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VASC ENDOVASCULAR SURG 2012 46: 617 originally published online 11 September 2012

DOI: 10.1177/1538574412457475

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Vascular and Endovascular Surgery
46(8) 617-623
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DOI: 10.1177/1538574412457475
http://ves.sagepub.com


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Abstract

Percutaneous-based procedures continue to increase as endovascular techniques improve and provide a less morbid approach than the open vascular procedures. The most common complications associated with either cardiac interventions or peripheral interventions involve the access point of the procedure. The retrograde femoral access has and is currently the most frequently used arterial access. Vascular surgeons have been responsible for management of complications following femoral-based procedures and now are a significant contributor to catheter-based diagnostic and interventional procedures. This review provides in-depth review of the literature on specific complications encountered during percutaneous femoral artery puncture. This review includes access complications related to the method of obtaining access (ie, best pulse fluoroscopic guided), direction of access either retrograde or antegrade, risk factors and incidence of complications based on best literature sources, and management strategies for specific complications.

Keywords

femoral artery, complications, management

Anatomy

The femoral artery is grossly located one-half the distance from the anterior superior iliac spine to the symphysis pubis. Just medial to the femoral artery lays the femoral vein, with the femoral nerve found lateral to the femoral artery. At the inguinal ligament, the femoral artery has branches that arise both medially and laterally as the inferior epigastric and lateral circumflex iliac arteries.

In the groin the common femoral artery divides into the femoral artery ultimately becoming the popliteal artery and the adductor canal, and the deep femoral artery (profunda femoris) typically a more lateral branch supplying branches to the thigh muscles and the collateral circulation to the popliteal artery. Successful compression of the femoral artery relies on a solid posterior surface to provide an apposing force to manual pressure. This solid surface is the head of the femur. In >90% of patients the femoral artery crosses over the femoral head with 99% of the bifurcation occurring below the midfemoral head (deep and femoral arteries).¹

Risk Factors for Complications

Patient-specific factors which have been associated with complications include female gender, extremes in body habitus (high or low body mass indices [BMIs]), previous access or bypass procedures, and high bifurcation of femoral artery. Factors related to surgical or procedural technique include left versus right groin, method of puncture (landmark vs fluoroscopic

vs ultrasound guided), site of arterial entry, size of sheath introduced, intra-/postprocedural anticoagulation, and use of closure devices.²⁻⁴

Thresholds for complications and reporting standards for complications are difficult to find during a literature search. The Society of Interventional Radiology in 2003 reported on Quality improvement Guidelines for Diagnostic Arteriography. Puncture site complications that qualified as a major adverse event threshold included the following: hematoma (requiring transfusion, surgery, or delayed discharge) 0.5%, site occlusion 0.2%, and pseudoaneurysm/arteriovenous fistula(AVF) 0.2%.⁵ The American college of cardiology benchmark for the incidence of *all* cardiac catheterization complications is <1% for diagnostic and 3% for interventional procedures.⁶ A thorough review could not define acceptable rates of access-related complications. Although they have published multiple guidelines, the society for vascular surgery has no specific guidelines or acceptable reporting standards.

The definition of major or minor access complication varies with nearly all articles published on the topic. Doyle et al reviewed the Mayo Clinic experience from 1994 to 2005 to assess the incidence, predictors, and impact on survival among

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patients with major femoral bleeding complications. Their definition included the following: hematoma >4 cm in diameter, which required blood transfusion, surgery or prolonged hospital stay, or femoral bleed requiring transfusion within 7 days of percutaneous coronary intervention (PCI) or retroperitoneal bleed confirmed with ultrasound or computed tomography.²

Understanding predictors of access-related complications is important in prevention by identifying high-risk populations. Angiographic predictors of femoral access complications include the “high-stick” penalty associated with retroperitoneal hemorrhage. Arteriotomy location above the most inferior border of the inferior epigastric artery in patients undergoing PCI was associated with 100% of all retroperitoneal bleeds.⁵ The location of femoral artery access and correlation of vascular complications as described by Pitta et al⁴ demonstrated a significant increase in the number of access complications, that is 18% versus 4% of those not within the confines of the inferior border of the inferior epigastric artery and the femoral bifurcation.⁶

Puncture Technique

Three techniques of femoral artery access are reported, with limited studies comparing the different methods including best pulse, fluoroscopy-guided access, and ultrasound directed. Fitts et al in a study of more than 2000 patients recommended fluoroscopy-guided femoral artery access instead of the landmark best pulse technique to reduce local complications, that is 1.9% versus 0.7%.⁷ In contrast to the results of this large non-randomized study, 3 randomized trials failed to show a statistical significant reduction in the number of access-related complications by using fluoroscopy to assist the puncture of femoral artery compared to puncture of the femoral artery by best pulse technique.⁸⁻¹⁰

Two prospective randomized studies have reported on access complications comparing to either “best pulse” or fluoroscopy-guided access to ultrasound-guided access by Duduck¹¹ and Seto,¹² respectively. The first study was a small randomized trial of 112 patients, which found no statistical difference in access complications but did show a statistically significant increase in time to access in ultrasound-assisted patients with a “good pulse” of 226 versus 161 seconds. The FAUST study enrolled (1004) patients who were randomized to either fluoroscopy-guided femoral access or ultrasound-guided access demonstrated the following statistically significant benefits of ultrasound-guided femoral artery access compared to a fluoroscopy-guided technique.

- more frequent common femoral artery punctures when the common femoral bifurcation occurred over the femoral head;
- increased first pass success;
- reduced mean time to access;
- reduced number of venipunctures; and
- reduced number of access complications.

Limitations to the study included exclusion of patients with nonpalpable pulses. This group may provide the largest benefit to ultrasound-guided puncture. Additionally, the statistical significant difference in access complications was only secondary to the number of hematomas exceeding 5 cm. There were no differences in dissections, AVF, or pseudoaneurysm formation noted between the 2 groups.

Some physicians prefer to initially access with a micro puncture needle instead of a 19-gauge arterial needle. The theoretical benefit of the micropuncture needle include a smaller diameter puncture if accidental venipuncture occurs or if the needle has to be removed if there is an unsuccessful attempt to pass the wire. However, in cases of successful access a larger sheath is inserted and complication rates will occur with the final sheath size. However, no prospective or randomized studies are available to provide data for comparison. It is our group’s preference to currently use fluoroscopic guidance in patients with normal BMI, and either Doppler needle or ultrasound for patients with large BMI or distorted landmarks based on body habitus. Limited information has been specifically written about the use of Doppler needles to obtain femoral artery access. In 1 small series however the number of large hematomas was reduced by using a “smart needle.”¹³

Puncture Direction (Retrograde Versus Antegrade)

The most common direction of puncture in most practices is the retrograde femoral artery approach. For infrainguinal interventions, especially tibial artery interventions, there are some advantages of using an ipsilateral antegrade technique. This approach can allow improved pushability of devices and shorten the working length dramatically. Antegrade puncture is no doubt more technically challenging by landmark techniques compared to retrograde femoral access. Other instances that make retrograde and up and over catheterizations more technically challenging or unfeasible include previous aortofemoral bypass, previous modular stent grafts not positioned on the aortic bifurcation, previous iliac stents with raised aortic bifurcation, and so on. It has been proposed that 60 cases are the learning curve threshold for this approach, with local complications declining substantially after this volume of cases has been achieved.¹⁴ Local complications have been reported to occur more frequently with antegrade punctures. Wheatley et al reviewed 745 antegrade femoral artery punctures compared to over 5000 retrograde access procedures and found nearly double the number of access site complications (5.9%) versus (3.2%) with an antegrade approach. Also, there was a statistically significant incidence of hematomas requiring transfusion in the patients who had an antegrade approach.¹⁵ Potentially ultrasound-guided antegrade femoral access could reduce the frequency of complications with this particular access approach. One study evaluated ultrasound-guided access with sheath insertion in either the common femoral or the superficial femoral artery (SFA) to compare the local complication rates. A statistical significant benefit was seen favoring puncture of the SFA with respect to speed of achieving access, the radiation

exposure, and hematoma incidence, however the frequency of pseudoaneurysms was statistically higher with access of the superficial femoral artery.¹⁶ Potentially the use of vascular closure devices could reduce local access complications since complications appear more frequent than with retrograde femoral access. Duda et al reported the results of suture-mediated closure of antegrade access in 80 patients with either the Techstar and Prostar Plus devices (Perclose, Menlo Park, California), with 96% achieving successful stand alone hemostasis despite full anticoagulation. Crossover to manual compression was required in 2 patients with only one major complications of retroperitoneal bleeding. Five minor local complications occurred without the need of further intervention.¹⁷ Angioseal hemostatic closure device (St Jude Medical, St Paul, Minnesota) has been evaluated in several retrospective reviews with the largest in the literature by Lupattelli et al. In their cohort of 1889 patients hemostasis success was the same as that of 278 cases performed via a retrograde fashion at 97%. In this diabetic patient series the overall complication rate after antegrade puncture closure was not statistically different from that with retrograde closure or manual compression.¹⁸

In a smaller series evaluating the angioseal for antegrade use, factors that contributed to device failure were analyzed including coagulation parameters, body habitus, and vessel calcification. Only larger BMI was associated with failure of the angioseal device.¹⁹

Complications

The reported incidence of access site complications varies significantly in the literature. Most large series have significant limitations that are typical of retrospective reviews. Additionally the routine use of ultrasound following percutaneous procedures provides a more accurate assessment of the incidence access-related complications. The 5 most common complications include groin hematoma, pseudoaneurysms, AVF, retroperitoneal hemorrhage, vessel occlusion, and branch injury. Hirano et al evaluated 557 consecutive patients with ultrasonography to determine the incidence of AVF and pseudoaneurysms. The frequency of occurrence was 2.2% and 2.9%, respectively, with approximately one-half patients suspected of having a complication.²⁰

In a more recent series of 319 patients, the incidence of pseudoaneurysms was 5.3%, AVF 0.6%, and femoral artery dissection of 1.6%. Patients with complications were more likely to have had an intervention rather than a diagnostic procedure and concomitant administration of antiplatelet and anticoagulation medications compared to those without complications. Also statistically more frequently patients with access complications had hemodynamic disturbances during manual compression.²¹

An additional confounding rate on access complications concerns the use of either standard compression or vascular closure devices. Dangas et al reported a significant difference in complications seen with closure devices compared to manual compression. This included a review of over 5000 patients with

approximately 500 closure devices deployed. No difference was reported with the incidence of pseudoaneurysms or AVF, but there was statistical increase in major hematomas (hematocrit drop of 15%) and twice as many surgical access repairs.²²

Retroperitoneal Bleed

Hemorrhage into the retroperitoneal space (RPH) is the most life-threatening complication seen with femoral-based access. Large volumes of blood can be contained within the retroperitoneal space prior to the development of hypotension. The occurrence of this complication varies upon the study sample size, but in larger series it was 0.1% to 0.7%.²³⁻²⁵ These series samples ranged from 26 to 163 cases. The largest series reported three-fourth of patients received blood transfusions and 10% mortality. Predictors of development of a retroperitoneal bleed included low body weight, Angioseal device use, sheath placement above the inferior epigastric artery, women, use of IIb/IIIa inhibitors, and presentation of acute myocardial infarction.²⁶ Other factors that have been reported as increased risk of RPH include left femoral puncture and larger sheath size. A large series of over 100 000 patients reported bivalirudin use associated with a lower risk of RPH.²⁷ Signs and symptoms include suprainguinal tenderness and fullness, severe back and lower quadrant pain, and femoral neuropathy in up to one-third of patients. Typical presentation is within 3 hours of the catheterization procedure but may occur after 3 hours in up to one-fourth of cases.²³⁻²⁵ Imaging to access RPH should be performed with computed tomography, with and without contrast, which can identify active extravasation in patients to assess persistent hemorrhage. Kent et al reported 16% of patients requiring operative repair with a mean of 4 units of blood transfused.²⁴ The development of RPH is also associated with a higher frequency of postprocedure myocardial infarction, infection, and heart failure with in-hospital mortality of 6.6%.²⁷ Intervention should be performed on patients with refractory hypotension or on patients with an active "blush" on computed tomography. Either surgical repair or endovascular exclusion with a covered stent can be performed. Secondary to this highly morbid complication, routine femoral arteriography should be performed. Some authors suggest evaluation of sheath location prior to intervention to limit access defect and aborting planned procedure. Our group routinely evaluates access at the cessation of the procedure to evaluate for potential vascular closure device use and to assess location of sheath prior to removal. High sticks can then be assessed for potential endovascular techniques by either off-label use of percutaneous suture devices and close observation or contralateral access and sheath removal with balloon occlusion and subsequent covered stent placement.²⁸ Operative repair is classically described as retroperitoneal incision for proximal control but may be performed by groin incision and controlled by dividing or retracting the inguinal ligament and direct arterial repair by experienced surgeons.

Branch Perforation: Inferior Epigastric Artery Injury/Circumflex Iliac Artery

Few case reports are found in the literature involving injury to the inferior epigastric artery specifically; however, this is a known cause of retroperitoneal hemorrhage. This can occur when attempting to puncture the femoral artery either by laceration of the branch or by guide wire perforation during cannulation. Several techniques have been described to manage extravasations from these branches. Silva et al described a balloon tamponade technique with simultaneous injection and selective catheterization into the inferior epigastric artery.²⁹ Our group previously described an ipsilateral technique for embolization of the inferior epigastric artery. This involves placement of a 7Fr sheath into the ipsilateral common femoral artery and a safety 0.035" wire retrograde into the abdominal aorta, then placing a diagnostic catheter into the origin of the inferior epigastric artery so that embolization can be performed. The safety wire allows the sheath to be reinserted into the artery if sheath access is lost.³⁰

Occlusion/Dissections

Femoral artery occlusion is nearly nonexistent without the use of femoral artery closure devices. In 100 consecutive patients undergoing percutaneous suture-mediated closure, no major complications occurred in a manual compression cohort but 3 major complications occurred with the suture-mediated device including 2 dissections and 1 common femoral occlusion of which all occurred in women undergoing uterine artery embolization.³¹

Pseudoaneurysms

Iatrogenic femoral pseudoaneurysms (FPAs) occur in approximately 2% of cases following percutaneous-based procedures. The incidence has been reported as high as 8% in a series prospectively evaluating 273 patients postcatheterization. Pulsatile groin mass on physical examination had both a 100% positive and negative predictive value for the detection of pseudoaneurysm.³²

Pseudoaneurysms result from insufficient sealing of the arterial puncture site, resulting in bleeding into the groin, resulting in the formation of hematoma and a pseudo wall. Arterial punctures below the femoral bifurcation are more prone to false aneurysms secondary to the lack of posterior compression by the femur as opposed to a common femoral puncture. Risk factors for the development include larger BMI, $\geq 28 \text{ kg/m}^2$, larger number of cases performed per day in a particular room, larger sheath sizes, and preprocedural platelet count $< 200 \times 10^9 \text{ L}^{-1}$.³³

The side of access can also affect the risk of pseudoaneurysm. Popovic et al found a left groin puncture to be associated with an increased risk of FPA.³⁴

Physical examination findings often include groin hematoma and associated pain at the puncture site, occasionally a bruit can be detected with auscultation. Ultrasound is the mainstay in making the diagnosis of this postcatheterization

complication. Typical findings include an echolucent mass with flow detected by Doppler with a classic "to and fro" flow. Details of ultrasound include the maximum sac size, the amount of flow within the sac, number of sacs, the length and diameter of neck, and the origin of pseudoaneurysm that is profunda, common femoral.

Treatment should be considered in larger pseudoaneurysm that is those $\geq 3 \text{ cm}$ or in those who have poor compliance with serial duplex examinations. Complications related to FPA include rupture, local pain secondary to compression symptoms, and rarely distal embolization. Our experience as well as most other series includes a benign course with observation of small FPA. Toursarkissian in 1997 reported the outcomes of 196 pseudoaneurysms which were selectively treated including a size threshold of 3 cm. During follow-up at a mean of 23 days, 89% had spontaneous thromboses.³⁵

Historically, ultrasound-guided compression was the initial treatment modality. Ultrasound-guided compression is now rarely used secondary to low success rates in treatment of large pseudoaneurysms, which are the cases that most need treatment. Also, the procedure takes a long time for successful thrombosis of pseudoaneurysm and the procedure is very painful for the patient. Only 2 small prospective randomized trials have been performed to date comparing different treatments for postcatheterization pseudoaneurysms. Compression versus ultrasound-guided compression was compared with $>98\%$ success in both arms. Unfortunately this study did not report aneurysm sac size. Such a high success rate makes one speculate these were small aneurysms that were easily treated or required no treatment. This trial enrolled 84 patients in each arm.³⁶

The only prospective randomized trial comparing ultrasound-guided compression with duplex-guided thrombin injection exists to date. This series had a meager 15 patients in each arm. With 100% success with thrombin injection and an unsatisfactory 40% success in the ultrasound-guided compression arm with several patients requiring multiple compression settings to achieve this low success rate. This is in stark contrast to the compression trial listed above with $>98\%$ success with ultrasound or manual compression.³⁷ Other studies reportedly performed in a prospective manner includes Schneider et al which appears to be the largest series published with 274 patients and a 97% primary success rate and unaffected by the use of postprocedural anticoagulation medications.³⁸ Olson et al demonstrated in his prospective series similar initial success rates in 33 treated FPA with a 6% recurrence rate; in addition, one-half of the patients were treated on an outpatient basis.³⁹

We currently use as most other centers ultrasound-guided thrombin injection with our reported success exceeding 97%. We previously reported on a cost-effective management algorithm including a "point of service" with follow-up examinations based on clinical symptoms and postprocedural imaging in symptomatic patients only.⁴⁰

Endovascular treatment options are feasible but essentially make no sense to suggest there widespread use. Reports have included either covered stents or coil embolization.

Operative repair is now reserved for patients with failure of a second thrombin injection or in cases where surgery is required that is large hematoma requiring surgical evacuation or suspected infected pseudoaneurysm which is rare. The most recent report by Garcia et al in 79 patients exemplified why surgical repair is discouraged unless absolutely necessary. Their series reported 71% of patients experienced at least one postoperative complication, with a 19% infection rate and 12% surgical site dehiscence.⁴¹

Arteriovenous Fistula

Arteriovenous fistula occurs in less than 1% of cases following percutaneous arterial puncture. Risk factors for the development of AVF include a "low stick" below the common femoral artery bifurcation (with most originating from the deep or superficial femoral arteries), female sex, 2-fold increase with left groin puncture, Coumadin therapy, and higher intraoperative heparin doses.⁴²

Rarely is this complication symptomatic, with symptoms of heart failure, lower extremity edema, or arterial insufficiency. The diagnosis can be suspected by palpation, auscultation of a bruit, and confirmed with Doppler ultrasound. Kelm et al⁴² prospectively evaluated over 10 000 patients to determine the incidence of postcatheterization AVF. Duplex criteria included the following: an AVF was diagnosed if all of the following criteria are observed: (1) a colorful "speckled" mass at the level of the fistula with turbulent flow in the AV connection; (2) increased venous flow more to the proximal than to the contralateral side of the fistula, with a lack of respiratory variation and a pulsatile arterial component in the affected vein; and (3) decreased arterial flow distal to the suspected fistula. Only one-third of their patients had spontaneous closure during 1 year of follow-up. Estimated flow rates within the fistulas was <510 mL/min, which is lower than most hemodialysis fistulas that rarely require intervention related to excess flow. This is in contrast to Toursarkissian et al reported one of the largest series of observations of AVFs in 81 patients. During the observation period (up to 3 months) for both AVF and small iatrogenic false aneurysms, 81% of the AVF closed without further intervention.³⁵ Compression is an option for management of symptomatic patients but success is variable secondary to short fistula track or large fistula size. Other management options in symptomatic patients include surgical ligation of the communicating tract or endovascular exclusion. These endovascular interventions include stent graft exclusion or coil embolization. Both of which should be used with caution since the majority of patients are asymptomatic. In a series of 10 patients treated by Onal et al covered polytetrafluoroethylene (PTFE) stents were deployed in the deep femoral artery. No adverse events were noted in the 18 month mean follow-up. However, this approach should be used with caution secondary to the potential risks associated with this management strategy including side branch occlusion, thrombosis, and so on.⁴³

Hematomas

The incidence of hematoma formation following femoral artery catheterization varies greatly in the literature. Major series have used many different size thresholds for defining a minor complication and major complication. In addition to the size, the accuracy of measurement is poorly reported. Operative evacuation of hematoma is rarely required but prolonged hospitalization is not nearly as infrequent. Access site hematoma requiring transfusion has been associated with multiple risk factors: older age, lower BMI, female sex, concomitant renal, cerebrovascular, pulmonary, or peripheral vascular disease. Procedural-related factors include glycoprotein IIb/IIIa inhibitors, thrombolytic therapy, and postprocedure heparin. In-hospital mortality was 9× higher compared to those not requiring transfusions.⁴⁴

The incidence of major bleeding complications has dramatically reduced over the past two decades. In a review of the Mayo clinic experience with major femoral bleeding after percutaneous coronary interventions, the incidence of femoral hematoma's exceeding 4 cm, the frequency of blood transfusions, and femoral bleeding requiring surgery reduced substantially from 7% in the mid-1990s to 2.8% in early 2000s. Doyle et al speculated that the reduction in complications over a 10-year experience is likely secondary to smaller sheath sizes, careful titration of intraprocedural anticoagulation, and decreasing the use of postoperative heparin products. This decrease has occurred despite the infrequent use of vascular closure devices in 5% of their population. This series also demonstrated statistically significant increased risk of 30-day mortality in those requiring transfusions, with increasing transfusion requirements independently associated with greater risk of mortality during the perioperative period.²

Groin hematomas should be evacuated surgically if the hematoma expands despite adequate compression therapy, if the skin is compromised with the potential for necrosis, and if the groin is explored for other pathology.

Conclusion

Femoral-based access continues to be the most common access site by vascular surgeons. Understanding risk factors and complications related to access are imperative. Continued refinement in techniques will hopefully reduce access complications in future management.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: John E. Campbell, MD is a Speaker's Bureau for Abbott Vascular.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Garrett PD, Eckart RE, Bauch TD, Thompson CM, Stajduhar KC. Fluoroscopic localization of the femoral head as a landmark for

- common femoral artery cannulation. *Catheter Cardiovasc Interv.* 2005;65(2):205-207.
2. Doyle BJ, Ting HH, Bell MR, et al. Major femoral bleeding complications after percutaneous coronary interventions. *JACC Cardiovasc Interv.* 2008;1(2):202-209.
 3. Sherev DA, Shaw RE, Brent BN. Angiographic predictors of femoral access site complications: implication for planned percutaneous coronary intervention. *Catheter Cardiovasc Interv.* 2005;65(2):196-202.
 4. Pitta SR, Prasad A, Kumar G, Lennon R, Rihal CS, Holmes DR. Location of femoral artery access with vascular complications. *Catheter Cardiovasc Interv.* 2011;78(2):294-299.
 5. Singh H, Cardella JF, Cole PE, et al. Quality improvement guidelines for diagnostic arteriography. *J Vasc Interv Radiol.* 2003; 14(9 pt 2):S283-S288.
 6. Bashmore TM, Bates ER, Berer PB, et al. American College of Cardiology/Society for Cardiac Angiography and Interventions Clinical Expert Consensus Document on cardiac catheterization laboratory standards. A report of the American College of Cardiology Task Force on clinical expert consensus documents. *J Am Coll Cardiol.* 2001;15;37(8):2170-2214.
 7. Fitts J, Ver Lee P, Hofmaster P, Malenka D; Northern New England Cardiovascular Study Group. Fluoroscopy-guided femoral artery puncture reduces the risk of PCI-related vascular complications. *J Invasive Cardiol.* 2008;21(3):273-278.
 8. Abu-Fadel MS, Sparling JM, Zacharias SJ, et al. Fluoroscopy vs. traditional guided femoral arterial access and the use of closure devices. *Catheter Cardiovasc Interv.* 2009;74(4):533-539.
 9. Jacobi J, Schussler JM, Johnson KB. Routine femoral head fluoroscopy to reduce complications in coronary catheterization. *Proc (Bayl Univ Med Cent).* 2009;22:7-8.
 10. Huggins CE, Gillespie MJ, Tan WA, et al. A prospective randomized clinical trial of the use of fluoroscopy in obtaining femoral arterial access. *J Invasive Cardiol.* 2009;21(3):105-109.
 11. Dudeck O, Teichgraber U, Podrabsky P, Haenninen EL, Soerensen R, Rieke J. A randomized trial assessing the value of ultrasound-guided puncture of the femoral artery for interventional investigations. *Int J Cardiovasc Imaging.* 2004;20(5): 363-368.
 12. Seto AH, Abu-Fadel MS, Sparling JM, et al. Real-time ultrasound guidance facilitates femoral arterial access and reduces vascular complications. *JACC Cardiovasc Interv.* 2010;3(7): 751-758.
 13. Blank R, Rupprecht HJ, Schorrlepp M, Kopp H, Rahmani R. Clinical value of Doppler ultrasound controlled puncture of the inguinal vessels with the "Smart Needle" within the scope of heart catheter examination. *Z Kardiol.* 1997;86(8):608-614.
 14. Biondi-Zoccai GGL, Agostoni P, Sangiorgi G, et al. Mastering the antegrade femoral artery access in patients with symptomatic lower limb ischemia: learning curve, complications, and technical tips and tricks. *Catheter Cardiovasc Interv.* 2006;68(6): 835-842.
 15. Wheatley BJ, Mansour A, Grossman M, et al. Complication rates for percutaneous lower extremity arterial antegrade access. *Arch Surg.* 2011;146(4):432-435.
 16. Gutzeit A, Graf N, Schoch E, Sautter T, Jenelten R, Binkert CA. Ultrasound guided antegrade femoral access: comparison between the common femoral artery and the superficial femoral artery. *Eur Radiol.* 2011;21(6):1323-1328.
 17. Duda SH, Wiskirchen J, Erb M, et al. Suture-mediated percutaneous closure of antegrade femoral arterial access sites in patients who have received full anticoagulation therapy. *Radiology.* 1999; 210(1):47-52.
 18. Lupattelli T, Tannour F, Garaci FG, et al. Efficacy and safety of antegrade common femoral artery access closure using the AngioSeal device: experience with 1889 interventions for critical limb ischemia in diabetic patients. *J Endovasc Ther.* 2010;17(3): 366-375.
 19. Minko P, Katoh M, Gräber S, Buecker A. Obesity: An Independent Risk Factor for Insufficient Hemostasis Using the AngioSeal Vascular Closure Device After Antegrade Puncture. *Cardiovasc Intervent Radiol.* 2012;35(4):775-778.
 20. Hirano Y, Ikuta S, Uehara H, et al. Diagnosis of vascular complications at the puncture site after cardiac catheterization. *J Cardiol.* 2004;43(6):259-265.
 21. Banfic L, Kirhmajer V, Vojkovic M, Strozzi M, Smalceli A, Lasic Z. Access site complications following cardiac catheterization assessed by duplex ultrasonography. *Coll Antropol.* 2008;32(2): 385-390.
 22. Dangas G, Mehran R, Kokolis S, et al. Vascular complications after percutaneous coronary interventions following hemostasis with manual compression versus arteriotomy closure devices. *J Am Coll Cardiol.* 2001;38(3):638-641.
 23. Frank JJ, Kamalakannan D, Kodenchery M, Savoy-Moore RT, Rosman H. Retroperitoneal hematoma in patients undergoing cardiac catheterization. *J Interv Cardiol.* 2010;23(6):569-574.
 24. Kent KC, Moscucci M, Mansour KA, et al. Retroperitoneal hematoma after cardiac catheterization: prevalence, risk factors, and optimal management. *J Vasc Surg.* 1994;20(6):905-910.
 25. Farouque HMO, Tremmel JA, Shabari FR, et al. Risk for the development of retroperitoneal hematoma after percutaneous coronary intervention in the era of glycoprotein IIb/IIIa inhibitors and vascular closure devices. *J Am Coll Cardiol.* 2005; 45(3):363-368.
 26. Ellis SG, Bhatt D, Kapadia S, Lee D, Yen M, Whitlow PL. Correlates and outcomes of retroperitoneal hemorrhage complicating percutaneous coronary intervention. *Catheter Cardiovasc Interv.* 2006;67(4):541-545.
 27. Trimarchi S, Smith DE, Share D, et al. Retroperitoneal hematoma after percutaneous coronary intervention: prevalence, risk factors and management, outcomes, and predictors of mortality: a report from the BMC2(Blue Cross Blue Shield of Michigan Cardiovascular Consortium)registry. *JACC Cardiovasc Interv.* 2010;3(8): 845-850.
 28. Chan YC, Morales JP, Reidy JF, Taylor PR. Management of spontaneous and iatrogenic retroperitoneal haemorrhage: conservative management, endovascular intervention or open surgery? *Int J Clin Pract.* 2008;62(10):1604-1613.
 29. Silva JA, Stant J, Ramee SR. Endovascular treatment of a massive retroperitoneal bleeding: successful balloon-catheter delivery of

- intra-arterial thrombin. *Catheter Cardiovasc Interv.* 2005;64(2):218-222.
30. Bates MC, Campbell JE. Technique for ipsilateral rescue embolization of common femoral side branch vessel injury. *Catheter Cardiovasc Interv.* 2007;70(6):791-794.
31. Wagner SC, Gonsalves CF, Eschelman DJ, Sullivan KL, Bonn J. Complications of a percutaneous suture-mediated closure device versus manual compression vs. manual compression for arteriotomy closure: a case-controlled study. *J Vasc Interv Radiol.* 2003;14(6):735-741.
32. Mlekusch W, Haumer M, Mlekusch I, et al. Prediction of iatrogenic pseudoaneurysm after percutaneous endovascular procedures. *Radiology.* 2006;240(2):597-602.
33. Ates M, Sahin S, Konuralp C, et al. Evaluation of risk factors associated with femoral pseudoaneurysms after cardiac catheterization. *J Vasc Surg.* 2006;43(3):520-524.
34. Popovic B, Freysz L, Chometon F, et al. Femoral pseudoaneurysms and current cardiac catheterization: evaluation of risk factors and treatment. *Int J Cardiol.* 2010;141(1):75-80.
35. Toursarkissian B, Allen BT, Petrinc D, et al. Spontaneous closure of selected iatrogenic pseudoaneurysms and arteriovenous fistulae. *J Vasc Surg.* 1997;25(5):803-808.
36. Paschalidis M, Theiss W, Kölling K, Busch R, Schömig A. Randomised comparison of manual compression repair versus ultrasound guided compression repair of postcatheterisation femoral pseudoaneurysms. *Heart.* 2006;92(2):251-252.
37. Lönn L, Olmarker A, Geterud K, Risberg B. Prospective randomized study comparing ultrasound-guided thrombin injection to compression in the treatment of femoral pseudoaneurysms. *J Endovasc Ther.* 2004;11(5):570-576.
38. Schneider C, Malisius R, Kuchler R, et al. A prospective study on ultrasound-guided percutaneous thrombin injection for treatment of iatrogenic post-catheterisation femoral pseudoaneurysms. *Int J Cardiol.* 2009;131(3):356-361.
39. Olsen DM, Rodriguez JA, Vranic M, Ramaiah V, Ravi R, Diehrich EB. A prospective study of ultrasound scan-guided thrombin injection of femoral pseudoaneurysm: a trend toward minimal medication. *J Vasc Surg.* 2002;36(4):779-782.
40. Stone PA, AbuRahma AF, Flaherty SK. Reducing duplex examinations in patients with iatrogenic pseudoaneurysms. *J Vasc Surg.* 2006;43(6):1211-1215.
41. Garcia ESN, Gonzalez-Fajardo JA, Gutierrez V, Carrera S, Vaquero C. Femoral pseudoaneurysms post-cardiac catheterization surgically treated: evolution in progress. *Interact Cardiovasc Thorac Surg.* 2009;8(3):353-357.
42. Kelm M, Perings SM, Jax T, Laurer T, et al. A prospective study on incidence and risk factors of arteriovenous fistulae following transfemoral cardiac catheterization. *J Am Coll Cardiol.* 2012;40(2):291-297.
43. Onal B, Kosar S, Gumus T, Ilgit ET, Akpek S. Postcatheterization femoral arteriovenous fistulas: endovascular treatment with stent-grafts. *Cardiovasc Intervent Radiol.* 2004;27(5):453-458.
44. Waigand J, Uhlich F, Gross CM, Thalhammer C, Dietz R. Percutaneous treatment of pseudoaneurysms and arteriovenous fistulas after invasive vascular procedures. *Catheter Cardiovasc Interv.* 1999;47(2):157-164.