Department of Cardiothoracic and Vascular Surgery, Örebro University Hospital and Faculty of Medicine at Örebro University, Sweden*

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].

Corresponding author:
Viktor A. Reva, Department of War Surgery, Kirov Military Medical Academy, 6 Lebedeva Street, Saint-Petersburg, Russian Federation 194044.
E-mail: vreva@mail.ru

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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

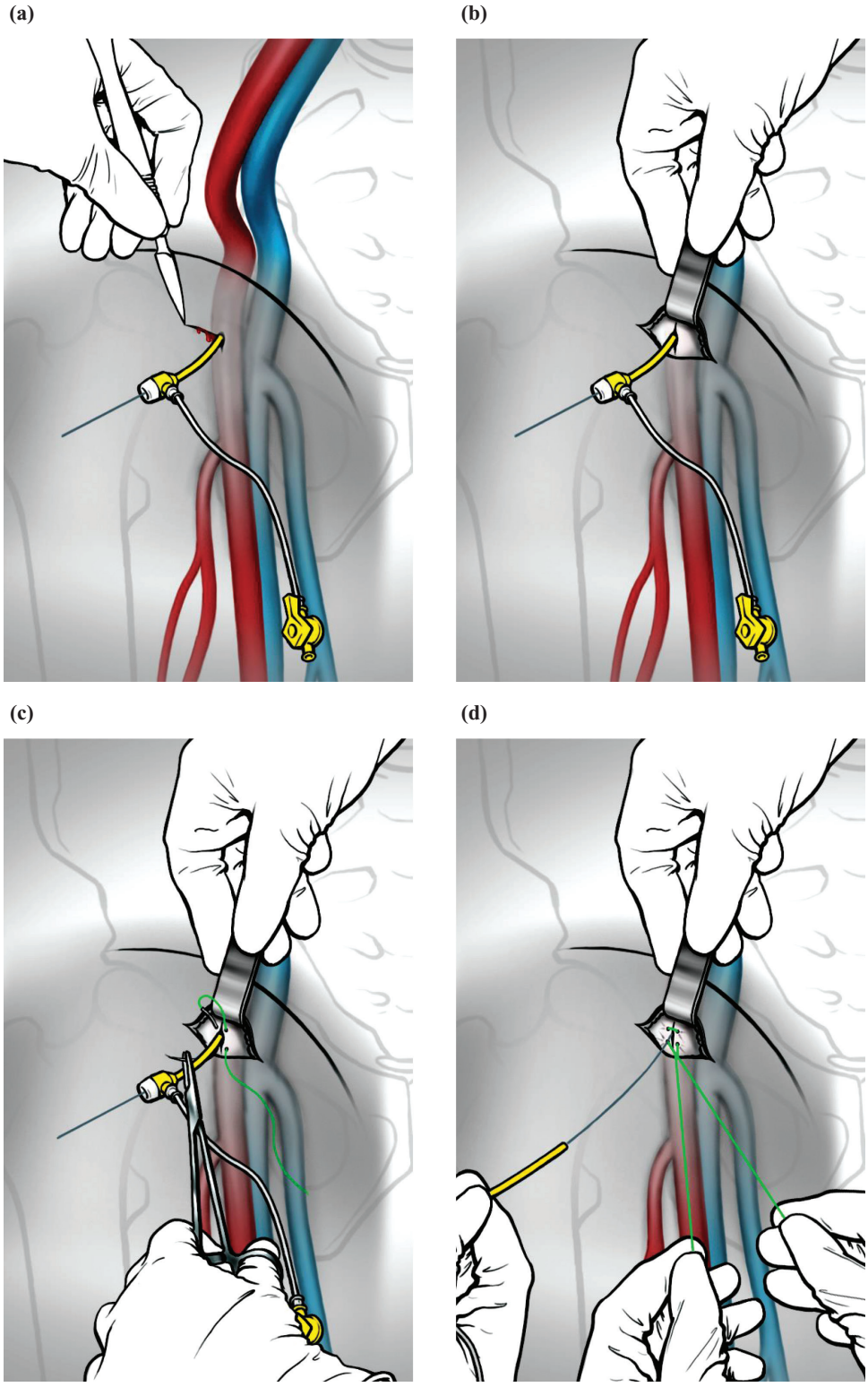

Figure 1 Schematic illustrations demonstrating the Fascia Suture Technique. (**a**) A transverse skin incision to explore the deep fascia. (**b**) The deep fascia is exposed around the sheath. (**c**) One mattress suture is applied around the sheath. (**d**) Sheath removal while tying a knot.

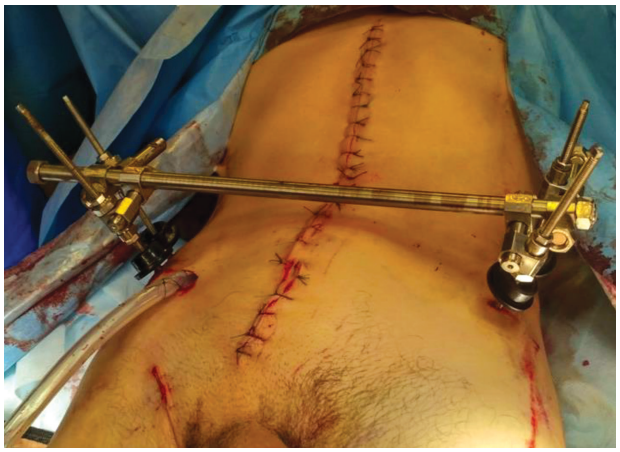

Figure 2 Postoperative view of Patient #2 after REBOA, explorative laparotomy, external pelvic fixation, preperitoneal pelvic packing, and application of the Fascia Suture Technique for femoral vascular closure.

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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