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REVIEW/STATE OF THE ART

Endovascular Treatment of Complications of Femoral Arterial Access

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Abstract Endovascular repair of femoral arterial access complications is nowadays the treatment of choice in a group of patients who cannot tolerate vascular reconstruction and bleeding due to advanced cardiovascular disease. Endovascular procedures can be performed under local anesthesia, are well tolerated by the patient, and are associated with a short hospitalization time. Ninitinol stent technology allows for safe stent and stent-graft extension at the common femoral artery (CFA) level, due to increased resistance to external compression and bending stress. Active pelvic bleeding can be insidious, and prompt placement of a stent-graft at the site of leakage is a life-saving procedure. Percutaneous thrombin injection under US guidance is the treatment of choice for femoral pseudoaneurysms (PAs); this can theoretically be safer with simultaneous balloon occlusion across the entry site of a PA without a neck or with a short and wide neck. In a few cases with thrombin failure due to a large arterial defect or accompanying arteriovenous fistula (AVF), a stent-graft can be deployed. The vast majority of catheter-induced AVFs can be treated effectively with stent-graft implantation even if they are located very close to the femoral bifurcation. Obstructive dissection flaps localized in the CFA are usually treated with prolonged balloon inflation; however, in more extensive dissections involving iliac arteries, self-expanding stents should be deployed. Iliofemoral thrombosis can be treated effectively with catheter-directed thrombolysis (CDT) followed by prolonged balloon inflation or stent placement. Balloon angioplasty and CDT can occasionally be used to treat stenoses and occlusions complicating the use of percutaneous closure devices.

Keywords Iatrogenic complications · Femoral catheterization · Pseudoaneurysm · Arteriovenous fistula · Stent-graft · Thrombolysis

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Introduction

The number of percutaneous endovascular interventions performed worldwide has been growing rapidly due to important technological advances, improved long-term clinical outcomes, and, also, the lower morbidity associated with these procedures compared with traditional surgical treatment methods. The common femoral artery (CFA) is the most common access site for endovascular procedures, and it is therefore essential for interventionists to know how to recognize and manage the complications associated with this type of access. The most frequent complications include hematoma, uncontrollable groin and/ or retroperitoneal bleeding, pseudoaneurysm (PA), arteriovenous fistula (AVF), and in situ arterial dissection with or without associated thrombosis [1–4]. Less frequent complications include distal embolization, nerve damage, abscess, and lymphocele (Table 1).

Risk Factors for Femoral Arterial Access Complications

Procedural Factors

Procedural factors, which mostly influence risk of complications, include use of a sheath size greater than 8 Fr [5]

Table 1 Complications of femoral arterial access

Type of complication	Incidence	Type of treatment
Hematoma or uncontrollable bleeding[a]	<1%	Endovascular Surgery reserved for rare selected cases
Pseudoaneurysm	0.2–0.5% after diagnostic angiography and 2–8% after coronary angioplasty	Percutaneous Surgery reserved for rare selected cases
Arteriovenous fistula	<0.1%	Conservative in asymptomatic patients Endovascular in symptomatic patients
Arterial dissection or thrombosis	<0.5%	Endovascular Surgical treatment reserved for cases of endovascular treatment failure
Distal embolization	<0.5%	Endovascular Surgical treatment reserved for cases of endovascular treatment failure
Nerve damage	Rare	Conservative
Abscess	Rare	Surgical
Lymphocele	Rare	Conservative

[a] Requiring either transfusion or invasive treatment

and faulty puncture technique, i.e., either puncture above the inguinal ligament or puncture of the superficial femoral artery (SFA) or deep femoral artery (DFA) [6–8]. Although puncture above the inguinal ligament significantly increases the danger of intraperitoneal bleeding, it is also clear that a retroperitoneal or abdominal wall hematoma can develop following arterial puncture below the inguinal ligament [9, 10]. This less recognized complication is the result of bleeding in the femoral sheath, which is the inferior extension of the pelvic and abdominal wall fascial layers around the femoral artery and vein. When the femoral sheath is transgressed at the time of vessel puncture, blood collected in this space after catheter or sheath removal may spread along the fascial planes continuous with the sheath into the retroperitoneum or, indeed, into the anterior abdominal wall. Additional complications can arise from hemostasis achieved by manual compression. This traditional technique, developed by Dr. Sven Seldinger in the 1950 s, requires a significant amount of pressure over the access site, along with bedrest, usually for 6 h afterward [11, 12]. Manual compression may cause pain for some patients and deep vein thrombosis due to femoral vein compression and stasis [13]. On the other hand, brief manual compression of less than 10 min can result in PA formation [11, 14]. This complication is often correlated with catheter and sheath dimensions greater than 8 Fr and concurrent anticoagulant and antiplatelet therapy [15–19]. In recent years, a number of percutaneous closure devices have been developed, with the hope of reducing the frequency of local complications and allowing early patient mobilization post endovascular intervention. Large clinical trials have indeed demonstrated patients' preference for the use of these closure devices compared to the long bedrest associated with the more traditional manual compression. However, these studies failed to demonstrate a reduction in local complications associated with the use of these devices [20–23].

Patient-Specific Factors

Patient-specific risk factors include arterial hypertension, female gender, coagulopathy, severe atherosclerosis of the common femoral and/or iliac arteries, heavy arterial calcification, hostile groin (excessive scaring following surgery or repeated angiography, graft material), high division of femoral artery, nonflexible hip, advanced age, obesity, erythematous skin, intertrigo and anticoagulation, antiplatelet or fibrinolytic medication [5, 24].

Endovascular Versus Surgical Treatment of Iatrogenic Femoral Complications

The success of surgical repair of iatrogenic femoral access lesions is nearly 100%, but this treatment is associated with a postoperative morbidity rate of up to 25% and a postoperative mortality of up to 3.5% due to the significant comorbidities of the treated patients [25]. These open surgical procedures, although very often performed under general anesthesia, are potentially hazardous, since they increase the stress load in these patients, many of whom are in an unstable condition; in addition, the existing hematoma and local tissue injury frequently found in such iatrogenically traumatized areas predispose to poor wound healing and postoperative infection, especially if interposition of a synthetic graft is needed [26]. All these, together with the often encountered significant blood loss, lead to prolonged hospitalization of the affected patients.

Endovascular treatment is gaining popularity as a therapeutic alternative to open surgery. These procedures can be performed under local anesthesia, are well tolerated by the patient, and are associated with a shorter hospitalization time than that of surgery. This avoids the need for general or locoregional anesthesia in a group of patients who are often affected by advanced cardiovascular disease and cannot tolerate vascular reconstruction and bleeding.

Endovascular Treatment of Specific Type Complications

Hemorrhage

Percutaneous femoral access is almost always associated with some bruising at the puncture site. A significant hematoma or uncontrollable bleeding requiring either transfusion or invasive treatment occurs in $<1\%$ of endovascular procedures and almost always occurs during hemostasis. A large hematoma can accumulate very quickly, sometimes despite manual compression, and alerts to immediate action. More sinister is occult bleeding into the pelvis, which typically occurs when the arterial puncture is above the inguinal ligament. While groin expanding hematomas are readily evident, a massive retroperitoneal hematoma can develop without any external sign of bleeding. It is vital to recognize clinical signs of pelvic bleeding while the patient is still on the angiographic table and, thus, can be treated on the spot; these include hypotension, tachycardia, loss of ipsilateral distal pulses, faintness, confusion, agitation, and abdominal pain. It is not unusual for an occult pelvic bleeding to be discovered in the ward several hours after the procedure, and in this context an unexplained tachycardia may be the first sign to be alert for.

As soon as there is suspicion of intra-abdominal bleeding, an abdominal CT scan should be obtained immediately to confirm or rule out the diagnosis. In the case of a positive finding—even suspicion of a minor leak—angiographic control to identify the possible site of extravasation and endovascular therapeutic actions should be carried out through contralateral retrograde femoral approach. By using a crossover technique in most cases, a braided 8-Fr introducer sheath 30–45 cm in length is inserted via the aortic bifurcation and placed at the level of the ipsilateral external iliac artery over a stiff Amplatz guidewire. Heparin (3000–5000 IU) is administered intra-arterially through the sheath. A stent-graft with a diameter 1 mm larger than the vessel diameter, to ensure correct anchorage, is subsequently advanced under fluoroscopy and deployed in order to cover the leaking point with adequate proximal and distal landing zones. However, attention should be paid so that the stent-graft does not cross the CFA bifurcation, and the origins of the DFA and SFA are not compromised. In the case of perforation of a heavily calcified access artery, gentle balloon dilation inside the stent-graft may be needed; in our experience, in such calcified vessels a 2-mm-oversized self-expanding stent-graft is sometimes needed to achieve complete seal of the leakage (Fig. 1). A completion angiogram is finally performed to confirm successful cessation of extravasation and maintained patency of the DFA.

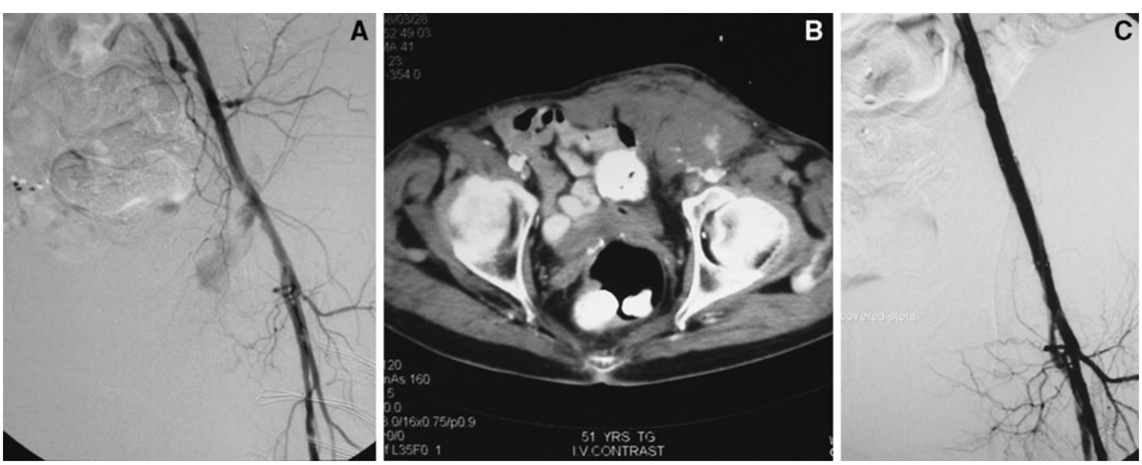

Fig. 1 A 46-year-old male on hemodialysis, with a history of severe coronary disease, underwent high antegrade puncture of a heavily calcified CFA for infrapopliteal PTA. Following sheath removal a rapidly increasing groin and scrotal hematoma developed despite manual compression. **A** Angiography demonstrates active extravasation from the proximal CFA just below the inguinal ligament level. **B** CT contrast-enhanced image demonstrates active extravasation from the proximal CFA and accompanying hematoma. **C** Following deployment of an 8 × 40-mm self-expanding ePTFE-covered stent (Fluency; C. R. Bard, USA) from a contralateral crossover approach, successful sealing of the perforation was achieved

One important concern regarding stenting of the CFA is the fear of stent damage by repeated flexion and extension of the hip joint and the fear by many interventionists that a stented artery cannot longer be used as a vascular access for cardiovascular interventions. Nevertheless, stenting of focal atherosclerotic CFA lesions has been reported to be overall successful in the short and midterm [27]. In addition, further vascular interventions are not precluded, since the artery can be punctured under fluoroscopy either above or below the stent, thus avoiding damage to the metallic struts [27]. Self-expanding stent-grafts, especially the new generation with nitinol endoskeleton, should be preferred in the area of the groin, because they show increased resistance to external compression and bending stress [28]. On the other hand, a stainless-steel balloon-expandable stent-graft, in a superficial area like the groin, is prone to compression, kinking, and fracture due to plastic deformation caused by repeated external forces. In any case, implantation of the shortest stent-graft possible is recommended to avoid these complications, as well as to reduce the risk of involuntary closure of the side branches [29, 30].

The most important advantage of stent implantation compared with surgical repair is the patient's rapid return to ambulatory activity. The majority of patients can be out of bed the next morning and leave the hospital 24 h later. However, surgical treatment may be inevitable in perforations at the bifurcation of the femoral artery or when stent-graft deployment is impossible due to extremely elongated, tortuous, or heavy calcified iliac arteries. Surgical repair is usually performed with primary arterial closure using placement of one or more sutures of nonabsorbable synthetic material in a transverse direction to avoid the creation of a stenosis. In the case of a severely damaged artery, resection of the damaged arterial section and placement of a vein patch may be needed. If the arterial defect is too large in a relatively narrow artery, a short bypass grafting may become inevitable.

Pseudoaneurysm

The reported incidence of femoral postcatheterization pseudoaneurysms (PAs) ranges from 2% to 8% after coronary angioplasty and stenting and from 0.2% to 0.5% after diagnostic angiography [31]. Symptoms and signs of PA are pain, swelling, and severe bruising at the site of recent arterial puncture, and clinical examination can reveal a palpable thrill or pulsatile mass. The most serious complication of PA is rupture, which is related mainly to the size of the PA sac; other complications include persistent pain and swelling around the affected area, distal embolization, local skin ischemia and necrosis, infection, and compression of adjacent vessels or nerves [32]. There is contradictory information in the literature regarding the smallest size at which a PA should undergo treatment; Toursarkissian et al. [33] recommend invasive treatment only in PAs >3 cm in diameter, while Kent et al. [34] found that spontaneous closure is expected only in PAs <1.8 cm in diameter. An explanation for this discrepancy may be the different anticoagulation status of the studied patients, as it is difficult for a PA to be thrombosed spontaneously in an anticoagulated patient. For this reason each institute must establish its own policy for the treatment of such lesions.

Duplex ultrasound (US) is the method of choice to confirm the presence of a PA and to evaluate its size, the presence of blood flow or thrombotic material inside, the communication with the artery, and the presence of multiple loculations. Multiloculated PAs are characterized by complex hemodynamics and must be carefully examined; a potential mistake made by inexperienced sonographers is to recognize the most superficial lobe of a bilobed PA correctly but to confuse the deeper lobe with the femoral artery [16, 35]. US can be used as a guidance modality for the treatment of PAs, to assess the success of treatment, and to monitor patients during follow-up. Catheter angiography can also diagnose a PA, but due to its invasiveness, this procedure is no longer used except before endovascular intervention or, occasionally, surgery.

For many years surgical open repair was the gold standard, but since 1991 US-guided minimally invasive therapy has been the first-line approach for the treatment of postcatheterization PA [36]. US-guided compression repair, a method which initially became popular at many institutions for many years, is both time and labor intensive, and patients very often require intravenous analgesia or sedation to tolerate the procedure. In addition, this method suffers from a significant failure rate, which ranges between 30% and 40% in anticoagulated patients [37]. In recent years, thrombin injection under US guidance became very attractive as a valuable alternative to compression repair. Despite the limited evidence based on randomized controlled trials (RCTs) comparing US-guided compression versus percutaneous thrombin injection [38], the latter is nowadays the treatment of choice for noncomplicated femoral artery PAs with a distinct neck. It is a quick, safe procedure which can be performed in any relatively clean room with standard ultrasound equipment and needles. Most importantly, anticoagulation does not seem to affect the efficacy of the procedure.

Most interventionalists favor the use of human thrombin since bovine thrombin has the potential to induce allergic reactions. Autologous thrombin is another potential alternative for injection; its application is reliable, simple, and safe, and in addition, it is cheaper than commercial bovine or human thrombin [39]. During the procedure, it is imperative to confirm that the needle is placed into the center of the PA cavity to avoid injection into a native vessel (Fig. 2). To decrease the incidence of clot embolization into the native arterial tree, it is probably best to inject multiple small volumes and wait for thrombosis between each injection rather than injecting a single large volume.

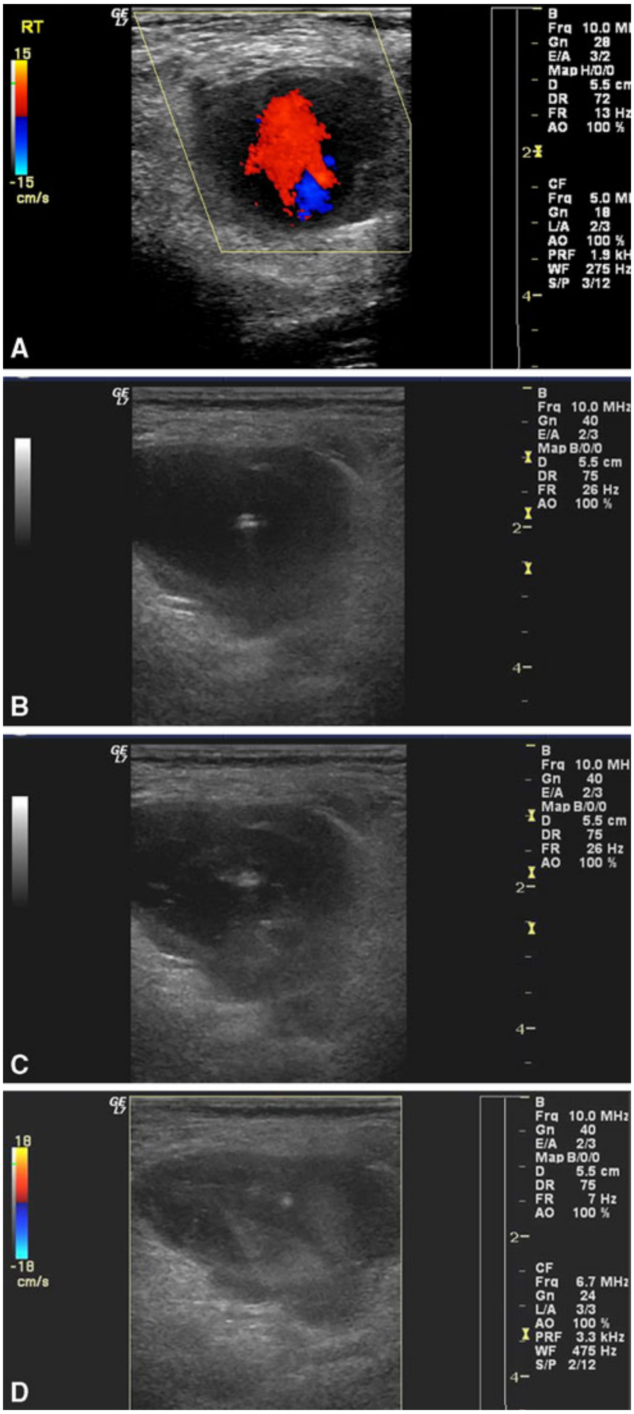

Fig. 2 During US-guided percutaneous thrombin injection it is important to confirm that the echogenic tip of the needle is placed into the center of the PA cavity away from the PA neck, to avoid thrombin leakage into the native artery. **A** Color flow image of a PA after percutaneous transluminal coronary angioplasty. **B** The echogenic tip of the needle in the center of the PA cavity. **C**, **D** Progressive thrombosis of the PA seen between small-volume injections

The therapeutic efficacy of the method is very high, demonstrating an overall thrombosis rate between 90% and 100% [15, 40–45]. In the majority of PAs containing a single lobe a thrombin dose of 500–1000 IU is adequate. In patients with bilobed PA, injection and thrombosis of the lobe not directly joint with the native femoral artery can be performed first, followed by a second injection into the lobe communicating with the femoral artery in the case where it remains patent after the first injection [35, 42]. However, others recommend that the lobe closest to the artery should be injected initially, assuming that if the proximal lobe is thrombosed, flow to the distal lobe would also cease [46].

Thrombin leakage into the femoral artery during percutaneous PA treatment is a real and well-recognized complication, despite the fact that clinical significant arterial thrombosis or distal embolization is rare due to the protective effect of the natural anticoagulant mechanism [47, 48]. Where the neck of the PA is absent or is short and wide, percutaneous thrombin injection can theoretically be safer with simultaneous balloon occlusion across the entry site of the PA (Fig. 3) [49]. According to this method, the contralateral femoral artery is catheterized and a check angiogram identifies the site of the PA. A balloon catheter corresponding to the vessel size is subsequently passed over the aortic bifurcation and placed across the PA neck. Under US guidance a 19- to 22-G needle is advanced percutaneously into the PA and the balloon is then inflated. After pulsatile flow inside the PA sac stops, thrombin is injected. The balloon is kept inflated for about 10–15 min, and after deflation both angiography and US are performed to assess for complete thrombosis of the PA. There is no proof, from the small series available, that there are reduced complications with the use of this method compared with thrombin injection without balloon protection [43, 50, 51]. It is advocated that this method should be done not routinely in all cases, but only in the case of complex PAs and those with wider necks [32]. Elford et al. [51] proposed application of this method if the neck is <3 mm in length or wider than a point source.

The thrombin failure rate can be high in cases associated with extensive damage to arterial wall. Sheiman et al., in a study of 54 patients with simple CFA iatrogenic PAs treated with percutaneous US-guided thrombin injection, concluded that their failure rate of 9% was due to an underlying sonographically occult vascular injury due to vessel laceration or infection [52]. They also speculated that the need for a dose >1000 U of thrombin for PA thrombosis is an indirect indicator of a large arteriotomy

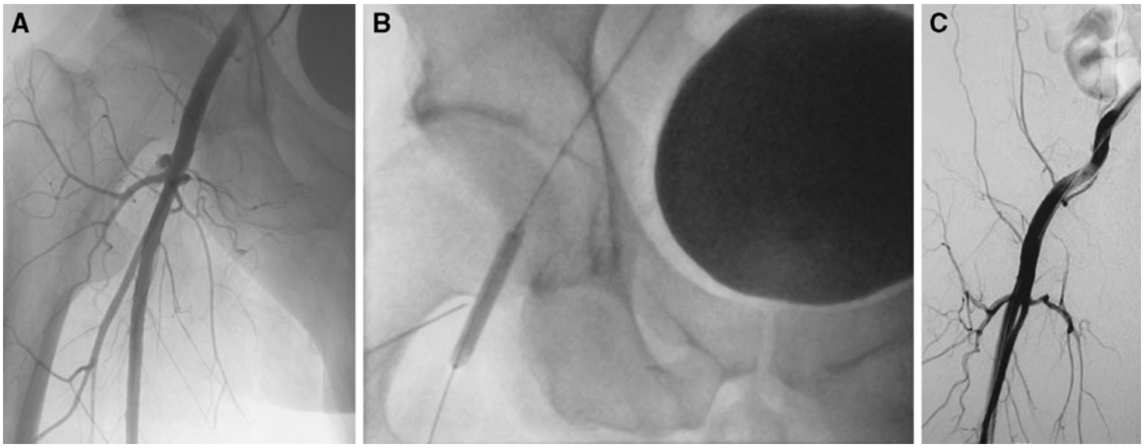

Fig. 3 **A** A postcatheterization pseuroaneurysm (PA) with a short and wide neck just at the femoral bifurcation. **B** A 6-mm-diameter angioplasty balloon was introduced from a contralateral femoral approach, positioned across the neck of the PA, and inflated. Under US guidance, a 21-gauge needle has been inserted percutaneously into the PA. **C** Completion angiography after the percutaneous injection of thrombin and removal of the balloon catheter demonstrates successful thrombosis of the PA

site defect requiring closer clinical follow-up. A possible explanation is that damaged endothelium at sites of a large arteriotomy or laceration expresses thrombomodulin, which complexes with thrombin to activate protein C. Activated protein C is known to activate an anticoagulation pathway [53] and reduce the relative size and number of fibrin fibers within maturing thrombus [54]. In the case of thrombin failure a second or third attempt can be made before resorting to surgery [15, 32].

Stent-grafts can be a reliable minimally invasive option for femoral arterial PAs that cannot be repaired with US-guided thrombin injection or that accompany an AVF [55, 56]. This approach is particularly helpful in high-risk patients and provides a good alternative to surgical repair. It can be an excellent treatment for PAs of the DFA, thereby avoiding an open surgical procedure while preserving the patency of the deep femoral artery. Moreover, short covered stents can effectively treat PAs originating from the SFA without extension to the CFA, which may be the site of future catheterization.

Stent-grafts should be used with caution in younger patients with a long life expectancy, since the long-term patency of these devices is suboptimal [55]. The subacute occlusion rate is relatively higher with covered stents compared to bare stents, due to late-onset endothelization, which triggers a thrombogenic reaction [57, 58]. Polyethylene tetraphythalate (PAT)-covered stents (e.g., Wallgraft, Boston Scientific, USA) appear to be more thrombogenic and immunogenic compared to polytetrafluoroethylene (PTFE)-covered stents, especially in smaller-caliber vessels [58, 59]. Therefore, young patients who are good candidates may warrant surgery rather than stent implantation. In addition, the costs of the device are prohibitive for routine use in a potentially large patient population, despite the fact that they compare favorably with the costs of surgical intervention. Other limitations of stent-grafts include extreme elongation and tortuosity of the iliac arteries prohibiting contralateral femoral access, location of the PA close to the femoral arterial bifurcation, potential deformation or fracture of the stent at a site of mobility near the hip, and restrictions to reuse the groin for access in the future.

Two other minimally invasive techniques with rather historical value should also be mentioned. Transarterial thrombin injection into the PA through the neck was reported in a few cases as a method to treat PAs, mainly located in sites not immediately accessible to the percutaneous root, such as the DFA [60]. Its main drawback compared to percutaneous thrombin injection is that it is an invasive procedure, which generally requires arterial access from the contralateral femoral artery. Filling of the PA cavity with coils, either through a transcatheter approach or directly through a needle placed percutaneously into the cavity, has also been abandoned as a therapeutic procedure, due to several drawbacks: coils may potentially increase pressure within the cavity leading to rupture, they may prevent shrinkage of the PA after occlusion, and they may also act as a nidus for infection [32].

Surgical treatment of femoral PAs is reserved for rare selected cases. These include (a) a rapidly expanding PA due to continuous bleeding in a relatively fit young patient, (b) an infected PA, (c) symptoms due to local compression on the femoral artery (distal ischemia), femoral nerve (neuropathy), or skin and surrounding soft tissues (ischemic changes), and (d) failure of percutaneous treatment. Complications of surgical treatment include bleeding (7.4%), neuralgia (5.2%), and death (2.1%) [31, 61].

Arteriovenous Fistula

Distal puncture is the main cause of postcatheterization femoral AVFs, and the incidence of this type of complication varies from 0.006% to 0.88% [3, 62, 63]. The clinical diagnosis of a femoral AVF made by palpation and auscultation can easily be confirmed by color Doppler ultrasonography [64]. According to the study results of Kelm et al. [62], the majority of patients who develop AVFs do not need invasive treatment, as usually no clinical signs of hemodynamic significance appear during follow-up. However, long-standing AVFs can lead to high-output cardiac failure, aneurysmal degeneration of the artery, and limb edema [3, 65–68]. In symptomatic patients, noninvasive procedures such as prolonged bandaging and US-guided compression have been suggested as first-line treatment methods, but their effectiveness is restricted by the fact that these patients are all on anticoagulation and antiplatelet regimens for their coronary artery disease [36, 65]. In addition, very often the fistula track is too short or too large to be compressed effectively by the transducer.

Stent-graft implantation appears to be an attractive endovascular treatment option for catheter-induced AVFs, with patency rates between 88% and 100% [29, 55, 56]. In the vast majority of cases this type of AVF originates from either the DFA or the SFA (Fig. 4). Both these locations are far enough from the hip joint and sufficiently protected from stent deformation and fracture. In addition, noncoverage of the CFA allows future catheterizations from the ipsilateral femoral access. A major concern for stent-graft implantation is the presence of lesions near the femoral arterial bifurcation because of the danger of occlusion of the DFA or SFA after stent-graft placement; however, this problem very often can be solved with precise placement of a short stent-graft under "roadmap" guidance. To accomplish this task and taking into consideration the typical AVF location away from the hip flexion point, many advocate the use of balloon-expandable stent-grafts, which either are crimped manually onto a 5-Fr, 5.0-mm, or 6.0-mm peripheral angioplasty balloon (Jostent Peripheral Stent Graft; Jomed, Rangendingen, Germany; stent lengths of 12–28 mm and expandable diameters of 4–9 mm) or are premounted on the balloon catheter (Advanta V12 covered stent; Atrium Medical Corp., Mijdrecht, The Netherlands; stent lengths of 16–59 mm and stent expansion range of 5–10 mm). The stent-graft is delivered through a 45-cm-long introducer sheath advanced to the contralateral side across the aortic bifurcation over a stiff guidewire. In order to prevent migration of the Jostent Peripheral Stent Graft on the carrying balloon, this must be inflated up to 1-atm pressure after it is inserted into the sheath. Roadmap and multiple angiographic projections should be used for precise placement of the stent-graft.

The newer self-expanding stent-grafts, with a nitinol endoskeleton, can be delivered more easily than the balloon-expanding ones at the site of the fistula, while they show no foreshortening or jumping during deployment; however, the fact that the smallest length available is 40 mm can be considered a relative disadvantage of their use.

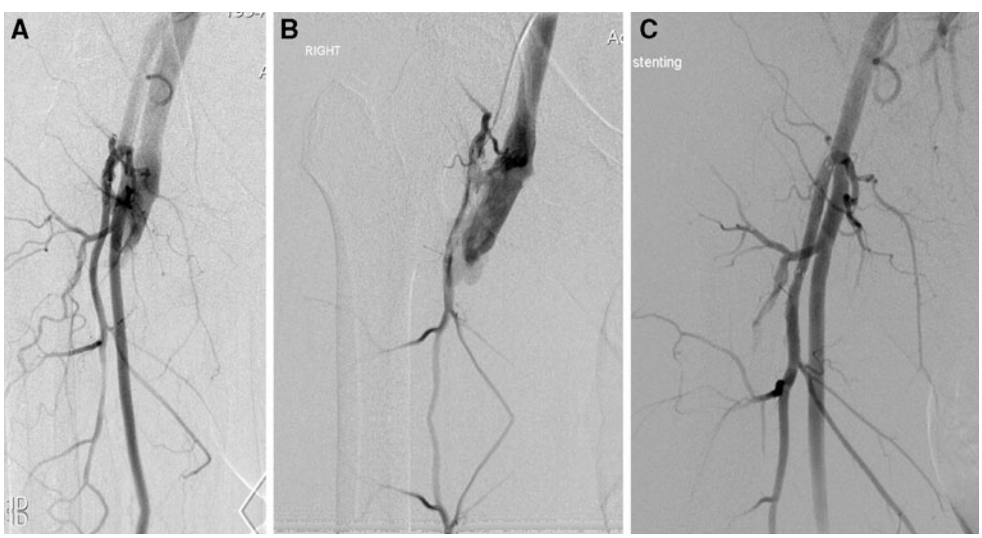

Fig. 4 A 54-year-old male presented with right groin pain and hematocrit drop, 24 h after coronary angiography. Clinical examination found a pulsatile mass at the puncture site and moderate leg edema. **A**, **B** Angiography through a contralateral femoral approach demonstrates simultaneous contrast opacification of the right common femoral vein (CFV), due to arteriovenous communication between the deep femoral artery and the CFV, created from a low puncture during coronary angiography. **C** Completion angiogram after deployment of a 6 × 40-mm, self-expanding, double-ePTFE-layer, nitinol-covered stent (Fluency; C. R. Bard, USA) from a contralateral crossover approach demonstrates successful sealing of the arteriovenous fistula

Although limited long-term follow-up data are available, percutaneous coil or *N*-butyl-cyanoacrylate embolization can alternatively be performed as an endovascular treatment approach, if the connecting channel of the AVF is long enough [69, 70].

Surgical repair of catheter-induced AVFs is associated with risks of complications such as hemorrhage due to venous hypertension in the arterialized venous site and groin infection. In addition, in cases of AVF the surgeon often finds a tangle of vessels that makes it difficult to identify the fistula track [5, 29].

Arterial Obstruction

Intimal dissection or arterial thrombosis due to femoral catheterization occurs in <0.5% of cases, and although not always limb-threatening, it can seriously compromise walking exercise, which is an important component of cardiac rehabilitation in patients with coronary disease [26]. Fortunately, in the majority of patients subintimal passage of the guidewire or catheter is immediately recognized and another arterial access is selected or the procedure is postponed, with no sequelae to the vessel patency [71]. However, it is not unusual for arterial thrombosis to become apparent only after completion of a coronary catheterization procedure. A possible explanation is that either the guidewire is redirected by the operator to the true lumen after initial dissection or it follows a subintimal route with spontaneous re-entry to the true lumen; the second mechanism explains more convincingly the more extensive dissections also involving the external iliac artery (EIA) [72]. This extensive vessel injury, in combination with perhaps excessively firm external compression applied after sheath removal, may cause a severe obstruction to flow in the iliofemoral region, resulting in acute thrombosis. Surgical repair usually requires a major reconstructive procedure in addition to thrombectomy, as in the majority of patients with coronary disease, the iliofemoral vessels are affected by atherosclerosis as well [73, 74]. In addition, up to 50% of those presenting with critical ischemia may suffer permanent disability after operation [75].

In the case of an obstructive dissection flap localized in the CFA, prolonged inflation of a standard angioplasty balloon of appropriate diameter very often results in successful apposition of the intima and underlying media; however, in more extensive dissections involving the EIA, self-expanding stent deployment is essential to restore long-term vessel patency [76]. In order to avoid stenting of the CFA, very often a combination of stenting above the level of inguinal ligament and prolonged balloon inflation at the CFA level is sufficient to resolve ischemia; however, in many cases the stent must be extended at least to the proximal CFA (Fig. 5). With new flexible self-expanding nitinol stents this seems not to be a major problem anymore, as these stents can effectively withstand external compression at the hip flexible point, while at the same time an arterial segment uncovered by the stent very often remains for femoral puncture under fluoroscopic or US guidance [27].

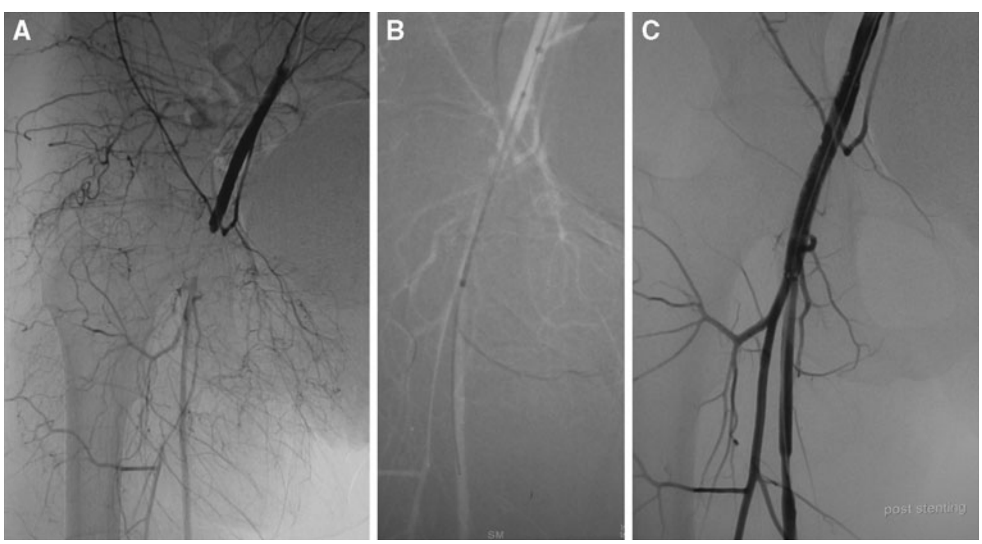

Fig. 5 A 69-year-old female with severe coronary disease underwent coronary angioplasty and stenting. Following sheath removal, she developed acute ischemia of the right leg. **A** Angiography through a contralateral femoral approach demonstrates total occlusion the CFA due to obstructive dissection. Due to her unstable condition it was decided to be treated with endovascular methods. **B**, **C** Direct CFA stenting with a 7 $\times$ 60 self-expanding nitinol stent (Luminexx; Bard) was performed through a contralateral crossover approach. Completion angiography shows restoration of CFA patency, with no compromise of SFA and DFA patency. The contralateral femoral artery could be used for future catheterization procedures

Catheter-directed thrombolysis (CDT) seems to be an acceptable alternative to primary surgical revascularization in iatrogenic acute iliofemoral thrombotic occlusions, although there are no large series in the literature supporting its widespread use [72, 77–79]. The most commonly used lytic agents for intra-arterial thrombolysis in such cases are rt-PA and urokinase, often with the adjunct of catheter suction. A typical scheme for urokinase is 240,000 IU/h for 2 h, reduced to 120,000 IU/h for another 2 h, then 60,000 IU/h until lysis is complete, and for rt-PA a typical scheme is three or four 5-mg boluses at 5- to 15-min intervals, followed by a continuous infusion of 0.5–2.5 mg/h for the remainder [72, 77, 78, 80]. Although there is no difference in efficacy or safety between rt-PA and urokinase, the rate of thrombolysis with rt-PA tends to be more rapid during the first hours of the procedure [81, 82]. In addition, rt-PA is associated with fewer side effects of nausea and vomiting compared with urokinase [82]. Regarding rt-PA delivery, it seems that the initial high-dose transthrombus boluses, followed by continuous infusion, significantly accelerate lysis without compromising the outcome [72, 80]. Following successful lysis, percutaneous transluminal angioplasty with prolonged balloon inflation is almost always needed as a complementary procedure, and in approximately half of cases an additional self-expandable endoprosthesis should be placed in order to treat more extensive dissections proximal to the CFA [72].

Distal embolization can rarely occur during femoral cathetertization and this is amenable to CDT, although aspiration thrombectomy is also a helpful adjunct to remove such emboli [83]. Collagen embolization to the politeal and crural arteries, following the use of the Duett and Angio-Seal closure devices, has also been reported in the literature [84, 85]; in such cases CDT can be used as the initial treatment choice, with surgical treatment being reserved for cases of endovascular treatment failure [86–88].

Endovascular Management of Complications Related to Percutaneous Closure Devices

Percutaneous closure devices are safe and effective even in relatively small-caliber arteries and in vessels affected by connective tissue disorders [89–92]. These devices offer the advantage of early ambulation and hospital discharge; however, patients should be carefully supervised at initial mobilization from bedrest following placement of a closure device [93]. Systems with suture-mediated or collagen plug mechanisms have an intravascular component, which is thought to account for the occurrence of arterial stenosis or occlusion. Preliminary data show that PTA can be used successfully to treat stenosis or occlusions at the arterial access site, following hemostasis using a suture-mediated percutaneous closure device [94, 95]. Caution is also advised when deploying Angio-Seal devices in patients with antegrade punctures [96]; in such cases the CFA can become occluded and stents are often needed to restore patency due to inadequate balloon angioplasty [97]. More complex endovascular procedures, such as the combination of excimer laser angioplasty and balloon dilatation as well as use of the Silverhawk plaque excision system, have also been applied successfully in Angio-Seal-induced stenoses and occlusions [98, 99]. On the other hand, placement of the Angio-Seal above the inguinal ligament may result in active bleeding, which can be managed with stent-graft deployment [100].

The StarClose is a novel system which achieves hemostasis via a nitinol clip placed on the outer arterial wall; this system has been found to have a high technical and clinical efficacy [14]. However, despite its extravascular nature, femoral stenosis can occur, as the nitinol clip tines may be hooked directly through the anterior femoral arterial wall into the posterior intimal wall, causing retraction of both into the purse-string configuration [101]. This nitinol-clip-induced luminal narrowing can even progress to arterial thrombosis, leading to severe acute limb ischemia [102]. Furthermore, if the vessel locator wings are lodged against an atheromatous plaque, the sliding element of the device advances the nitinol clip through the vessel wall, resulting in laceration [103]. All of these StarClose-induced complications should be managed surgically.

Conclusions

Endovascular repair is a less invasive treatment option than surgery for the treatment of various types of iatrogenic femoral access complications. Stent-grafts are safe, effective, and durable devices for the treatment of uncontrollable bleeding, AVFs, and, occasionally, PAs not amenable to treatment with percutaneous thrombin injection. In extensive iliofemoral obstructive dissections, self-expanding stents should be deployed. The unique structure and design of the new self-expanding nitinol stents and stent-grafts allow for safe extension of these devices at the CFA level. CDT followed by prolonged balloon inflation or stent placement can be used effectively in the case of iliofemoral thrombosis.

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