Narrative Review Article

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Endovascular Solutions for Iliac and Lower Extremity Junctional Injuries

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Hemorrhage is the second leading cause of death in trauma and non-compressible torso hemorrhage is the leading cause of preventable death within this population. Vascular injuries to the pelvis and lower extremity junctional zone may be difficult to control with direct pressure and complex to approach with open surgery. Endovascular interventions such as balloon occlusion, stenting, and embolization are potential alternatives or adjuncts to traditional open surgery in patients with blunt or penetrating vascular injuries to the pelvis. This review of the literature will outline contemporary endovascular management strategies for iliac and junctional zone injuries.

Keywords: *Trauma; Endovascular; Iliac; Groin; REBOA; Non-Compressible Torso Hemorrhage; Junctional Zone*

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INTRODUCTION

Hemorrhage is the second leading cause of traumatic death after direct central nervous system (CNS) injury [1]. Unlike CNS injuries which are often difficult to treat and irreversible, hemorrhage is directly amenable to intervention, particularly when occurring in accessible regions of the body. Nonetheless, it still accounts for 35% of pre-hospital deaths and 40% of in-hospital deaths that occur within 24 hours of hospital arrival [2]. Currently, non-compressible hemorrhage from truncal and abdominal injuries is the leading cause of preventable deaths due to hemorrhage [3]. Although traditional techniques and technology have focused on the treatment of compressible sites of hemorrhage, novel endovascular adjuncts for hemorrhage control now allow for remote, yet direct treatment of these injuries, previously thought to be accessible only by open surgical exploration.

Over the last 15 years of combat operations, military surgeons have developed a wealth of practical experience in treating junctional hemorrhage. The success of deployed vascular surgeons applying endovascular techniques to the care of patients with vascular injuries has led to a broader reappraisal of the use of endovascular technology for the diagnosis and management of junctional and extremity injury [4]. While endovascular management of traumatic vessel injury is increasing overall [5], endovascular intervention for iliac vessel and junctional trauma within the civilian sector is not

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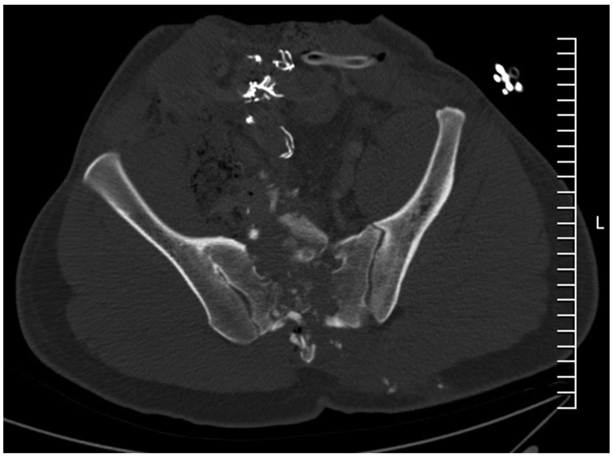

Figure 1 CT angiogram slice from pelvis showing pelvic fracture and active bleeding.

yet commonplace [6,7]. This review will discuss the emerging role of endovascular technology for diagnosis, initial control, and definitive repair of junctional hemorrhage of the lower extremity in the civilian population.

Diagnosis of Injury

Patients presenting with pelvic or lower extremity trauma are at risk for major vascular injury. While there is no consensus as to which patients require screening for vascular injury, indications to consider further investigation of vascular injury can be categorized as hard or soft signs [8]. Hard signs include pulsatile bleeding, expanding hematoma, the absence of distal pulse, or evidence of ischemia. Patients with hard signs of vascular injury require prompt intervention to prevent mortality and reduce morbidity from these injuries. Successful intervention typically requires invasive surgical treatment, either open, endovascular, or a combination approach. Soft signs indicating a risk of significant vascular injury include compelling mechanism, proximity of wound to major vascular structures, or selected orthopedic injuries. These cases may warrant additional diagnostic evaluation for vascular injury especially in instances of pelvic trauma where retroperitoneal hemorrhage can easily be masked. The choice of diagnostic testing and imaging modality depends on patient stability, comorbidities, concomitant injuries, and the available resources and expertise.

For stable patients, multidetector computed tomography (CT) has become the first line for imaging in trauma [9]. It is non-invasive, rapid, and can identify vessel injuries in addition to associated bone, soft tissue and other organ injuries (Figure 1). In an aging population, this modality also affords the diagnosis of underlying comorbid vascular diseases or aberrant anatomy that may inform endovascular treatment options. It also allows for preoperative planning to ensure appropriate selection and sizing of endovascular devices prior to an intervention. CT angiography (CTA) has the disadvantage of requiring contrast without the benefit of affording therapeutic intervention. This increases the risk associated with contrast exposure in patients who may require subsequent administration during endovascular interventions under fluoroscopic guidance and may not be suitable for patients with renal disease. When used to assess blunt traumatic injuries to the pelvis, CTA is not 100% specific for excluding the need for angiography. The Eastern Association for the Surgery of Trauma guidelines for pelvic fracture hemorrhage noted a specificity of contrast extravasation on CT to predict the need for angiography of 85–98% [10].

An alternative imaging modality is diagnostic angiography. This can be performed in an interventional suite, hybrid operating room, or operating room equipped with mobile fluoroscopy arm. The resources and expertise available and patient physiology may dictate the appropriate setting for diagnostic angiography and its utility in combination with open surgery or other endovascular interventions. Access may be achieved with an arterial sheath placed away from the point of injury. An appropriate catheter can then be advanced close to the zone of injury to ensure that contrast reaches the site of interest in enough concentration to afford an accurate diagnosis. Measurements of vessel diameter and treatment length can be made using the fluoroscopic images or with an intravascular ultrasound (IVUS) catheter. IVUS can complement angiography for the diagnosis of subtle intraluminal injuries such as dissection flap or intramural hematoma [11]. In patients with significant renal impairment, contrast allergy, or in those who have already exceeded recommended doses of contrast administration, diagnosis can be achieved with intravascular ultrasound or carbon dioxide (CO_2) angiography. CO_2 angiography has been demonstrated to be as sensitive as traditional fluoroscopy without the risk of contrast nephropathy or contrast allergy [12].

A disadvantage of using angiography as the first line diagnostic modality in trauma patients is its invasive nature and inability to provide information about other non-vascular injuries. Apart from when an arteriovenous fistula is present, to exclude arterial or venous injury both arteriography and venography must be performed along the whole zone of injury, increasing the time required as well as the contrast and radiation exposure to the patient.

Surgical exploration may be the diagnostic modality of choice when patients are unstable or have hard signs of vascular injury. The traditional approach to vascular injury management involves proximal and distal control of injured vascular segments; however, this can be particularly challenging in cases of pelvic or lower extremity junctional injuries where adequate exposure can be time-consuming and sufficient vascular control can be difficult due to the presence of extensive branching and natural collateralization. This frequently results in ongoing and significant hemorrhage during exploration. In the groin, control of the injured vessel may require dissection both above and below the inguinal ligament, leading to large and morbid wounds that are prone to complications such as infection, lymphocele, or seroma. Remote endovascular approaches (angiography or venography) allow for minimally invasive diagnosis of iliac or junctional injuries. If appropriate, the same access point can then be utilized for intervention and repair in many instances. Additionally, arterial sheaths can remain in place for hemodynamic monitoring and venous catheters can be used for resuscitation in the post-intervention period. Furthermore, post-intervention angiography can demonstrate the safety of access, effectiveness of the intervention as well as the adequacy of distal perfusion.

Hemorrhage Control

Control of bilateral lower extremity, junctional, or pelvic hemorrhage can be challenging and time-consuming. Achieving this control by endovascular means can at times be more rapid and selective. Remote access with a vascular sheath must be achieved first. Sheath size and operator expertise will determine whether access is best achieved percutaneously or by open cut-down. Larger sheaths will allow for the employment of a greater range of endovascular devices, but will also carry a greater risk of complications. The selection, positioning, and deployment of the balloon will depend on the vessel to be occluded and the experience of the provider. In the elective setting, this technique is employed during major gynecological and orthopedic pelvic surgery by placing deflated occlusion balloons into the internal iliac arteries for rapid hemostasis in the event of major bleeding [13–16]. In trauma situations, it is more common to occlude the common iliac artery (CIA) or aorta.

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is the technique of occluding the aorta in either zone 1 (between the left subclavian and the celiac branches) or zone 3 (caudal to the most caudal renal branch) to both limit hemorrhage and restore proximal hemodynamics [17]. This can be performed with or without radiographic guidance and the catheter is often introduced via femoral artery access (Figure 2). The American College of Surgeons Basic Endovascular Skills in Trauma (BEST) course describes zone 3 REBOA for the control of pelvic trauma with hemodynamic instability or uncontrolled lower extremity junctional hemorrhage [18]. Zone 3 occlusion is generally well tolerated with published reports of survival following occlusion times in excess of an hour [19]. Distal ischemia during zone 3 occlusions can potentially be mitigated by employing the intermittent or partial REBOA (I-REBOA and P-REBOA) techniques when resuscitation efforts and the clinical situation permit [20,21].

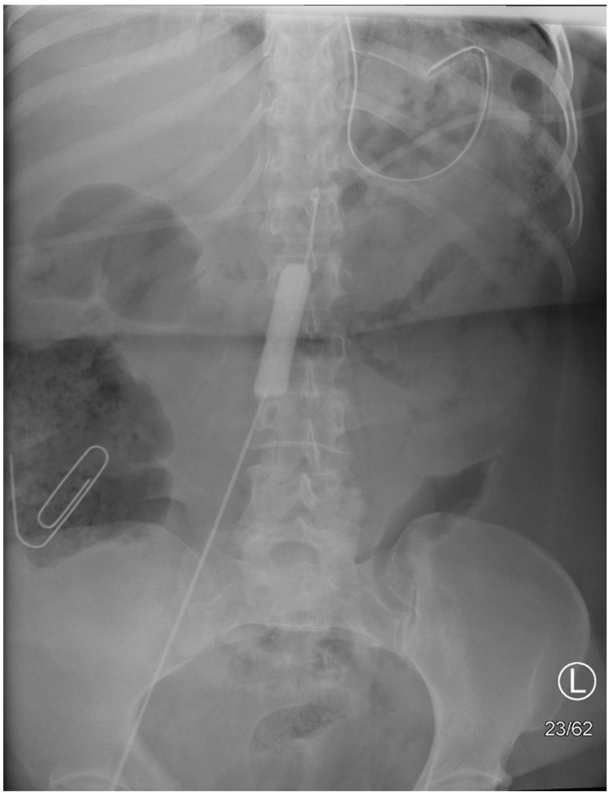

Figure 2 Zone 3 aortic occlusion with non-radiographically placed ER-REBOA® catheter.

While not yet common practice, REBOA is rapidly gaining popularity and advances in technique and catheter technology may continue to expand its utility. As well as use in trauma centers, this technique has been used in the pre-hospital setting in both civilian and military environments [19,22]. Variations of its application and effects in trauma are being researched currently in animal studies [21] and monitored in human registries [23].

Definitive Management

Endovascular management of iliac and junctional zone vascular trauma is most commonly utilized in blunt and iatrogenic injuries [6,7]. Embolization of arterial injury is quickly becoming the preferred method of management for hemorrhage following blunt pelvic trauma [24]. While less commonly performed, penetrating injuries of pelvic veins and arteries have also been embolized [7].

Guidelines from the Eastern Association for the Surgery of Trauma and the Western Trauma Association regarding the management of hemodynamically significant pelvic fractures both recommend selective angioembolization as the treatment of choice [10,24]. This approach may be undertaken in lieu of or after preperitoneal packing and pelvic stabilization, depending on the urgency of the situation. Diagnostic angiography may be helpful in patients with persistent hypotension following resuscitation and stabilization of pelvic fractures, to allow for identification and embolization of sources of continued bleeding. Arteries showing an abrupt cut-off of flow or vessel narrowing might also indicate an injury that requires intervention. In cases where selective embolization is not possible, non-selective occlusion of the internal iliac artery may be lifesaving but ischemic complications are more likely following this less-selective approach [25].

Endovascular management of iatrogenic iliac artery injury is well-established. Management of a ruptured or lacerated CIA or external iliac artery (EIA) using a covered stent has been widely reported during spinal and endovascular surgery [26–29]. In patients with underlying arterial disease, excessive manipulation of the pelvis may result in a dissection flap that can lead to significant distal ischemia. If recognized promptly, endovascular revascularization might be possible with a combination of thrombectomy, angioplasty, or stenting [30,31]. Arteriotomy defects formed during angiographic procedures can cause significant bleeding, arteriovenous fistulae or pseudoaneurysms if not closed. Covered stents are effective at closing these defects but need to be inserted from remote access sites such as the contralateral femoral artery [28]. Stenting has been described above, below and across the inguinal ligament [32].

Temporary endovascular revascularization for iliac and junctional zone artery trauma has only been sparsely described in the literature [33]. Placement of a femoral covered stent in lieu of an open intravascular shunt prior to fracture fixation has been described as a method to achieve revascularization of the lower extremity during repair of orthopedic injuries [34]. It may be possible to use this technique in pelvic vessels using a percutaneous, open, or hybrid approach instead of a shunt, patch or bypass. Temporary stenting could also be employed in a contaminated field. There have been mixed outcomes of this in other areas of the body and currently, there is no real consensus as to the management of a stent in an infected field [35].

As with iatrogenic injuries, stenting (Figure 3) and embolization are potential treatments for iliofemoral injury in trauma patients. Both covered and uncovered stents have been successfully deployed to treat iliac arterial and venous injury. In their case reports of successful endovascular treatments in blunt trauma patients with hemodynamically significant external iliac vein injuries, Merchant et al. used a covered stent from a contralateral approach and Sofue et al. used an uncovered stent from an ipsilateral retrograde approach [36,37]. The potential benefits of this technique in iliac veins include a reduction in the need for complex dissection and possible division of the iliac artery to access the vein for open repair and a significant reduction in blood loss which occurs when the retroperitoneum is opened. In open surgery, a venous injury might be controlled with ligation rather than repair meaning that stenting has the added advantage of maintaining outflow from the limb.

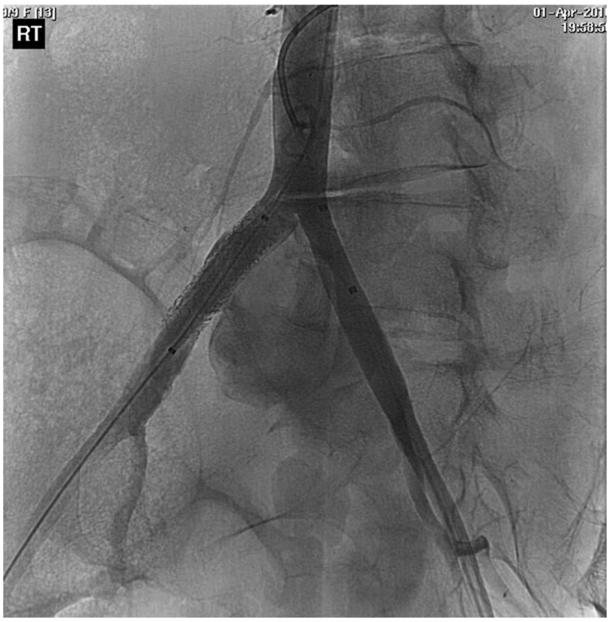

Figure 3 Right common iliac artery injury repaired with covered stent.

Endovascular surgery is not without its complications. Trauma patients can have a prothrombotic tendency due to factors such as pelvic fracture, blood transfusions, tranexamic acid administration, and surgery [38]. While venous thromboembolism may also be seen in surgery, introducing a foreign body into a vessel lumen and restricting flow increases this risk [39]. Thrombosis and arterial dissection during endovascular procedures leading to vessel occlusion and the need for extremity amputation are also documented in the acute setting. These complications may also be resolved with an endovascular procedure such as thrombectomy and stenting.

DISCUSSION

The progression of endovascular techniques into trauma surgery and recent military experience has led to several exciting developments in both hemorrhage control and definitive management of pelvic vascular injury. Data from the US national trauma data bank registry from 2002–2006 showed 10% use in blunt iliac injury and 1.8% use in penetrating iliac injury [7]. This is consistent with an 11% endovascular intervention rate for blunt CIA and EIA injuries in a large series from Baltimore [6]. In this study, patients requiring intervention for bleeding from iliac branches, however, had a much higher endovascular rate (96%). With the ongoing development and uptake of REBOA and familiarity with endovascular techniques, intervention rates for CIA and EIA injuries may increase in similar registry reviews in the future.

We have described a range of emerging techniques for pelvic vascular trauma using technologies that are already in common use for the treatment of vascular disease. It is difficult to directly compare the outcomes of endovascular management of pelvic trauma with traditional open surgery as registry groups and series are small and unmatched. As hybrid endovascular operating rooms become more available and trauma teams have better access to 24-hour endovascular expertise, the percentage of interventions may reach a level that permits trials. Despite a modicum of published literature, registry data and clinical reports show that in select patients, endovascular management of iliac and lower extremity junctional vascular trauma is possible as the sole treatment modality or as an adjunct to open repair.

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