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Interventional REVIEW

Percutaneous Treatment of Iatrogenic Femoral Artery Access Complications

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ABSTRACT

Percutaneous minimal invasive treatment of iatrogenic femoral artery access complications (IFAACs) is considered as a first choice treatment in selected cases. Percutaneous procedures are performed under local anaesthesia, are better tolerated by the patient, and are associated with a shorter hospitalisation time, compared to open surgery. Bleeding complications can be insidious and life-threatening and prompt sealing of arterial leakage with stent-grafts or embolisation are life-saving procedures. Percutaneous US-guided thrombin injection is the treatment of choice for femoral pseudoaneurysms. The vast majority of arteriovenous fistulas (AVFs) can be treated effectively with stent-graft implantation even if the AVF is located very close to the femoral bifurcation. Catheter-directed thrombolysis assisted by subsequent prolonged balloon inflation or stent placement is able to treat effectively acute arterial thrombosis. Occasionally stenoses or occlusions provoked by percutaneous closure devices can also be managed by endovascular means.

KEY WORDS
femoral catheterisation; iatrogenic; pseudoaneurysm; dissection; arteriovenous fistula; stent graft

1. Introduction

Percutaneous endovascular interventions, including diagnostic cardiac catheterisation and percutaneous coronary intervention (PCI), are being performed worldwide in growing numbers during the past two decades [1-3]. This is attributed mainly to important advances in technology, substantially improved long-term clinical outcome, and most of all due to the lower morbidity and mortality associated with these procedures compared to traditional surgical treatment options. The common femoral artery (CFA) is traditionally being used as the preferred access site for the majority of percutaneous

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coronary and peripheral arterial endovascular procedures [1-4]. Despite technological advances in interventional procedures, better materials used and newer antiplatelet and antithrombotic regimen, iatrogenic femoral artery access complications (IFAACs) still occur [1-4]. The incidence of IFAACs for diagnostic cardiac catheterisation alone ranges between 0.8% and 1.8% [1-6]. For percutaneous coronary interventions the reported incidence is even higher, in the range of 5.4% to 20%, depending on the definition and criteria for IFAACs used [1-6]. The rate of haemorrhagic access site complications following peripheral interventions is reported in the range of 1.0% to 11% [7-8]. In addition, considering the more complex endovascular procedures performed nowadays such as endovascular abdominal aortic aneurysm repair (EVAR), thoracic endovascular aneurysm repair (TEVAR) and transcatheter aortic valve replacement (TAVR) which require larger access sheaths (even>20Fr) the incidence of IFAACs is likely to increase [7-8]. The true incidence of all access site complications arising from non-coronary interventions such as in the aforementioned and from peripheral vascular interventions is basically unknown and it is likely that the total incidence of vascular access site complications is greatly underestimated [7-8]. Taking into account the above mentioned facts, it is easy to understand the reason why IFAACs remain an important source of increased morbidity and mortality with an additional economic impact due to prolonged hospital stay and raise of health costs [1-8].

Nevertheless, IFAACs can be managed endovascularly obviating thus the need for surgical treatments. Endovascular repair of these complications is considered the treatment of choice since we are dealing with a group of patients who cannot tolerate major operations and vascular reconstructions due to advanced comorbidities [1-8]. In this review article, an overview of the spectrum of percutaneous endovascular treatment of iatrogenic femoral artery access site related complications is provided. It is of paramount importance for clinicians and especially interventionists to know firstly how to recognise and secondly how to manage effectively the complications associated with femoral vascular access.

2. Classification of iatrogenic femoral vascular access complications

Iatrogenic Femoral Artery Access Complications (IFAACs) can be subdivided into the following four categories:

(a) ***Bleeding complications:*** They could be presented as a local superficial haematoma, as an uncontrollable groin or abdominal wall haematoma and as a retroperitoneal or intrapelvic haemorrhage/haematoma. It may require transfusion, prolonged hospital stay, and/or cause a drop in haemoglobin of >3.0 g/dL [1-4]. Several classification systems are currently in use for bleeding complications. The SIR (Society of Interventional Radiology) classification system for peripheral interventions and the TIMI (Thrombolysis in Myocardial Infarction) and GUSTO (Global Use of Strategies to Open Occluded Arteries) classification systems for coronary interventions are the most common ones [8-10]. Several definitions of bleeding have been also used in other published clinical trials and registries and every system incorporates a different combination of patient-laboratory data elements and then ranks these combinations into severity categories (minor-moderate-severe) [8-10].

(b) ***Arterial complications:*** These are related directly to the catheterised artery itself and include: Arterial dissection alone or with associated thrombosis and partial or total vascular occlusion, pseudoaneurysm (PA) formation, iatrogenic arteriovenous fistula (AVF) and distal embolisation [1-4].

(c) ***Combined complications:*** Any combination of the aforementioned bleeding and arterial complications.

(d) ***Local non-vascular complications:*** These are very rare complications at the access site and include local nerve damage-irritation, local infection, abscess formation, and lymphocele formation [1-4]. Their management is conservative except for abscesses which require surgical or percutaneous drainage.

The classification of IFAACs is summarised graphically in **Table 1**.

3. Risk factors for iatrogenic femoral artery access complications

It is essential for interventionists to be familiar with the predisposing risk factors for IFAACs, in order to avoid or limit them [2, 5, 8-11]. Because prevention of IFAACs may represent an important step in improving outcomes, several risk scores-models have been prospectively validated in patients undergoing coronary or peripheral interventions [12-13]. Specifically for haemorrhagic complications, quite a few independent bleeding risk factors have been identified, prospectively validated, and incorporated into clinical bleeding risk scores that are used in

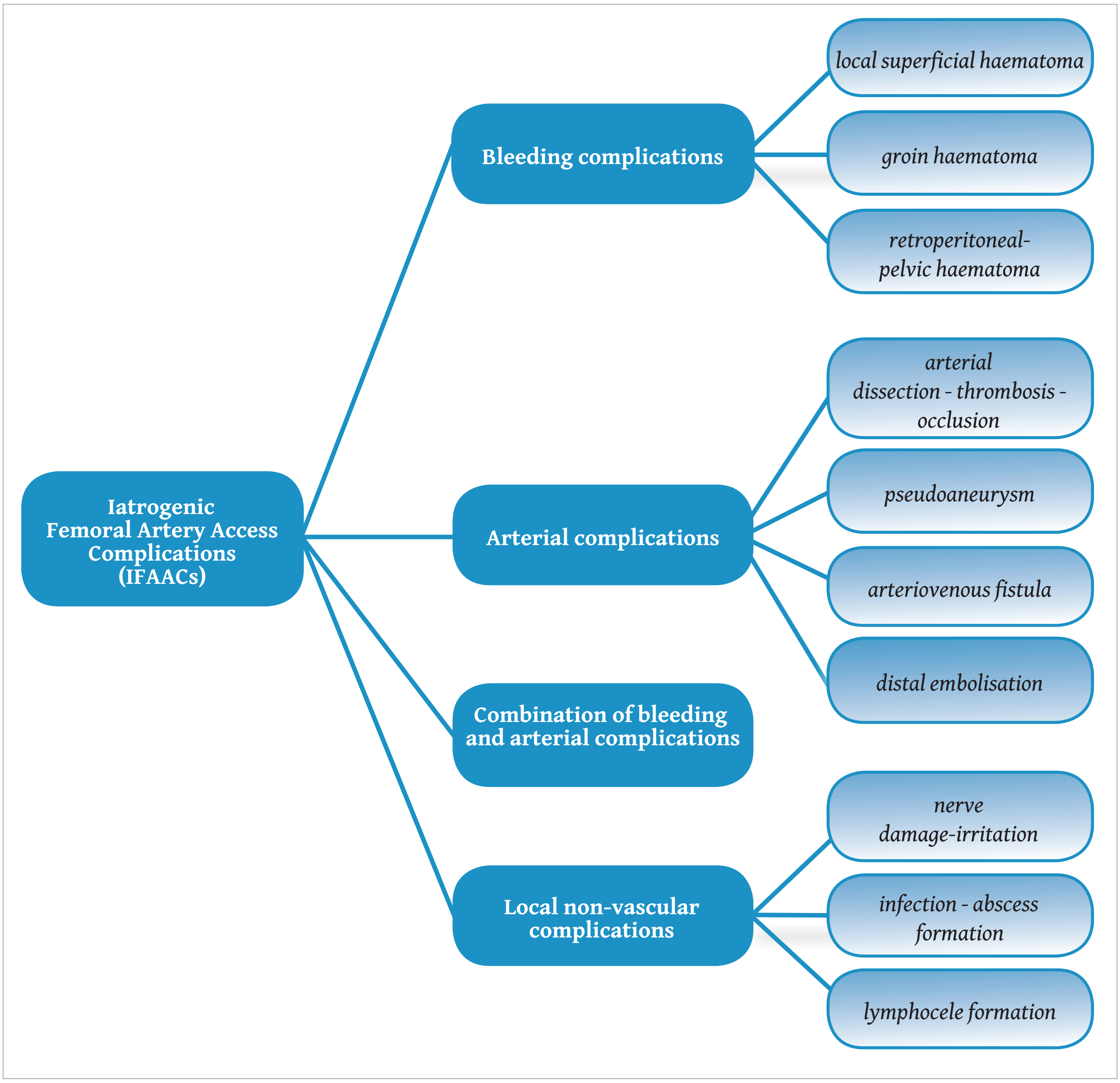

Table 1. Classification of femoral artery access site complications

current clinical practice [12-13]. In general, risk factors can be classified as modifiable (procedure related) and nonmodifiable (patient related). Modifiable risk factors are related to the endovascular procedure itself and are associated with the femoral access site, the medications used and the haemostasis technique [2, 5, 8-13]. Modification of these technique/procedure-related factors can reduce the likelihood that a patient will experience an IFAAC after a procedure. Non modifiable risk factors are patient-specific factors that may predispose to IFAACs and include advanced age, female gender, body mass index (BMI), arterial hypertension, severe atherosclerosis and tortuosity of the common femoral and/or iliac arteries, high division of the common femoral artery and renal dysfunction [2, 5, 8-13]. **Tables 2 and 3** summarise the aforementioned risk factors.

3.1 Clinical features and evaluation of iatrogenic femoral artery access complications

The diagnosis of vascular access site related complications is made on the basis of a combination of clinical and imaging findings [11-16]. A history of previous endo-

Table 2. Modifiable (procedure related) risk factors

Femoral access site	• *Sheath/catheter size:* Larger size >8 Fr predisposes to IFAACs • *Number of attempts:* Repeat or multiple punctures of the vessel increase the likelihood of complication • *Faulty puncture technique:* A high puncture above the inguinal ligament is associated with increased likelihood of intra-abdominal haemorrhage. A low puncture at SFA or DFA predisposes to pseudoaneurysm, local haematoma, and arteriovenous fistula formation. It must be clear that a retroperitoneal or abdominal wall haematoma can develop following arterial puncture below the inguinal ligament
Medications	• *Anticoagulant agents:* unfractionated heparin (UFH), low molecular weight heparin (LMWH), and direct thrombin inhibitors • *Anti platelet agents:* glycoprotein IIb/IIIa inhibitors, adenosine diphosphate inhibitors (clopidogrel and prasugrel), and aspirin • Correct knowledge of the mechanism of action of each medication, modification of the type and dosage of medications used before, during and after the procedure, and constant monitoring of the patients' reactions to the prescribed medication may reduce the likelihood of IFAACs
Haemostasis technique	• *Manual compression:* Remains the "gold standard" for obtaining haemostasis at the vascular access site and is achieved by compressing the femoral artery against the femoral head. It requires a significant amount of pressure over the access site for 15-20 min, along with bedrest, usually for 6 h afterwards. Brief manual compression <10 min, usually due to arm fatigue, may lead to in pseudoaneurysm formation. Lengthy compression may lead to in deep vein thrombosis • *Vascular closure devices:* A number of percutaneous closure devices have been developed (with sutures, collagen like plugs, and staples/clips). Despite initial enthusiasm, studies failed to demonstrate a reduction in IFAACs associated with the use of these devices. In cases of vascular closure device failure, manual compression must be applied to accomplish haemostasis.

vascular procedure (either diagnostic or therapeutic) increases the likelihood of a complication in the area. Patients experiencing IFAACs will present with a variety of clinical findings depending on the type of complication. A summarised view of the most common clinical features is presented in **Table 4**.

Imaging plays a vital role in the recognition of IFAACs and guides appropriate patient management [11-16]. Although history and clinical examination may identify the presence of complications, colour Doppler and duplex ultrasound can make the differential diagnosis between haematoma, pseudoaneurysm, arteriovenous fistula or other local complication [17]. If IFAACs are detected, further imaging work-up may be performed with computed tomographic angiography (CTA) or magnetic resonance angiography (MRA) [18-21]. CT angiography particularly has become a powerful tool for assessing the potential IFAACs and for planning further therapy in a fast, reliable, and noninvasive manner [18-21]. However, digital subtraction arteriography (DSA) remains a valuable tool for the final diagnosis of IFAACs and the majority of patients with clinical and imaging findings suggestive of a vascular complication should have a complete assessment *via* DSA when intervention is carried out [18-22].

4. Percutaneous treatment of iatrogenic femoral artery access complications

In the treatment of IFAACs, surgical procedures such as primary repair, surgical reconstruction with partial resection, ligation, and bypass surgery were frequently used options and are still in everyday use [20-25]. However, recent advances in endovascular techniques have

Table 3. Non-modifiable (patient related) risk factors

Advanced age	Advanced age (>70 yrs) is linked to increased incidence of IFAACs possibly due to local vascular changes (e.g. vessel tortuosity) or more advanced vascular disease (atherosclerosis and heavy arterial calcification)
Female gender	Compared to men, women have a greater risk for IFAACs possibly due to increased incidence of comorbidities present.
Body mass index (BMI)	Obesity may predispose to IFAACs due to technical difficulties during catheterisation. On the other hand, the risk of major bleeding was proven higher in underweight patients possibly because overweight patients are being screened more often and the arterial atheromatous disease is identified sooner
Arterial hypertension	Elevated blood pressure during percutaneous endovascular procedures and especially during sheath removal has been shown to increase the risk of IFAACs
Severe atherosclerosis and tortuosity of the common femoral and/or iliac arteries	Increase the likelihood of IFAACs due to difficulties during catheterisation and wire manipulation.
High division of the common femoral artery	Increase the likelihood of IFAACs due to difficulties during catheterisation
Renal dysfunction	Creatinine clearance <60 mL/min has been identified as a major risk factor for bleeding

created significant and effective alternatives to surgical therapy. This minimally invasive approach has a high success rate with low associated mortality and morbidity indexes, and avoids the complications related to open surgical approach [20-25]. In addition, micropuncture sets can be used for low profile safe femoral access, to minimise further the overall rate of access site complications (at a small additional direct cost) [20-25]. In the following sections we review the various percutaneous endovascular techniques that may be used to facilitate treatment of the most common IFAACs.

4.1 Haemorrhage

Bleeding complications related to the puncture site represent the most common vascular access site complication [1-7]. Small superficial haematomas resolve spontaneously with time and only conservative measures are needed such as application of local pressure to access site, prolonged bed rest, modification or interruption of anticoagulant and antiplatelet medication, patient hydration and serial monitoring of blood cell counts [8-13]. Significant local, abdominal wall or groin haematomas or uncontrollable retroperitoneal or intrapelvic bleeding that require either transfusion or invasive treatment occur in <1% of endovascular procedures [12-13]. If there are physical findings or clinical suspicion of uncontrollable bleeding, an abdominal-pelvic CT scan should be obtained immediately to confirm or rule out the diagnosis. CT angiographic protocols can be also applied if MDCT technology is available and assist in the detection of even minor leaks [18-19]. Diagnostic DSA and consequent endovascular therapeutic procedures of the complicated femoral access site could be carried out through a contralateral retrograde femoral approach, an ipsilateral or a transbrachial approach according to the individual patient and available resources [2, 4, 7, 18]. Covered stents (stent-grafts) represent the endovascular treatment of choice to cover the leak, although lifelong

Table 4. Femoral artery access site complications and clinical presentation

Local haematoma	• Visible swelling - ecchymosis and palpable hardening at the puncture site • Pain in the access site or groin area that can occur at rest or with mobilisation • May result in haemoglobin and blood pressure decrease and tachycardia *(observed in large, ucontrollable blood loss)*
Retroperitoneal haemorrhage	• Symptoms may be vague and not obvious • Back or ipsilateral flank pain • Abdominal pain-abdominal distention • No obvious swelling • Ecchymosis is a late sign • Haemoglobin and haematocrit decrease • Hypotension and tachycardia
Pseudoaneurysm	• Usually a visible haematoma is present • Local swelling, pain and ecchymosis • Pulsatile local mass • Audible-palpable bruit- thrill in the area • If large, may cause compression femoral neuropathy which is manifested with limb weakness • If ruptured, severe pain and hypovolemic signs present
Arteriovenous fistula	• Usually asymptomatic • Rarely a bruit and/or thrill at puncture site • Signs of arterial insufficiency and deep vein thrombosis in complicated cases • Congestive heart failure in severe cases
Arterial dissection/thrombosis/occlusion	• Manifested with the classic signs of limb ischaemia: pain, pulselessness, paralysis, paraesthesia, pallor
Nerve damage	• Manifested with signs of femoral neuropathy: pain and numbness at access site and leg weakness
Infection	• Manifested with the classic signs of local infection: tenderness, erythema, swelling and fever • In cases of abscess, pus formation or purulent discharge (*fistula*) at access site is detected • White blood cell count elevation

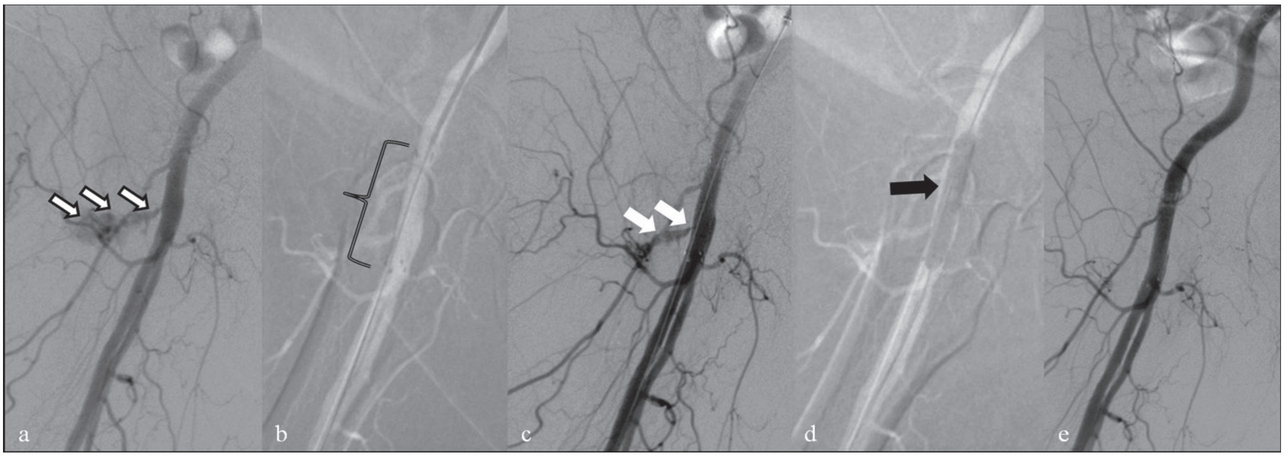

Fig. 1. *(a) Right CFA extravasation (black-white arrows) after catheterisation for coronary intervention in a female patient. (b) A 7x40 mm nitinol self-expandable stent-graft (noted with bracket) was deployed from the contralateral approach, and the persisting extravasation (noted with arrows in c) was postdilated with a 7x40 mm balloon (black arrow in d), offering a good result (e)*

antiplatelet therapy might be required. A brief description of the crossover technique, which is one of the most common procedures in the treatment of IFAACs, is presented herein. Following local anaesthesia with lidocaine 1 %, the contralateral CFA is punctured with an 18-G hollow needle (modified Seldinger technique). A standard 0.035" J-typed Teflon-coated guide-wire is inserted into the arterial lumen, and a 6-Fr sheath is introduced. First, a pelvic angiogram through a pigtail catheter at the level of aortic bifurcation should be obtained and usually demonstrates the site of extravasation. The J-typed Teflon-coated guide-wire is exchanged to a 0.035" angled soft hydrophilic wire (*Terumo*) and over the 0.035" guide-wire a catheter is inserted to engage the contralateral common iliac artery. A 5-Fr Cobra 1 type catheter is used in the majority of such cases; if the angulation of the aortic bifurcation is very steep, a Simmons 1 or similar type catheter is preferred. A second elective arteriogram is obtained to verify the leak. The Cobra catheter is advanced and the wire is exchanged to a 0.035" 180 cm long Amplatz stiff type guide-wire. The Cobra catheter is removed and the standard 6-Fr, 11 cm sheath is exchanged for a long, 30-45 cm, 6-Fr, straight-tip sheath. A stent-graft is subsequently advanced and deployed under fluoroscopic guidance, preferably sheathlessly, in order to cover the leaking point. After deployment, the 6-Fr, 30-45 cm sheath is reintroduced, to seal the artery and perform contrast injections. Heparin (3,000-5,000 IU) should be administered intra-arterially through the sheath in all cases of stent deployment to prevent thrombosis. Attention should be paid to the stent-graft diameter and length. Adequate proximal and distal landing zones should be verified and usually a stent-graft diameter 1 mm larger than the vessel diameter is needed, to ensure correct anchorage and minimise the risk of migration. In cases of perforation of a calcified artery, a 2-mm-oversized self-expanding stent-graft may be needed to achieve effective seal of the leakage. In addition, in such cases gentle balloon dilation inside the stent-graft may be required. In all cases, attention should be paid so that the stent-graft does not extend above the CFA bifurcation, and the origins of the DFA (deep femoral artery) and SFA (superior femoral artery) are not compromised for future use in surgical procedures. A completion angiogram is finally performed to confirm successful cessation of active extravasation and verify maintained patency of the lower extremity arteries. Regarding stent-graft selection, self-expandable stent-grafts, especially polytetrafluoroethylene-covered nitinol stents, should be preferred in superficial areas like the groin, because they show increased resistance to external compression and bending stress compared to stainless-steel balloon-expandable stent-grafts [2-4, 23]. An important issue in stent-graft implantation is the predilection of the right size in order to reduce the risk of inadvertent closure of vital arterial side branches.

In the less frequent occasion of bleeding originating from small arterial branches, a stent graft cannot be deployed and in such cases coil embolisation is the endovascular treatment of choice [24-25]. These small arte-

Fig. 2. *(a) Large pseudoaneurysm (black-white arrows) of the right SFA complicating a cardiac catheterisation in a female patient. Notice the high bifurcation of the right CFA. (b - c) The lesion was treated with the use of a 6x40 mm self-expandable nitinol stent-graft (noted with bracket) introduced from a contralateral approach with an excellent result*

rial leakages can initially go undetected; however they typically evolve to lifethreatening retroperitoneal or intraabdominal haemorrhage [24-25]. Despite initial identification of contrast extravasation on CTA, the exact anatomical site can only be localised with superselective DSA. The application of microcatheters facilitates safe entry even in very distal vessels in order to perform safely coil embolisation without inadvertent closure of healthy neighbouring arterial side branches. An example is presented in **Fig. 1**.

4.2 Pseudoaneurysms

The reported incidence of femoral postcatheterisation pseudoaneurysms (PAs) ranges from 0.2% to 8% [26-32]. The lowest incidence is observed in diagnostic procedures and the highest incidence is seen after coronary angioplasty and stenting. Duplex ultrasound (US) is considered the method of choice to diagnose a PA [26-32]. In addition, US can provide valuable haemodynamic information through waveform analysis. The actual PA size, the presence of blood flow or internal thrombus inside the PA, the anatomic characteristics of the neck of the PA, and the presence of multiple PA lobules are valuable PA characteristics evaluated with US [26-32]. US can also be used as a guidance modality for the treatment of PAs and to assess the outcome of treatment by monitoring patients during follow-up. For pseudoaneurysms that are challenging to evaluate with US, CTA is a more reasonable imaging solution than DSA and although catheter angiography can also be used to diagnose a PA, due to its invasiveness is only used during the endovascular intervention [26-32].

US-guided PA compression remains a reliable method of treatment of small superficial PAs [26-32]. However US-guided compression is time consuming, stressful for the patient, and also very painful that even sedation may be required, so nowadays most interventionists prefer the far more fast, comfortable and efficient technique of US-guided thrombin injection [26-32]. Several studies have shown high therapeutic efficacy of this method with an overall thrombosis rate up to 100% [26-31]. Regarding

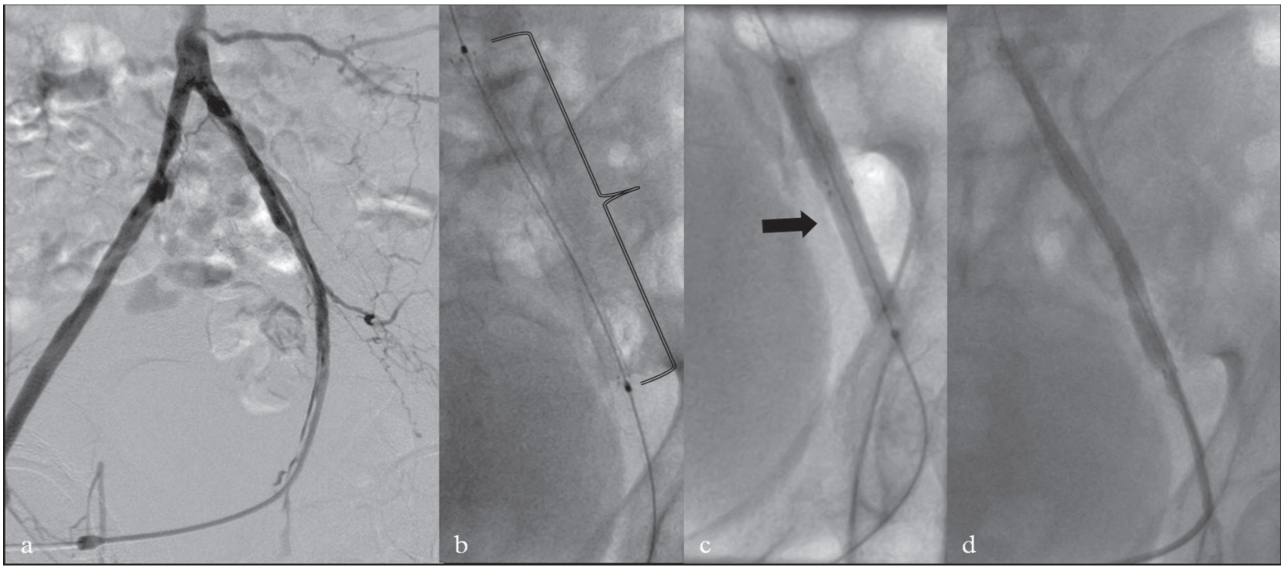

Fig. 3. *(a) Iatrogenic extensive dissection of the left EIA in a male patient, treated with a 7x100 mm nitinol self-expandable stent (noted with bracket in b), post-dilated with a 6x60 mm balloon (arrow in c), giving an excellent final result (d)*

technical considerations, it is of paramount importance first to confirm that the needle is placed into the center of the PA sac to avoid accidental injection into the artery [26-31]. For that, constant thrombin delivering in small doses under continuous US guidance is preferred instead of a single large volume thrombin injection. In the vast majority of cases a thrombin dose of 500-1,000 IU is usually adequate. In complicated multilobular PAs, multiple injections and thrombosis of all lobules is most frequently required to achieve successful treatment. Concerning the type of thrombin used there are three options, with more interventionists favouring the use of autologous thrombin or human thrombin instead of bovine thrombin, because the later has the potential of allergic reactions, although rare cases of severe allergy to human thrombin have been also reported [26-32]. Finally, the aforementioned US-guided thrombin injection method can be assisted with endovascular balloon inflation in cases of wide PA neck communication with the native artery [2, 26-31]. This method prevents involuntary thrombin leakage into the arterial circulation. Through contralateral femoral approach, a balloon catheter matching to the vessel size is advanced over the aortic bifurcation and placed across the wide PA neck. Under US guidance a 19- to 22-G needle is inserted percutaneously into the PA and the balloon is then inflated. Thrombin is injected only after US verifies no flow inside the PA sac. The balloon is usually kept inflated for about 10-15 min after the injection and after deflation PA thrombosis is confirmed both angiographically and ultrasonographically. However, there are no reported benefits from this combined method compared with US guided injection alone and all studies have shown that thrombin injection is a fast and safe method even in cases of PAs with wide neck communication [2, 26-31]. Another useful technique which recently appeared in the literature is occlusion of the PA neck using para-aneurysmal saline injections combined with US guided compression [32].

Covered stents can be a reliable, minimally invasive option for PAs that are not suitable/or in which US-guided thrombin injection has failed, as well as in complicated cases in which PA is accompanying an AVF [33-36]. Endovascular management with stent-grafts aims to exclude a PA from the circulation. This approach is particularly useful in high-risk patients and provides a good alternative to open surgical repair. It could be an excellent therapeutic option for the treatment of PAs arising from the deep femoral artery (DFA), thus avoiding open surgical reconstruction which puts in danger the patency of the DFA. Furthermore, short length stent-grafts can effectively treat PAs arising from the SFA without extension to the CFA, which may be used as the access site for future catheterisations. Regarding stent-graft application, appropriate patient selection is of paramount importance [33-36]. Younger patients with a long life expectancy should not be treated with covered stents since long term results of their patency remain suboptimal and surgery is usually preferred in

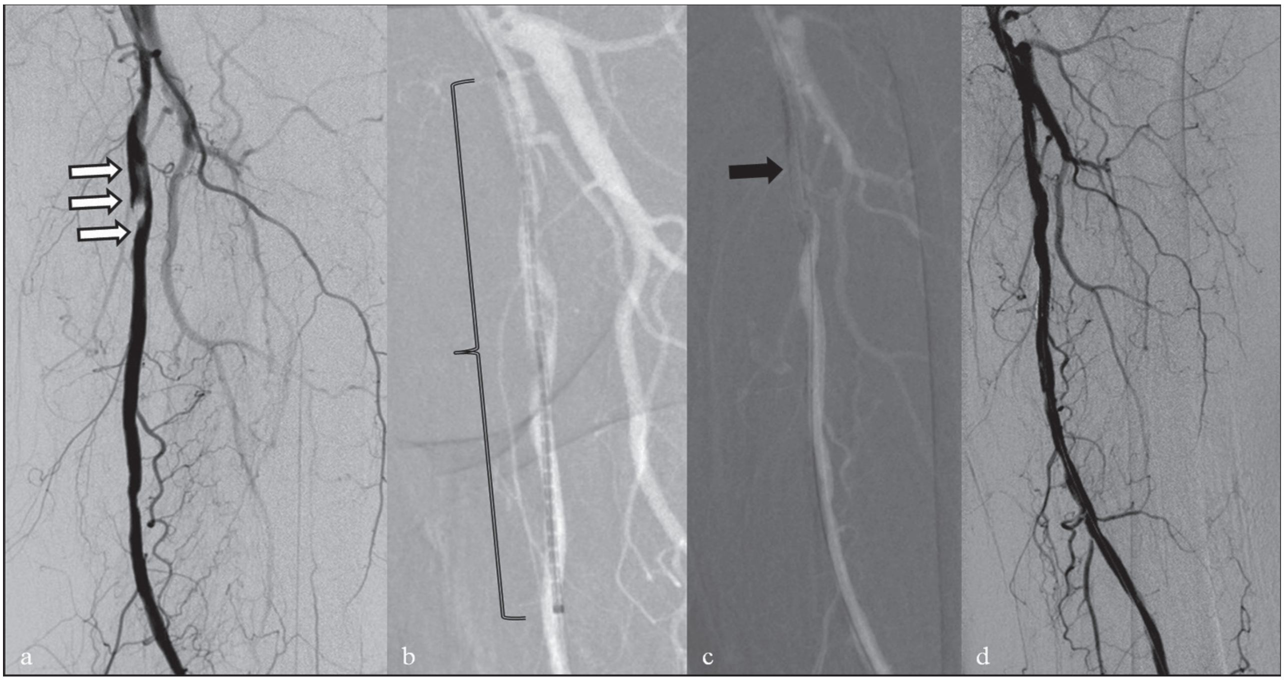

Fig. 4. *(a) Male patient with an iatrogenic left SFA dissection (black-white arrows) during attempted antegrade access, treated with a 6x100 mm self-expandable nitinol stent deployment (noted with bracket in b) using an ipsilateral popliteal approach, postdilated with a 5x40 mm balloon (black arrow in c), to a good final result (d)*

such cases. Studies have shown that late-onset in-stent endothelisation develops which triggers a thrombogenic reaction and compromises stent-graft patency resulting in in-stent thrombosis and occlusion [2, 33-36]. Other limitations of stent-grafts that preclude their routine use in the treatment of PAs are: High cost of the material, anatomic difficulties (iliac vessel tortuosity and/or heavy calcification) that preclude stent deployment through the crossover technique, potential kinking and stent-graft fracture at the level of inguinal crease and partial coverage of CFA which potentially can compromise its use for future percutaneous and open surgical vascular procedures. An example is shown in **Fig. 2 .**

4.3 Treatment of Arterio-Venous Fistulas

Iatrogenic arterio-venous fistulas (AVFs) result from the development of direct communication between an artery and a vein and are usually associated with a faulty puncture technique or after multiple attempts to catheterise [2]. Impaired clotting is another contributing risk factor for the development of iatrogenic AVFs. The incidence of this complication is <1% and is usually asymptomatic. Therefore, in the majority of patients who develop postcatheterisation AVFs an invasive treatment is not needed, since usually no haemodynamic significant clinical signs develop during follow-up [2, 5]. Nevertheless, in long-standing AVFs severe complications may arise. These are the result of arterial steal and abnormal venous return and can lead to high-output congestive cardiac failure, aneurysmal dilatation-degeneration of the involved artery and limb ischaemia [33-36]. Limb ischaemia and skin ulcerations may occur due to the blood steal through the fistula and the accompanying venous hypertension. Bacterial endocarditis has also been reported as a result of abnormal venous drainage [33-36]. In symptomatic patients, initial conservative measures can be applied such as prolonged bandaging and US-guided compression [33-36]. Their effectiveness however is limited by the fact that these patients are all on anticoagulant and antiplatelet medications for their coronary artery disease and clotting is compromised. In addition, the fistula track may be too short or too large to be compressed successfully by the transducer.

Given the significant improvement in stent technology, covered stent implantation for traumatic AVFs has become a quite popular endovascular method of treatment [2, 5, 33-36]. The usage of covered stents for AVFs treatment is technically easy with reported high technical success rate and a low complication rate. In the vast majority of cases, postcatheterisation AVFs originate from either the DFA or the SFA in locations that are far enough from the hip joint and thus stent grafts can be inserted without the fear of stent deformation, kinking and fracture [2]. Roadmap guidance and multiple angiographic projections prior to balloon inflation can be useful for precise stent-graft placement. The newer self-expandable nitinol stent-grafts can be delivered more easily than the balloon-expandable ones at the site of the AVF [2, 33-36]. Another endovascular treatment method which has been described is embolisation with metallic coils or N-butyl-cyanoacrylate, however there is insufficient data from the literature [2, 33-36]. In addition a limitation of the embolisation method is that it is applicable only if there is sufficient length of the connecting channel-fistula neck of the AVF to secure the coil and glue without the risk of migration [2, 33-36].

4.4 Treatment of arterial occlusion

The incidence of intimal arterial dissection or thrombosis post femoral catheterisation has been reported to occur in <0.5% of cases [37-38]. Apart from the fact that it can potentially become limb-threatening, it can also seriously affect cardiac rehabilitation programs in patients with coronary disease since it limits walking exercise [37-38]. In the majority of patients subintimal passage of the guide-wire or catheter is immediately recognised during the procedure and the procedure is postponed or another arterial access is selected. Nonetheless, it is not unusual for arterial dissection and thrombosis to become evident only after completion of the endovascular procedure, because the guide-wire very often follows a subintimal route with subsequent re-entry to the true lumen [1-7]. Endovascular treatment of catheter-induced obstructive arterial dissections of the CFA with prolonged inflation of a standard angioplasty balloon of appropriate diameter has been proven efficient and results in successful apposition of the intima and underlying media layers and restores normal arterial flow [1-2, 37-38]. However, in more extensive dissections involving the EIA, self-expandable bare stent deployment is essential to restore long-term vessel patency. A useful technique for avoiding stenting of the CFA is the combination of stenting above the level of inguinal ligament and prolonged balloon inflation at the CFA level [1-2, 37-38]. If the stent must extend at least to the proximal CFA then a flexible self-expandable stent with nitinol endoskeleton must be selected. This new generation of stents has shown excellent performance at the flexible hip joint, without evidence of kinking-fracture and at the same time allows future percutaneous femoral access of the distal uncovered part of the CFA.

Catheter-directed thrombolysis is another endovascular, revascularisation method in acute iatrogenic ilio-femoral thromboses, although there are no large cohort studies in the literature supporting its widespread use [37-38]. The most commonly used intra-arterial thrombolytic agents are recombinant tissue plasminogen activator (rt-PA) and urokinase, often in conjunction with catheter suction and thromboaspiration [37-38]. Although there are no differences regarding safety or efficacy between rt-PA and urokinase, rt-PA tends to show a more rapid rate of thrombolysis during the first hours of action. An additional advantage of rt-PA is that it is associated with fewer side effects of nausea and vomiting compared to urokinase [37-38]. Following successful thrombolysis, additional prolonged balloon angioplasty is almost always necessary as a complementary procedure. In addition, literature data have shown that in approximately half of cases self-expandable stents should be deployed in order to maintain vessel patency. Illustrated cases are presented in **Fig. 3** and **4.**

4.5 Treatment of complications related to vascular closure devices

Percutaneous vascular closure devices (VCDs) offer a comparable alternative to manual and mechanical compression for achieving haemostasis after endovascular procedures [39-44]. The development and use of VCDs is widespread and is becoming more common since they have been demonstrated to reduce time to haemostasis, facilitate early ambulation, and potentially decrease length of hospital stay. Interventionists performing endovascular procedures should be aware of their indications, any risks associated with their use, as well as the advantages and disadvantages of the various commercially available devices, and any complications that may occur [39-44]. In current practice, literature reports show that VCD failure is rare, but when it happens, it is associated with a significant increase in the risk of vascular complications. For this reason, patients following placement of a closure device should be closely supervised at initial mobilisation from bedrest and in patients with a known VCD failure additional careful monitoring and close follow up is mandatory [39-44].

VCDs can be classified into three main categories: Collagen based, suture based, and staples or clips [39-44]. Suture and collagen plug based VCDs have an intravascular component, which carries the risk for arterial stenosis or occlusion. In such cases, balloon angioplasty alone or in combination with stenting is needed to restore patency. Small case series and scarce case reports describe the application of more complex endovascular procedures for the treatment of VCDs complications [39-44] such as the combination of excimer laser angioplasty and balloon dilatation or the use of the Silverhawk plaque excision system [39-44]. Alternatively, stent-graft deployment can also be considered a reliable solution in VCDs failure and complication. Even with the latest generation of nitinol clip based VCDs, complications have been described ranging from nitinol-clip-induced luminal narrowing and thrombosis to nitinol-clip-induced vessel wall laceration that usually require surgical therapy [43-45].

4.6 Surgical options & comparison of endovascular to surgical treatments

Vascular surgeons can successfully manage the complications following catheter-based diagnostic and interventional procedures through a variety of surgical repair techniques [1-7]. In the treatment of IFAACs, surgical procedures such as partial resection, ligation, and primary repair or bypass surgery are frequently used options [20-24]. In certain situations such as after closure devices' failure, in local infection with abscess formation or in rare cases of PAs which are rapidly expanding, show continuous bleeding or in fit young patients with a long life expectancy surgical treatment may be considered the first line therapeutic option [39-45]. The success rate of surgical reconstructions in iatrogenic femoral access lesions has been reported near 100%, but on the other hand open surgery is associated with an increased postoperative morbidity index of up to 25% and an increased postoperative mortality of up to 3.5% as a result of the significant comorbidities present in this group of cardiovascular patients [1-7, 19-27]. Open surgery is performed under general or locoregional anaesthesia, contrary to local anaesthesia used in endovascular treatments and this increases the periprocedural stress load in patients. Additional relative disadvantages of surgical options are the local tissue injury and loss which predisposes to poor wound healing and increase the likelihood of postoperative infections, especially if synthetic reconstruction grafts are used [1-8, 22-25]. Most of these operations are also associated with significant blood loss, in comparison to endovascular procedures. In cases of retroperitoneal or intrabdominal haemorrhage the vascular surgeon is required to perform extensive and meticulous exploration to find and ligate the extravasating vessel, and this time-consuming task is potentially hazardous in patients who are affected by advanced cardiovascular disease and are in unstable condition [1-11]. All these factors mentioned above lead to prolonged hospitalisation of the affected patients and increased mortality and morbidity. For these reasons endovascular treatment has gained popularity as a therapeutic alternative to open surgery, but needless to say both methods are effective and close collaboration between the cardiologist, the vascular surgeon and the interventional radiologist is imperative for appropriate patient management.

5. Summary

In summary, complications related to percutaneous femoral artery access for transcatheter procedures represent a growing health problem, as cardiac or peripheral endovascular arterial interventions are commonly preferred than open vascular procedures. There has been an increasing interest in intensifying careful patient selection and pre-intervention measurements to reduce these adverse events and to define practice principles that generally should assist in producing high quality medical care. Percutaneous treatment of artery access site complications is considered nowadays the treatment of choice. They are performed under local anaesthesia, are better tolerated by the patient, and are associated with a shorter hospitalisation time, compared to open surgery. Advancements in nitinol stent technology allow for safe stent and stent-graft deployment in a majority of IFAACs. Bleeding complications can be insidious and life threatening and prompt sealing of arterial leakage with stent-grafts or embolisation. Percutaneous US-guided thrombin injection is the treatment of choice for femoral pseudoaneurysms. In large arterial defects or accompanying arteriovenous fistula, stent-grafts can be deployed. Arterial dissections can be treated with balloon angioplasty alone or in more extensive dissections involving the iliac arteries, by deployment of self expandable stents. Catheter-directed thrombolysis assisted by subsequent prolonged balloon inflation or stent placement is able to treat effectively acute arterial thromboses. Finally, several complications related to percutaneous closure devices could also be managed endovascularly. Several patient and procedural variables independently predict IFAACs and risk assessment for the potential development of a complication with knowledge of the endovascular means of treatment could facilitate the appropriate selection of therapy to improve post-intervention outcomes. **R**

Conflict of interest:
The authors declared no conflicts of interest.

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