Case Report

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Damage Control Strategies For Vascular Injuries – A Report From The Amazon

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Patients may sustain vascular injuries in rural areas or isolated locations, which are very common in the vast area of the Amazon rainforest. In situations like this, patients may take many hours, or even days, to get access to hospitals capable of dealing with these potentially lethal injuries, arriving in severe conditions that may require damage control strategies. Among the currently available techniques for damage control resuscitation and damage control surgery, the endovascular balloon occlusion of the aorta (REBOA) and temporary vascular shunts play an important role, but appropriate devices are often unavailable; in such scenarios, surgeons' expertise on how to improvise devices, using more accessible materials, can be lifesaving. This paper presents a case of femoral vessel injury in a patient who required REBOA and vascular shunt improvisation; discussions regarding possible improvisation strategies are provided and technical steps on how to implement them are described.

Keywords: *REBOA; Vascular Shunts; Damage Control; Vascular Injuries.*

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INTRODUCTION

Although expeditious rescue and early treatment are paramount for the management of vascular injuries, in many vast areas and isolated locations around the world this cannot always be accomplished. The Amazon rain forest is distributed between eight countries, with 60% of its area located in Brazilian territory [1]; because of the great distances to be covered and frequent unavailability of air rescue, access to hospitals capable of managing vascular injuries may take hours and even days.

Previous studies have shown that the victims of vascular injuries that require terrestrial transportation for more than 200 km tend to arrive in severe shock with critical limb ischemia, frequently requiring damage control strategies, and have a higher probability of limb loss and death [2].

The cornerstones of vascular damage control are resuscitation, hemorrhage control and blood flow reestablishment. In recent decades, resuscitative endovascular balloon of the aorta (REBOA) has been used as a temporary adjunct, redistributing the circulating blood volume, raising arterial pressure and increasing heart and brain perfusion. Many models are currently available around the world but, unfortunately, in many regions, none is commercialized [3,4].

Regarding limb reperfusion, unstable patients are unsuitable for complex techniques, such as autologous venous grafts. If the injury cannot be treated by simple ligature or lateral suture, the implantation of a temporary vascular shunt (TVS) is usually advised [5], but industrial models are frequently unavailable in less-provided regions.

This article reports a case in which materials often available in general hospitals were improvised for REBOA and TVS.

Ethical Approval and Informed Consent

Informed consent from the patient was obtained; ethical approval was not required as all data were anonymized.

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The patient endorsed the description of her clinical course for educational purposes.

CASE REPORT

A 27-year-old female patient sustained a penetrating injury from an agricultural lawn mower blade to her left thigh at an isolated area in the Amazon region. She was rescued by boat and ambulance in an approximately 400 km journey to the hospital, which took about 8 hours. Unfortunately, no additional pre-hospital data was able to be retrieved.

On admission, airways were clear, the patient had no palpable peripheral pulses and blood pressure was 80 × 50 mmHg. The blade was still in place at the femoral vessel topography and no active hemorrhage was noticed (Figure 1).

The patient was immediately taken to the operating room (OR), received general anesthesia and had her clothes removed; during this process the blade was unintentionally dislodged, but no bleeding was triggered. The anesthesiologist gave the alert that the carotid pulse was no longer palpable, but pulsatility was still detected on ultrasound and arterial blood pressure was 76 × 40 mmHg. The traumatic wound was tamponed with a surgical sponge and a cut down to the left common femoral artery was made, aiming for both proximal control and aortic occlusion.

Common, profunda and femoral (superficial) arteries were dissected. A small transverse arteriotomy was performed at the common femoral artery and a 6 Fr Fogarty thrombectomy catheter was inserted, advanced until the xiphoid topography and inflated for an aortic Zone 1 occlusion; arterial pressure rose to 101 × 47 mmHg and a carotid pulse was reassumed (Figure 2).

The balloon was kept insufflated while surgical exploration confirmed a complete transection of the femoral artery and vein (both thrombosed at that time) and a femur fracture. Thrombectomy and local anticoagulation were performed, and pieces of an 18 Fr nasogastric tube were inserted as TVSs for both the artery and vein; fasciotomies of four compartments were performed on the leg and orthopedic surgeons installed an external fixator for the fracture (Figure 3).

After 30 minutes the aortic balloon was deflated, the catheter was removed and the arteriotomy was closed. The patient was sent to the intensive care unit (ICU) for continued resuscitation.

At postoperative day 2 the patient was stable, distal pulses were palpable on the right lower limb, no distal pulses were palpable on the left side, but the left foot presented satisfactory perfusion. The patient was moved back to the OR; the arterial shunt was still patent and the venous one was occluded.

TVSs were explanted; the femoral vein was ligated, and a segment was harvested and used as an interposition graft, restoring femoral artery flow. After 2 more days the patient was discharged from the ICU and remained waiting for fasciotomy closure by the plastic surgery team.

Figure 1 The blade: in place and after unintentional removal. (**a**) Blade still in place at femoral vessel topography in the emergency room. (**b**) Blade after being removed in the operating room (a 20 cc syringe was used for scale).

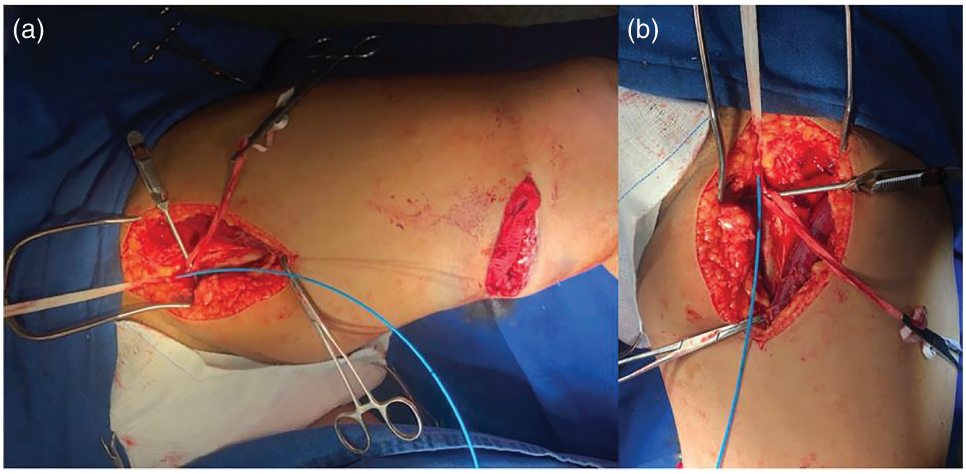

Figure 2 Intraoperative: access for REBOA insertion. (**a**) Proximal incision for common femoral artery access; notice the traumatic wound tamponed by a surgical sponge. (**b**) 6 Fr Fogarty catheter introduced at the common femoral artery.

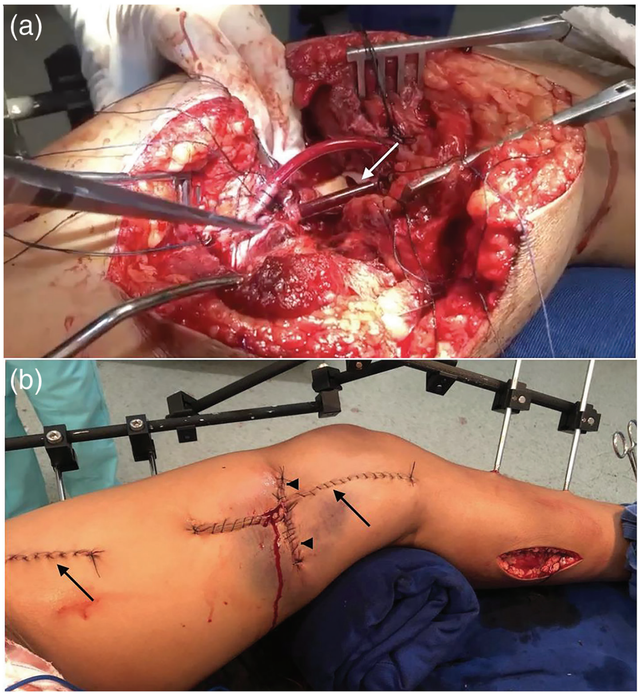

Figure 3 Intraoperative: shunts in place and surgical incisions. (**a**) Arterial and venous shunts (nasogastric tube pieces) in place, the arrow points to the femur fracture. (**b**) Arrows point to the surgical incisions (the proximal one for REBOA insertion and arterial control, and the distal one for the vascular exploration). The arrow heads point to the traumatic wound. Notice one of the leg incisions for fasciotomy.

DISCUSSION

REBOA was first described in 1954, during the Korean War [6,7]. As the years passed by, specific devices were developed and currently at least 22 commercial devices, with diameters ranging from 5 Fr to 14 Fr, are available [8].

Three aortic zones have been stablished for REBOA insufflation; insufflation in Zone 2 should be avoided, to prevent visceral ischemia; the most common trauma-related indication for aortic Zone 3 occlusion is hypovolemic shock secondary to pelvic fractures and aortic Zone 1 occlusion can be performed in a variety of scenarios related to hypovolemic shock [9].

Access site complications are related to the device diameter and the operator's proficiency in gaining vascular access. Earlier REBOA models were 14 Fr, usually placed after cutdown to the common femoral artery, and access site complications were about 21%. Most modern devices are <7 Fr and they are frequently inserted under ultrasound guidance, with an approximately 7% complication rate [10].

Evidence suggests partial and intermittent REBOA lead to fewer ischemic complications and some of the new catheters are made specifically to achieve partial occlusion (pruned REBOA) [11].

In this case, since no industrial device was available, a REBOA device was improvised with a 6 Fr Fogarty catheter. The catheter could be inserted through a 6 Fr introducer sheath, but neither sheaths nor any other endovascular resources were available. Previous studies have shown that the descending aorta diameter in young patients ranges from 17 to 20 mm. Because a 6 Fr Fogarty catheter can achieve a 12 mm diameter when inflated at its maximum volume (4.5 cc), partial aortic occlusion can be achieved in young patients [12].

If the catheter had been inserted through a cutdown made for the contralateral common femoral artery, with TVSs in place, the balloon could have been deflated, restoring vascular flow through the shunts, allowing the arteriotomy to be sutured with limb circulation already reassumed. On the other hand, a surgical cutdown on the ipsilateral side of the injured vessels, as performed in this case, provides proximal arterial control and REBOA access simultaneously. The arteriotomy can be narrow, so that it can be quickly closed by a few stiches or by a purse string suture around the catheter [5,13].

In an even more austere scenario, if a Fogarty catheter is not available and aortic occlusion is required, the surgeon may consider inflating a Foley catheter inserted though the axillary artery, or cross clamping the descending aorta through thoracotomy.

After stopping the bleeding, flow restoration is the next priority. Vessel reconstruction may require complex procedures, such as bypasses with an autologous vein graft, but time-consuming techniques are unsuitable for unstable patients. TVSs have long been proved to be effective for vascular damage control [14].

All lower extremity veins are amenable to ligation if the situation requires it, but experimental and clinical data suggest that shunting the vein, as performed in this case, provides better outflow, reducing vascular resistance and improving the arterial shunt function. There are many commercial shunts available. They can be either inserted in a "loop" or "in-line" fashion. Looping shunts are easier to insert, but the in-line configuration tends to offer better flow [15].

Fixation is usually obtained by Rummel tourniquets or by inflating balloons at the extremities, simultaneously occluding the vessel's edges and avoiding bleeding [16].

There are two important limitations regarding the use of commercial TVS models in damage control: the diameter of many shunts may be unsuitable for fitting the lumen of larger vessels, commonly injured in scenarios like the one reported in this paper, and commercial models are frequently unavailable at hospitals located in underserved areas.

Any material with adequate length and diameter can be used to improvise a TVS [17,18] and nasogastric tubes come in a variety of diameters that suit most of the injured vessels.

When using TVSs, some technical steps should be kept in mind:

(1) Shunts should be inserted into unobstructed vessels. If patency cannot be assured by antegrade and retrograde bleeding from the vessel's edges, a Fogarty catheter of appropriate size (usually 3 or 4 Fr for extremity injuries) may be used for arterial thrombectomy, while venous thrombectomy (because of venous valves) is usually obtained by manual compression or by using elastic bandages [16].
(2) After patency has been confirmed, the vessels' edges should be flushed with saline and heparin to prevent early re-occlusion. The literature is not unanimous on how to do this, but many surgeons dilute 1 mL (5.000 IU) of heparin in 250 mL of saline and flush each vascular stump with approximately 20 mL of that solution [16,19].

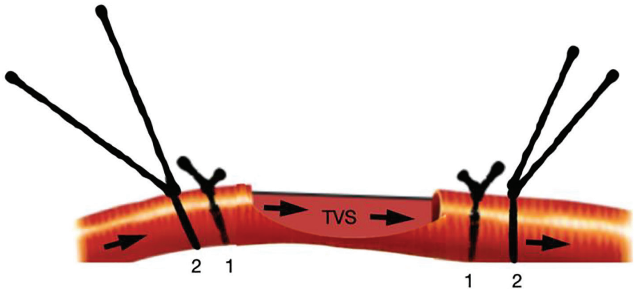

Figure 4 Temporary vascular shunt insertion: the arrows refer to the vascular flow direction; 1 and 2 represent cerclage knots. Notice the long lengths left on purpose, to help identify the structures during reoperation. TVS: temporary vascular shunt.

(3) Larger TVS diameters tend to offer better flow and longer patency, but they should comfortably fit the vascular lumen, avoiding excessive endothelial damage. The vein is usually compatible with a larger shunt than its corresponding artery. If any residual vessel wall remains, it can be kept, preventing vessel edge retractions [16,20].
(4) For fixing improvised TVS, external cerclage knots should be applied. Two independent cerclages on each vascular edge provide additional security, preventing TSV dislodgement and hemorrhage. Leaving a long length on these cerclages helps identify the structures during reoperation [20] (Figure 4).
(5) The presence of a TVS, partially filling the vessel's lumen, limits the flow, and thus prophylactic fasciotomies should be performed; this favors TVS function and reduces compartmental syndrome consequences [18,21].

CONCLUSION

REBOA and temporary vascular shunts have become essential tools for vascular damage control. Unfortunately, access to proper commercial devices is uneven around the globe.

When dealing with severe vascular injuries, especially in rural or underserved areas where access to appropriate devices is not possible, surgeons may need to improvise materials to accomplish certain surgical strategies and deliver the best possible treatment they can. The practical key points presented in this paper may be helpful in such scenarios.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Author Contributions

All the authors substantially contributed to the study and manuscript writing.

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