Review Article
Role of Endovascular Intervention in Femoral Artery Trauma

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ABSTRACT:

Femoral artery trauma is one of the most frequently encountered vascular injuries in trauma centers worldwide, accounting for 70% of all recorded peripheral vascular injurie. These represent critical medical emergencies, typically arising from traffic accidents, occupational incidents, injuries from sharp objects, or iatrogenic trauma during medical procedures[1]. Recent advances in endovascular intervention techniques have revolutionized the management of vascular trauma, offering minimally invasive alternatives alongside traditional open surgical repair. However, further research is needed on long-term outcomes and patient selection criteria to optimize the use of these techniques.

Keywords: *Femoral artery trauma, endovascular.*

1. Introduction

Femoral artery trauma is one of the most frequently encountered vascular injuries in trauma centers worldwide, accounting for 70% of all recorded peripheral vascular injurie [1]. These are critical medical emergency situations, commonly occurring after traffic accidents, occupational accidents, injuries from sharp objects, or medical procedures. Despite significant advancements in diagnosis and treatment, extremity vascular injuries still carry relatively high mortality and amputation rates, at 7.5% and 11%, respectively [2]. Among these, femoral artery and vein injuries account for the majority of deaths caused by peripheral vascular trauma. Inappropriate diagnosis and treatment of arterial injuries can lead to catastrophic consequences[2].

In recent years, endovascular intervention methods have increasingly been employed in managing extremity vascular trauma, thanks to advancements in technology and techniques. These endovascular procedures can simultaneously facilitate diagnosis (angiography to detect extravasation) and treatment (emergency embolization or placement of covered stents to maintain vascular integrity) in cases of peripheral vascular injury. This approach is particularly beneficial in situations where bleeding sites are difficult to access or identify. Benefits of managing vascular injuries via endovascular methods include lower mortality and morbidity compared to open surgery, reduced blood loss, quicker recovery, decreased risk of complications such as nerve injury and venous bleeding from

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vascular dissection, and lower rates of surgical site infection[3].

2. Limitations of Traditional Open Surgery

Open surgery remains the foundational and most common approach for managing femoral artery injuries; however, this method has several significant limitations and drawbacks. One of the primary disadvantages of open surgery is its invasiveness, which can result in extensive soft tissue damage. To access the femoral artery, surgeons must make large skin incisions, expose the artery, and perform vascular suturing or grafting. This procedure carries the risk of damaging adjacent nerves, lymphatics, and veins, increasing the likelihood of limb edema, motor dysfunction, and prolonged recovery times. A retrospective study by Asensio et al. (2006) analyzing femoral artery injuries reported an amputation rate of 2.7% after open surgery, primarily due to prolonged ischemia and severe soft tissue damage associated with extensive vascular dissections[4].

One significant limitation associated with open surgical repair of femoral artery injuries is the relatively high incidence of surgical site infections. According to Wolosker et al, the rate of infection following open surgery for femoral artery trauma can reach as high as 15%, particularly in cases involving extensive soft-tissue injury and prolonged ischemia. Deep surgical site infections not only extend hospitalization and increase healthcare costs but also carry the potential risk of severe complications, including arterial endarteritis and limb loss due to irreversible tissue damage[5].

Another limitation is the prolonged recovery time compared to endovascular intervention. A comparative study by Potter et al. (2021) reported an average hospitalization duration of 8 days following open surgical repair versus 4.25 days for endovascular treatments, demonstrating significant reduction in hospital stay with endovascular approaches ($p < 0.05$)[6]. This increased hospital stay raises medical costs and negatively impacts patients' quality of life, particularly for workers who need to promptly return to their jobs.

Finally, open surgery carries a higher risk of recurrent thrombosis and future arterial stenosis. Even with successful arterial revascularization, direct vascular suturing or autologous grafting can result in secondary stenosis or thrombosis, potentially causing long-term blood flow obstruction. In a comparative analysis by Potter et al. (2021), open surgery for femoral artery injuries was associated with a one-month thrombosis rate of approximately 5%, whereas endovascular stenting showed a significantly lower thrombosis incidence (<2%), indicating improved short-term patency and reduced complications for endovascular repairs[7].

3. Endovascular Intervention

Endovascular intervention for extremity vascular trauma generally involves positioning the patient supine under fluoroscopic guidance in an angiography suite. Common vascular access points include the contralateral common femoral artery or the brachial artery, depending on injury location and patient anatomy. After obtaining vascular access through standard percutaneous techniques, angiography is performed to localize the injury, characterize the lesion, and guide intervention. The choice of specific endovascular technique-such as embolization, covered stent placement, or balloon occlusion-is based on the type, location, and severity of the vascular injury. Two main endovascular interventions commonly used in peripheral artery trauma are embolization and covered stent placement (stent grafting). The choice between embolization and stent grafting depends on the location and size of the vascular injury, whether the injury occurs in a main artery or a distal branch, and the characteristics of the injury (e.g., active extravasation or pseudoaneurysm formation). Other interventions, such as temporary balloon occlusion, which is often employed as an adjunct to open surgery, and percutaneous thrombus aspiration, are less frequently used.

3.1. Embolization

Endovascular embolization is typically recommended for actively bleeding injuries located in terminal branches or smaller, less critical arteries, such as distal branches of the deep femoral artery or muscular branches of the superficial femoral artery. A retrospective analysis by Doody et al. (2008) showed that embolization achieves technical success and immediate hemostasis in approximately 95% of peripheral arterial injuries involving distal branches[8]. Similarly, Moramarco et al. (2014) reported successful embolization outcomes in more than 90% of cases, demonstrating its reliability as a minimally invasive alternative [9]. Furthermore, recent recommendations from the Brazilian Guidelines on Traumatic Vascular Injuries (2023) explicitly advocate the embolization of femoral artery branches-particularly the deep femoral artery-as a definitive management strategy, assigning it a grade 1C recommendation [10].

In such cases, open surgical exploration and control of bleeding can be difficult and time-consuming due to severe tissue swelling and diffuse bleeding, making anatomical landmarks challenging to identify and obscuring the specific bleeding sites. Conversely, angiography-guided embolization facilitates rapid localization and definitive hemostasis, preserving intact arterial segments and reducing complications often associated with prolonged surgical dissection.

3.2. Covered Stent Placement

If bleeding or injury involves a major blood vessel where embolization may lead to limb ischemia or other complications, covered stent placement becomes the preferred endovascular treatment option. Covered stent placement is recognized as a suitable alternative to open surgery for treating peripheral arterial aneurysms, pseudoaneurysms, arteriovenous fistulas (AVF), arterial rupture, and vessel perforation [11-13].

However, potential complications associated with this approach include stent thrombosis, deformation or kinking of the stent, loss of arterial branches after stenting, and intimal hyperplasia. Chopra et al. (2016) reported a 30% stent occlusion rate at a median follow-up of 132 days in patients treated for traumatic axillosubclavian artery injuries, raising critical concerns about the long-term durability and patency of stents [14]. For young patients with a long life expectancy, the long-term outcomes of covered stent placement remain unclear, making open surgery potentially preferable in this population [15]. Therefore, careful patient selection and long-term follow-up are crucial in optimizing outcomes following covered stent placement.

Currently, commonly used stents include self-expanding stents and balloon-expandable stents. Each type has distinct advantages, limitations, and clinical indications that must be carefully considered when planning intervention. **Self-expanding stents** are generally made from nitinol, a shape-memory alloy, allowing them to automatically expand after deployment. These stents are particularly advantageous in tortuous vessels, anatomically challenging areas, or in regions subject to dynamic stress such as joint flexion points, due to their flexibility, durability, and resistance to deformation. They conform well to vessel anatomy, reducing the risk of stent fracture or deformation over time [12, 16]. However, self-expanding stents have limitations, including lower radial strength compared to balloon-expandable stents, and they may not provide immediate precise placement, making them less ideal in acute settings where rapid and exact stent positioning is essential [17]. In contrast, **balloon-expandable stents**, typically made from stainless steel or cobalt-chromium alloys, provide greater radial strength, enabling immediate and precise stent positioning, particularly beneficial in emergency situations where rapid control of active bleeding or vessel rupture is required. Their high radial force is useful in cases of severe vascular injury, pseudoaneurysms, or dissections needing immediate structural support and hemostasis[8, 17]. Nevertheless, these stents have limited flexibility, making them more prone to deformation or kinking, especially when placed in mobile anatomical sites (e.g., the femoral artery near joint flexion points) [12]. Additionally, balloon-expandable stents may carry a higher risk of arterial wall injury during deployment due to the inflation process, especially in heavily calcified or fragile arteries.

In summary, selection between self-expanding and balloon-expandable stents should be based on specific clinical contexts and injury characteristics. Self-expanding stents are preferred in anatomically complex or mobile arterial segments requiring flexibility and adaptability, while balloon-expandable stents are ideal for acute traumatic lesions requiring immediate, precise placement and high radial support.

In cases of late failure with endovascular stenting, such as stent occlusion, surgical bypass can be subsequently performed electively, ensuring optimal and safe restoration of vascular circulation.

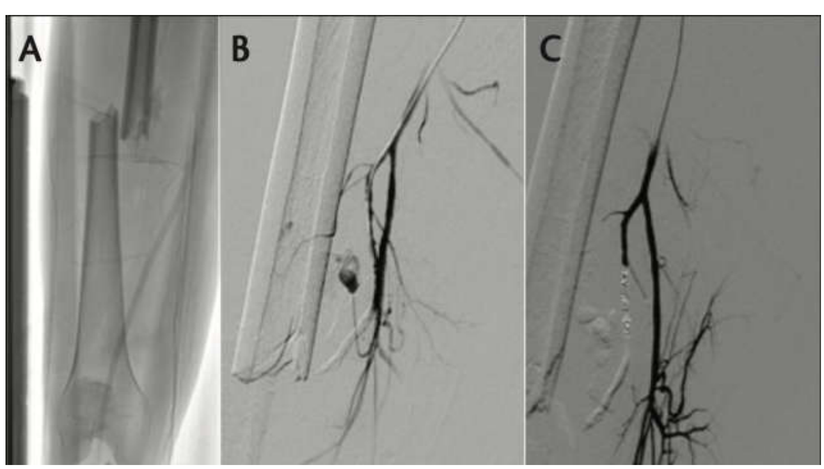

Figure 1. Radiograph showing displaced transverse fracture of the femoral shaft (A). Selective superficial femoral artery angiogram demonstrating bleeding source (B). Post-embolization angiogram showing successful hemostasis (C)[9]

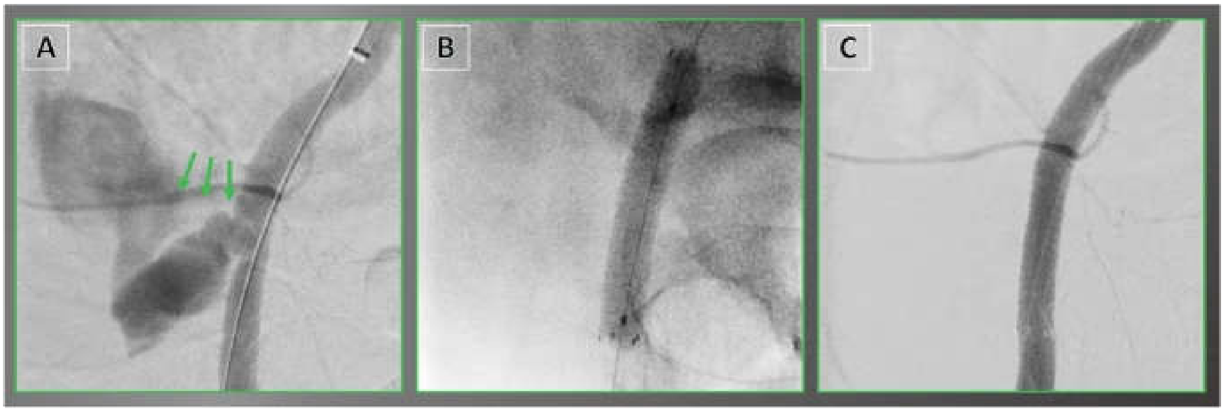

Figure 2. (A) Active extravasation (blue arrow) from the common femoral artery. (B) Covered stent placement covering the injury site. (C) Final angiogram demonstrating successful bleeding control[18]

3.3.Choosing Between Endovascular Intervention and Open Surgery?

Since the early 2000s, indications for endovascular intervention have expanded to include penetrating or blunt vascular injuries, particularly in cases involving pseudoaneurysms, dissections, or partial vessel-wall tears[6]. The advantages of endovascular intervention have already been discussed—such as its minimally invasive nature, reduced blood loss, and shorter hospital stay. Scott et al. (2015) reported a significant reduction in blood loss with endovascular intervention (150 mL vs. 825 mL, $p < 0.001$), highlighting the minimally invasive advantage of endovascular techniques in managing traumatic arterial injuries[3].

However, endovascular interventions are not without limitations and potential complications. Stent-related issues such as thrombosis, intimal hyperplasia, and stent migration are concerns, especially in anatomically mobile or high-stress regions [19]. Balloon-expandable stents, despite their precision, may deform or cause vessel trauma in dynamic vascular territories [20]. Furthermore, technical limitations arise in cases of massive hemorrhage or complex injuries involving major bifurcations, where rapid open surgical control remains essential [21]. These considerations underscore the importance of proper patient selection and institutional capacity when choosing an endovascular approach.

Although data demonstrate substantial benefits from endovascular interventions, limitations such as a lack of long-term follow-up data, non-randomized study designs, and heterogeneity in study criteria reduce the reliability and generalizability of these findings. Therefore, larger, randomized clinical trials with more comprehensive evaluations are required to clearly establish the effectiveness of endovascular methods compared to open surgery.

In clinical practice, standardized application guidelines remain lacking due to variations in anatomy, injury severity, and the skills of the intervention team[21]. Rather than positioning endovascular methods as a universal replacement for open surgery, current clinical practice increasingly emphasizes a case-by-case decision-making process based on anatomical, hemodynamic considerations, patient comorbidities, and resource availability.

Patient selection remains one of the most critical determinants influencing the effectiveness of endovascular interventions. Currently, clear consensus on indications and contraindications for endovascular intervention has not been fully established. Primary indications include injuries in anatomically complex or difficult-to-access regions, such as the proximal common femoral artery, iliac arteries, or small branches of the deep femoral artery; patients with significant comorbidities or high risk unsuitable for open surgery; and injuries effectively treated by covered stent placement or embolization, such as pseudoaneurysms, intimal tears, or bleeding from smaller arterial branches [3, 10, 13]. In cases of acute limb ischemia (due to thrombosis or embolism), endovascular interventions, including thrombus aspiration/removal and stent placement, may facilitate rapid revascularization[22, 23]. Many cases of acute ischemia secondary to trauma on a background of chronic arterial disease are now managed using hybrid methods (surgical thrombectomy combined with balloon angioplasty and stenting of distal lesions), leveraging the strengths of both approaches[24].

Contraindications for endovascular interventions also remain unstandardized and typically depend on patient characteristics, injury specifics, and technical limitations. Major contraindications include complete arterial transection and infection at the injury site, due to the heightened infection risk post-procedure[3]. In cases involving heavily calcified or severely tortuous arteries, or complex associated injuries such as fractures or compartment syndrome, endovascular intervention must be carefully considered, as open surgery may offer a more comprehensive treatment option[13, 25].

Some guidelines recommend that endovascular interventions should be selectively applied to hemodynamically stable patients without clear evidence of vascular injury. Conversely, patients who are hemodynamically unstable or have evident signs of vascular injury should be managed with open surgery by trauma or vascular surgical teams[26]. However, some trauma specialists argue that hemodynamic stability does not necessarily have to be a prerequisite for endovascular intervention. Several small-scale studies have successfully applied endovascular interventions for hemodynamically unstable patients with traumatic injuries to the subclavian, axillary, and brachial arteries [27].

The anatomical location and type of injury also influence treatment selection. As previously discussed, embolization is suitable for active bleeding in terminal branches or smaller, less critical arteries, such as distal branches of the deep femoral artery or muscular branches of the superficial femoral artery[8, 10]. Covered stent placement in lower extremities has also been successful for treating injuries to the common and superficial femoral arteries; however, most of these cases involve vessel dissections, pseudoaneurysms, or arteriovenous fistulas[26]. Complete arterial transections typically present difficulties in crossing the injury endovascularly, making open surgery a more appropriate choice.

Additionally, patient characteristics play a crucial role. Trauma patients generally tend to be younger than patients with chronic diseases, making the patency rates of covered stents and the long-term outcomes of embolization methods particularly important. Given that the use of covered stents for penetrating trauma patients is relatively new, long-term patency rates have not been fully established, and further evaluation of the long-term feasibility of these endovascular therapies is needed. Conversely, elderly trauma patients with multiple comorbidities face higher risks of complications from invasive open surgery. In these situations, endovascular interventions offer significant advantages, such as reduced mortality, decreased intraoperative blood loss, and lowered infection risk, ultimately improving outcomes and shortening recovery times.

The decision to utilize endovascular approaches also often depends on the preferences of individual practitioners and the capability of the healthcare facility, rather than standardized guidelines[25]. Studies have noted substantial variations in access to and outcomes from endovascular techniques, reflecting dependence on the hospital infrastructure and surgeon training[3, 28, 29].

Hybrid surgery has also been proposed as an effective treatment approach for patients with vascular injuries [30]. Endovascular therapy can serve as a temporary or stabilizing measure, providing rapid resuscitation and hemorrhage control, thereby facilitating the subsequent transition to open surgery, whether emergently or electively. Techniques such as endovascular balloon occlusion can rapidly achieve temporary bleeding control and stabilize patients prior to open surgical procedures.

In summary, despite the numerous benefits offered by endovascular interventions in managing lower-extremity arterial trauma, patient selection and treatment choices still require individualized assessment based on injury characteristics, patient conditions, and institutional capabilities. Current guidelines remain non-standardized, necessitating further research to optimize clinical decision-making.

4. Limitations in the Application of Endovascular Interventions for Femoral Artery Injuries in Vietnam

In Vietnam, as well as in other developing countries, endovascular interventions are currently mainly applied in chronic vascular conditions and primarily concentrated at major medical centers [31, 32]. At present, endovascular interventions in trauma care in Vietnam are primarily concentrated in the management of visceral and aortic vascular injuries, where open surgery is technically challenging and associated with higher morbidity[33, 34]. In contrast, the use of endovascular techniques for extremity vascular trauma, such as femoral artery injuries, remains limited. Most available data consist of isolated case reports rather than systematic series[35]. The successful deployment of these interventions requires strict infrastructural and organizational standards, including access to a dedicated DSA suite, availability of covered stents and embolization tools, and a multidisciplinary team composed of vascular surgeons, interventional radiologists, anesthesiologists, and trained nurses. Most provincial hospitals lack dedicated interventional radiology suites or sufficient expertise in this field.

While some provincial hospitals have begun developing endovascular capabilities through national initiatives and inter-hospital cooperation, progress remains uneven and heavily reliant on external support. A major barrier is the shortage of formally trained personnel in interventional vascular techniques. Even when DSA equipment is available, many centers are unable to independently perform emergency endovascular procedures. Furthermore, Vietnam lacks standardized national clinical guidelines for the use of endovascular methods in trauma, and interdepartmental coordination is often limited or inconsistent.

Additionally, treatment costs further limit the widespread adoption of these techniques in Vietnam. Endovascular interventions typically carry higher costs than traditional vascular surgery due to the expense of supplies and specialized equipment. Each covered stent used in peripheral arteries is costly, varying by type. In contrast, open surgery involving direct vascular repair usually has significantly lower material costs (e.g., sutures, venous patches). Even when artificial grafts are required, the price of a PTFE graft tends to be lower compared to a covered stent. Consequently, patients often face high out-of-pocket expenses, restricting access and affordability for many individuals.

5. Conclusion

Open surgery remains the cornerstone of vascular trauma management due to its ability to address a wide range of injury types. However, in selected femoral artery injuries, particularly those involving pseudoaneurysms, distal branch bleeding, or high-risk surgical candidates, endovascular intervention offers a less invasive and effective alternative. In anatomically complex cases or when diagnosis is uncertain, intraoperative angiography and hybrid strategies combining endovascular and open techniques can optimize both speed and safety. For healthcare facilities in Vietnam, where access to full endovascular resources may be limited, adopting a stepwise, case-based integration of these modalities, supported by multidisciplinary collaboration and targeted training, represents a pragmatic and impactful approach to improving trauma care.

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