Paper:
Dorman, S. & Obaid, D. (2019). Vascular access and closure for cardiovascular intervention. *Heart, 105*(16), 1279-1288.
http://dx.doi.org/10.1136/heartjnl-2018-313049

Vascular Access and Closure for Cardiovascular Intervention

Daniel R Obaid[1], Stephen H Dorman[2]

1. Swansea University Medical School and Morriston Cardiac Centre, Swansea, UK.

2. Bristol Heart Institute, Bristol, UK.

Correspondence to

Dr Stephen Dorman,

Bristol Heart Institute, Bristol, BS2 8HW, UK.

Stephen.dorman@uhbristol.nhs.uk

Learning Objectives

To choose the most appropriate access site for a cardiovascular intervention.

Learn how to gain access and achieve closure of the radial and femoral artery.

Learn how to minimise vascular complications.

Introduction

Selective coronary angiography initially required surgical cut down to access the brachial artery(1). Subsequently, in 1967 Melvin Judkins described a direct percutaneous approach via the femoral artery(2) an easily palpated vessel with high procedural success that would go on to become the default arterial access route. However, despite decades of experience with femoral access, vascular complications and bleeding remain a concern and are still a significant cause of mortality in cardiovascular intervention(3). Percutaneous coronary intervention (PCI) via the radial artery was first described by Kiemeneij in 1993(4) and early studies appeared to show a virtual elimination of access site complications(5). Initially the technique remained a niche interest of early radial pioneers but usage in the UK has increased from 14% in 2005 to 84% in 2016 replacing the femoral artery as the most popular access site for intervention(6)

Selection of Radial or Femoral Arterial Access

Radial artery access reduces vascular complications across all patient groups(7) and is now recommended as the standard route for PCI(8). However, there are groups where the benefit is more pronounced. The superficial course and small caliber of the radial artery simplifies haemostasis allowing early ambulation(9) and reducing cost(10) making it ideal for patients who cannot tolerate prolonged bed rest, on anticoagulants or are undergoing PCI in the day case setting. A mortality benefit for radial access has been shown in patients with acute coronary syndrome and ST elevation myocardial infarction in both large randomized control trials(11) and meta-analysis(12) making this a strong indication for radial PCI. However, there remain procedural reasons when femoral access is required (large-bore access for transcatheter aortic valve intervention (TAVI), mechanical circulatory support or complex coronary interventional procedures) and in a small proportion of patients unfavourable radial approach anatomy results in cross-over to femoral access. For this reason, interventional cardiologists must be familiar with best practice for both access sites.

Radial Artery Access - Patient Preparation

The right radial approach is most commonly used for ergonomic reasons. The right arm is placed alongside the body in a supine position supported by a dedicated arm board. Contralateral venous access should be obtained in case of vasovagal reaction requiring resuscitation and to allow administration of analgesia or sedation. The right groin should also be prepared in high-risk cases to facilitate rapid central venous and femoral arterial access if needed.

The left radial is a feasible alternative and is preferred if there is a requirement to image a LIMA graft or if the right radial pulse is absent. Accessing the left radial may be uncomfortable in larger patients whilst the left arm is at the patient’s side in which case the arm is extended at 80 degrees for arterial cannulation and then positioned back across the body for the remainder of the procedure. Catheter orientation from the left radial approach more closely approximates that of the femoral approach and the operator is three times less likely to encounter subclavian tortuosity(13). This may account for evidence that the left radial route is associated with lower fluoroscopy time in elderly patients or with operators in training(14). In a randomized controlled trial of 1493 patients undergoing coronary angiography there was no difference in operator radiation exposure from femoral or right radial access but it was higher with left radial access(15). There is often a requirement to stand closer to the patient to manipulate catheters from the left radial artery so if utilizing this access, extension tubing to allow the operator to maintain distance should be used.

Routine pre-procedural sedation is administered by 58% of operators(16). The radial artery has a muscular wall with numerous α-adrenergic receptors that make it prone to developing intense spasm(17). A randomized controlled trial of 2013 patients showed lower rates of spasm and femoral cross over after fentanyl and midazolam(18) so whilst not used universally it remains a useful adjunct in patients with high adrenergic states such as those with acute myocardial infarction or heightened anxiety.

It is no-longer considered necessary to perform an Allen's test to determine the patency of the ulnar-palmar arch prior to radial access(6) and relying on this will likely exclude a significant number of patients who would benefit from radial access unnecessarily. Multiple studies have utilized radial access in patients with an abnormal Allen's test and none developed any clinical or subclinical consequences(11, 19). Ischaemic complications have been described in patients with connective tissue disease and severe Raynaud's(20), but are very rare and in these patients the balance of risk with the reduction in vascular complications should be considered when choosing access.

Radial Artery Access Technique

The radial artery is usually accessed 2cm proximal to the styloid process (figure 1). A small amount (1-2mls) of local anaesthetic is administered initially at the puncture site to avoid distorting the anatomy. A short micropuncture needle is then advanced on a shallow trajectory until the anterior wall of the artery is punctured. A small caliber guide wire is then advanced through the needle with a rotating motion to avoid small side branches. At this point, the entry site can be further infiltrated with local anaesthetic and a skin nick made whilst the micropuncture needle is in-situ to prevent inadvertent damage to the guide wire. The micro puncture needle is removed, and the sheath is inserted over the guide wire.

An alternative technique is to transfix the radial artery with a "through and through" puncture. This is usually performed with a catheter over-needle system. Here the needle is advanced through both the anterior and posterior wall of the artery. The needle is withdrawn, and the catheter pulled back slowly until arterial flow is seen. At this point the guide wire is inserted. In a randomized trial of these two techniques in 412 patients there was no difference in access site complications but the "through and through" technique was associated with faster access and fewer attempts required(21). The radial artery is usually easy to palpate so ultrasound guidance is uncommon. However, a prospective randomized controlled trial of 698 patients has shown that routine use of ultrasound almost halved the average number of cannulation attempts required from 3.1 to 1.7(22).

Overcoming difficulties with catheter advancement in the radial artery

Radial spasm was the most common reason for transradial failure in a series of 2100 patients (1.6% of cases)(23). The majority of radial operators (86%) use a spasmolytic agent following sheath insertion(16) and meta-analysis reveals a combination of verapamil and nitroglycerin is the most effective(24). To reduce radiation exposure, it is permissible to initially advance the guide wire and catheters up the arm without fluoroscopy(25). However, if resistance is felt or patient discomfort then an arm angiogram should be performed. Due to the frequency of anomalous anatomy (occurring in 14% of a series of 1540 patients) some operators routinely perform minimal contrast volume arm angiograms in order to avoid trauma or spasm in tortuous or small calibre arm vessels(26). Anatomical anomalies range from those that have a minimal effect on success rate such as high bifurcation of the radial artery (present in 7%) often associated with smaller caliber arteries and a tendency to spasm which resulted in failure in only 4.6% of cases, to full 360 degree radial loops present in only 2.3% but resulting in failure 37.1% of the time and requiring reducing before a guiding catheter can be advanced(26) (figure2).

Even if areas of adverse anatomy or spasm have been negotiated with a hydrophilic wire or a 0.014inch angioplasty wire it may not be possible to advance a guide catheter due to the "razer" effect of the edge of the catheter on the arterial wall(27). To overcome this the distal end of the guiding catheter needs to be tapered. This can be achieved in a standard guiding catheter using two techniques, balloon assisted tracking (BAT) (27) and the "5 in 6" technique (figure 3). These techniques have been used with high rates of success in different clinical situations and importantly can be used to maintain radial access in primary PCI with no increase in door to balloon times compared with switching to the femoral route(28).

Finally, in one series 0.9% of radial access cases failed because of subclavian tortuosity(23) and in another a retro-oesophageal right subclavian was present in 0.3% of cases(29) (figure 4). In these cases, the angle of advancement can be made more favorable by asking the patient to take a deep inspiration. If the guide wire remains biased toward the descending aorta then it can usually be directed with a Judkins right catheter toward the aortic root, which will be to the left of the descending aorta on a 30-degree LAO projection. There can be difficulty in catheter engagement of the coronary ostia and it is often necessary to keep the .035 guidewire within the catheter to facilitate catheter manipulation and prevent kinking. Whilst the wire can be kept in the catheter right up to engagement of the coronaries it is important to ensure that there is a free back flow of blood and normal arterial pressure trace before injecting any contrast. If there has been any difficulty advancing the catheter into the aortic root catheter exchanges should be performed with a long 260cm guide wire in the aortic root so that wire position is not lost.

Management of Radial Access Complications

Vascular complications during radial access are rare and with early recognition and prompt management clinically significant sequelae can be avoided(30) (table 1). Dissection can occur from guide wire trauma or advancement of an oversized sheath or catheter in a small caliber artery. As these are retrograde to arterial flow they are usually self-limiting and require no specific treatment apart from careful observation. However, as they are usually accompanied by intense spasm (figure 4) they may require change to an alternative access. More significant arterial trauma can lead to vessel perforation, usually due to inadvertent advancement of a guide wire into a small side branch or radial anomaly (figure 4). Previously these would be managed with immediate manual compression, however if the segment has been traversed with a guiding catheter the procedure can be completed as the presence of the catheter prevents excess bleeding from the perforation site which will usually seal without further intervention by the time the procedure is completed and the catheter withdrawn(31). Patients should be monitored closely afterwards for evidence of forearm haematoma. If detected early this can be managed with conservative measures but if not addressed can lead to compartment syndrome which is very rare (1:25000) but requires urgent surgical fasciotomy(30).

Complication	Incidence	Risk factors	Prevention and Management
Radial artery occlusion	5% (may be higher as usually asymptomatic)	Larger sheath size. Multiple cannulations. Prolonged compression with interrupted antegrade radial flow. No anticoagulation	See table 2.
Radial artery spasm	5%	Multiple puncture attempts. Larger sheath size. Multiple catheter exchanges. Small or tortuous arteries. Patient anxiety.	Consider ultrasound to reduce puncture attempts and guide sheath size selection. Consider sub lingual GTN, spasmolytic cocktail and sedation. Minimize sheath and catheter size. Consider dedicated radial catheter (e.g TigerII, Terumo) to minimize catheter exchanges.
Local (Wrist) Haematoma	≤5%	multiple puncture attempts, anticoagulation	Analgesia, ice, additional compression bracelet.
Forearm haematoma	<2%	Inadvertent guide wire perforation, anticoagulation	Analgesia, ice, additional compression bracelet. Inflated BP cuff at 20mmHg below arterial blood pressure for 15-minute intervals. Monitor closely for signs of compartment syndrome which requires STAT surgical review.
Perforation	<1%	Guide wire trauma to small branch or radial anomaly. Use of hydrophilic wires without fluoroscopic guidance.	Perform arm angiogram if any resistance to guide wire advancement. Procedure can be completed if catheter or sheath in situ to prevent bleeding. Monitor closely for forearm haematoma and treat appropriately.
Pseudoaneurysm	<0.1%	Radial Artery trauma: large sheaths, Multiple puncture attempts, Inadequate compression post procedure	Evaluate with ultrasound. Depending on size consider: Prolonged compression with bracelet, ultrasound guided thrombin injection or surgical treatment.

Table 1. Radial Artery Access Complications

Limitations of Radial Access

The radial artery is usually between 2 to 3 mm in diameter and generally larger in men than women(32). This has the potential to limit the ability to perform complex Intervention requiring larger bore (>6F) guiding catheters. Saito et al found in 260 patients that the radial artery diameter was smaller than the outer diameter of a standard 7F sheath (Terumo, Japan) (2.95mm) In 29% of males and 60% of females(32). If a 7F guide catheter is required one option is to use 7F Glidesheath (Terumo) which can accommodate a 7F guiding catheter but has an outer diameter of 2.79mm (equivalent to a standard 6F sheath). Another is a 7F Sheathless guide catheter (Sheathless Eaucath, Asahi Intecc CO. Japan) these have an outer diameter 2.49mm and have been used to successfully complete complex interventions including crush stent bifurcations and rotational atherectomy(33). Finally, the Railway system (Cordis, a Cardinal Health company) consists of dedicated introduction and exchange inserts that allow conventional 7F guides to be used without a sheath.

Radial Artery Closure

The radial artery is easily compressible allowing immediate sheath removal independent of any anticoagulants given. Traditionally a compressive dressing or bracelet compression device (the most common being the TR band (Terumo) (figure 1), is used to give 2 hours continuous compression. Radial artery occlusion has been reported in around 5% of cases after compression haemostasis but is likely underreported as is virtually always asymptomatic(34). However, it is important as occlusion limits options for repeat arterial access and loss of a potential conduit in the future for coronary artery bypass grafting. Steps to reduce radial artery occlusion include anticoagulation(25) and patent haemostasis(35) and are listed in table 2.

Strategy	Description	
Reduce Sheath Size	Use smallest possible radial sheath. If ultrasound guidance has been used, ensure the diameter of the introducer sheath / radial artery is <1.	
Anticoagulation	Give heparin at a dose of 5000iu or 70iu/kg. Patients with contra-indications to heparin can be given Bivalirudin 0.75mg/kg.	
Patent Haemostasis	Step 1	Withdraw the arterial sheath 2–3 cm.
	Step 2	Apply the haemostatic compression device, 2 to 3 mm proximal to the skin entry site, and tighten it or inflate it, then remove the sheath.
	Step 3	Decrease the pressure of the haemostatic compression device to the point of mild pulsatile bleeding at the skin entry site. After 2 to 3 cycles of pulsatile bleeding, retighten the haemostatic compression device gradually to eliminate this pulsatile bleeding.
	Step 4	Evaluate radial artery patency by using the reverse Barbeau's test: (i) Place the plethysmographic sensor on the index finger of the involved upper extremity with the observation of pulsatile waveforms. (ii) Compress the Ulnar artery at the level of the wrist and observe the behaviour of the waveform. (iii) Absence of plethysmographic waveform is indicative of interruption of radial artery flow. (iv) If this occurs, the haemostatic compression pressure should be lowered to the point where plethysmographic waveform returns. This is evidence of antegrade radial artery flow. (v) Repeat stage (iv) after 15 minutes to ensure there is still patent haemostasis as post-procedural changes in blood pressure commonly occur.

Table 2. Strategies to Prevent Radial Artery Occlusion. Adapted from Rao et al 2014(25)

Ulnar Artery and Left Distal Radial Artery Access

Ulnar artery access is a potential alternative to the radial artery. However, the ulnar artery is situated deeper in the forearm and runs alongside the ulnar nerve making inadvertent nerve injury and forearm haematoma a risk. A meta-analysis comparing radial and ulnar approaches to coronary angiography and PCI showed no significant difference in access-site complications, but access-site crossover was significantly higher with ulnar access(36). More recently Kiemeneij has described the technique of using the smaller left distal radial artery within the anatomical snuffbox for alternative access. The technique is technically challenging making it only suitable for selected cases but has the potential advantage of greater operator and patient comfort(37).

Femoral Arterial Access – Patient Preparation

The key to reducing femoral access site complications is ensuring that sheath insertion is within the optimal site in the common femoral artery (CFA)(38).The CFA runs within the femoral sheath, adjacent to the femoral vein and nerve and is bordered superiorly by the inguinal ligament and inferiorly branches into the superficial femoral and profunda femoris arteries (figure 5A). Low punctures below the bifurcation result in more bleeding, pseudoaneurym(39) and AV fistula formation(40) due to the smaller artery size, superficial relationship of the femoral vein tributaries and absence of bony prominence for compression. High punctures above the inguinal ligament in the external iliac artery are not compressible risking retroperitoneal haemorrhage(41).

Historically operators have relied on a combination of palpation, surface anatomy and fluoroscopic landmarks to puncture the CFA. The point of maximal pulsation allows easy vessel cannulation and in one study correlated 93% of the time with the location of the CFA. The skin crease is readily identified but is frequently (72% of cases) located below the bifurcation(42). Using the bony landmarks of the anterior superior iliac spine and the pubic tubercle as a proxy for the inguinal ligament, a puncture 2-3cm below the mid inguinal point has been proposed however the correlation of the bony landmarks in cadaveric studies is poor(43). There is some evidence that a fluoroscopy guided approach can reduce femoral vascular complications(44). Studies have shown that 95% of the time the bifurcation of the CFA is at or below the mid femoral head leading to a proposed mid femoral head fluoroscopic target zone(45) (figure 5B). Some operators advocate use of a micropuncture kit (Cook Medical) to minimise complications. The evidence base for this is limited and observational studies have not shown clear benefit(46). However, this is intuitively attractive as it allows a 4F sheath to be placed and femoral sheath angiography undertaken to confirm position before a larger sheath is introduced (figure 5C).

Surrogate anatomical markers for identification of the common femoral artery can be misleading in cases of anatomical variation. In particularly challenging anatomy such as morbid obesity or peripheral vascular disease it may better to consider the radial approach. If this not possible then direct visualisation of the CFA with Ultrasound guidance should be performed (figure 5).

Ultrasound Guided Femoral Arterial Access

Ultrasound allows for real time visualisation of vessel cannulation(47). As far back as 2002 the National Institute for Clinical Excellence concluded that the evidence base for ultrasound guided central line insertion was sufficiently robust to mandate its use in this setting across the NHS in England and Wales. Ultrasound guidance in femoral vascular access was compared with traditional techniques in randomised control trials(48) and a recent meta-analysis(49) involving 1422 subjects showed a 49% reduction in overall complications as well as a 42% improvement in the likelihood of first-pass success. Whilst TAVI operators are increasingly recognising it's utility, uptake in the general interventional community has been slow as demonstrated in a recent small survey where only 13% of interventionists used it for femoral access(50). There is a learning curve associated with ultrasound guided puncture nevertheless usage is likely to grow given its proven efficacy in reducing vascular access complications.

Femoral Artery Access Technique

Femoral access is uncomfortable for the patient so consider sedation, especially if gaining large-bore access. Local anaesthetic is infiltrated, initially with a 25g needle to form a skin bleb, then using a 22g needle to just above the CFA and the tissue track. After making a small nick in the skin an 18g needle is introduced at an angle of between 30 and 45 degrees until it rests above the CFA where it may be observed to "dance" with the arterial pulse. A single anterior wall puncture is made and once good pulsatile flow through the needle is established then the needle is lowered to become more coaxial with the vessel and a 0.035-inch J tip guidewire introduced followed by a sheath.

If the sheath will not advance over the guide wire exclude a kinked guidewire and readjust wire position if feasible. If scar tissue is the problem, consider sequential dilatation with smaller dilators or exchange for a more supportive guidewire through the dilator. If there is resistance to advancement of the guidewire or catheter then an angiogram should be taken. Unlike the radial artery, spasm or anomalies of the femoral artery are not usually encountered. However, there may be a tortuous ileo-femoral system (figure 6A). This may need to be negotiated with a hydrophilic 0.035-inch guidewire. If catheter advancement or manipulation is not possible exchange over a diagnostic catheter for a stiffer guidewire (e.g. Amplatz extra stiff, Cook Medical) and consider use of a long armoured sheath (e.g Super Arrow Flex, Teleflex Medical).

Femoral Vascular Complications

Vascular complications remain the Achilles heel of femoral access. The use of larger sheaths and more potent antithrombotic medication mean that vascular complications are 2-3 times higher after PCI than with diagnostic angiography(51). Known risk factors for vascular complications include age > 70 years, female sex, Body surface area < 1.6m2, renal failure, urgent procedures, complex disease and use of glycoprotein IIb/IIIa inhibitors(52). In addition, punctures outside the target zone of the CFA result in a higher level of complications(38). Arterial dissection is usually caused by advancement of equipment without guide wire support (figure 6B). As they are retrograde they will usually settle with conservative management. Perforation has the potential to be a serious complication if it is not detected promptly (figure 6C). If bleeding occurs into the retroperitoneal space where it may be detected late and will not be controllable with compression it is associated with a mortality of 10%(53). An overview of femoral access complications and their management is provided in table 3.

Complication	Incidence	Risk factors	Management
Local (Groin) Haematoma	1-12%	Puncture outside CFA, multiple access attempts, laceration of branch vessel, high or low BMI, anticoagulation	Careful prolonged manual compression to push out the residual haematoma and achieve haemostasis.
Pseudoaneurysm	1-6%	Low puncture, short press, inexperienced manual compression	Evaluate with ultrasound. Depending on size consider: Ultrasound guided press, ultrasound guided thrombin injection, Surgical treatment.
Retroperitoneal haemorrhage	0.2-0.9%	High puncture with failure of closure device. Excess anticoagulation	Diagnosis: Hypotension and flank pain. CT Angiography or contralateral angiography to locate bleeding source and guide management. Management initially with IV fluid/blood product resuscitation. Percutaneous management possible but vascular surgical opinion mandated followed by percutaneous or surgical management.
AV fistula	<1%	Often from a low puncture where a femoral venous vessel overlies the superficial femoral artery.	Diagnosis with a systolic murmur, right heart overload. Seek vascular surgical opinion
Acute vessel closure	<1%	Associated with large intimal dissection and small caliber, diseased femoral vessels, large sheath to femoral artery ratio and the use of vascular closure devices	Urgent Vascular surgical review but percutaneous solutions with peripheral balloons and stents may be feasible
Infection	0.25%	Associated with diabetics, use of vascular closure devices. Typically blood culture positive for staphylococcus aureus. 6% mortality	Meticulous aseptic technique. Avoidance of VCD's when infection risk high.

Table 3. Femoral Artery Access Complications

Femoral Artery Closure

Manual compression remains the commonest method of femoral access closure worldwide. It is highly effective for small sheaths but does mean prolonged patient immobilisation. Since the 1990's there have been ongoing developments of vascular closure devices (VCD) and the latest generation now provide faster haemostasis compared with manual compression. They have not however been proven to reduce vascular complications and indeed concern remains that rare complications such as ischaemia or infection are increased by their use. Compared to manual compression randomised control trial data shows no superiority for VCD in risk of bleeding (54) and meta analyses reveals VCD have a significantly shorter recovery time but higher rates of groin infection (0.6% vs 0.2%, P = .02 and a trend toward increased risk of ischaemic complications (0.3% vs 0%, P = .07) and need for vascular surgery (0.7% vs 0.4%, P = .10)(55) .

Manual Compression

Effective manual compression requires a relaxed normotensive patient and the table height adjusted for operator comfort. 3 fingers should be placed just above the puncture site and the sheath removed under sufficiently gentle pressure to avoid milking any thrombus out of the sheath during removal. Firm pressure is then required for a minimum of 8-10 minutes with patient ambulation possible 2 hours later. Longer compression times are needed for larger sheaths or with more potent antiplatelet or antithrombotic regimes. The femoral sheath should be removed as soon as safely possible following a procedure as long dwell times are associated with increased complications. If unfractionated heparin has been given, then compression is typically delayed until the ACT is less than 180s. External compression devices can also be used as an alternative or adjunctive device to manual compression. Femostop (Abbott/St Jude Medical) is an external clamp device with a clear air-filled plastic bubble which permits variable pressure inflation.

Vascular Closure Devices

Guidelines support the use of VCD to provide faster haemostasis and early ambulation but not to reduce vascular complications and they also mandate a femoral angiogram to assess suitability(56). A rotational angiogram is recommended of the femoral sheath to identify the puncture position, vessel calibre, adjacent plaque disease and so clarify suitability for device closure. The two most commonly used VCD are the Angio-seal (Terumo) and the Perclose Proglide (Abbott). The Vascular complication rates of these are similar(57) but operator experience and familiarity is important(58) . The Angio-seal (Terumo) comes in 6F and 8F sizes and is popular due to its relatively short learning curve and high success rate. The mechanism relies on an intravascular biodegradable anchor which actively approximates with a collagen plug. The anchor should resorb within 3 months. The principle concern relates to the residual material left behind risking infection or ischaemia. The Perclose Proglide (Abbott) is a suture based active approximator that aims to mimic a surgical suture. It has a longer learning curve and higher failure rate than the Angioseal(57) but can be pre deployed and used as a single unit or as multiple devices so is also suitable for large bore closure. It uses a pre-tied polypropylene monofilament suture that allows successful closure to be assessed on the table whilst maintaining wire access with a standard 0.035” wire. An overview of current VCD is shown in table 4.

Product	Company	Closure method	Access site closure	Further instructions for use
Angio-seal ™	Terumo	Active approximation between intravascular anchor and collagen plug	6-8F	http://www.terumois.com/products/closure/angio-seal-vascular-closure-devices/angio-seal.html
StarClose SE®	Abbott	Active approximation using an extra vascular nitinol clip		https://www.vascular.abbott/us/products/vessel-closure/starclose-se-vascular-closure-system.html
Perclose Proglide	Abbott Vascular	Active approximation using pre-tied suture device	5-21F (arterial) Venous (5-24F)	https://vascular.abbott.com/perclose-proglide-learning-center-intl.html
MYNXGRIP®	Cordis	Passive approximation using an unanchored extravascular plug	5-7F arterial	https://emea.cordis.com/emea/cardiology/close/mynxgrip-vascular-closure-device.html
MANTA ™	Essential Medical Inc	Large bore closure – Active approximation using an anchor/plug mechanism	10-25F Arterial	http://www.essmedclosure.com/
Prostar XL	Abbott	Large bore closure with active approximation using paired polyester sutures attached to 4 nitinol needles	8.5-10F Arterial	https://www.vascular.abbott/us/products/vessel-closure/prostar-xl-percutaneous-vascular-surgical-system.html
Inseal Inclosure	Inseal Medical inc	Active approximation using a self-expandable nitinol frame covered with a biodegradable membrane	14-21F Arterial	http://www.insealmedical.com/

Table 4. Vascular Closure Devices Used Following Femoral Arterial Access

Large Bore Femoral Artery Closure

With the increasing use of large bore femoral access for TAVI and adjunctive haemodynamic support there has been renewed interest in optimising large bore vessel closure. Traditionally large femoral arteriotomy sites have been closed surgically or with prolonged manual compression. Manual compression is less effective and prone to complications in this setting and so “pre-closure” with a suture mediated vascular closure device has become commonplace. Perclose proglide (Abbott)and Prostar XL (Abbott) are the 2 most commonly used suture based preclosure devices. The Prostar XL has a longer learning curve, a sliding suture which must be hand tied and needles which move from intra to extravascular. Both devices appear equally efficacious in experienced hands. The Manta (Essential Medical inc) is a new anchor/plug based device and has shown promising early results. Irrespective of the closure device used a deep puncture into a small heavily diseased vessel through anterior wall calcium all predict a higher risk of device failure.

Conclusion

Safe arterial access and closure is a fundamental of interventional cardiology. Transradial access has emerged from a niche interest to the access site of choice in a large number of centres in more than 75 countries worldwide(16) and proficiency in it is essential in all those undertaking cardiovascular interventions. However, despite its success, there remains a small proportion of cardiovascular interventions that still require femoral access due to the need for large calibre access or procedural or anatomical constraints. As experience in femoral access decreases there is the potential for a paradoxical increase in femoral complications(59). This does not seem to have occurred during the widespread adoption of radial access in the UK(60) but given that femoral access is now often only performed in challenging situations it is vital that those undertaking cardiovascular interventions must maintain proficiency in managing femoral arterial access as well as becoming familiar with new developments such as ultrasound guidance.

Key Points

- Vascular access site complications are a significant source of morbidity and mortality in cardiovascular intervention performed from the femoral artery.

- Strategies to improve femoral puncture in the “safe zone” of the common femoral artery should be employed routinely of which ultrasound guidance is the most effective.

- Compared to femoral artery access, radial artery access results in fewer access site complications and a reduction in mortality in patients with acute coronary syndrome.

- Radial artery access presents procedural challenges that can be overcome with experience and specialist techniques.

- Radial artery access is now the predominant access site for percutaneous coronary intervention but there remain situations with femoral artery access is required so interventional cardiologists should be proficient at both.

Acknowledgemens: We thank Professor Alex Chase, Morriston Cardiac Centre, Swansea, UK for the images in figure 1 and Figure 5C

References

1. Sones FM, Jr., Shirey EK. Cine coronary arteriography. Mod Concepts Cardiovasc Dis. 1962;31:735-8.
2. Judkins MP. Selective coronary arteriography. I. A percutaneous transfemoral technic. Radiology. 1967;89(5):815-24.
3. Doyle BJ, Ting HH, Bell MR, Lennon RJ, Mathew V, Singh M, et al. Major femoral bleeding complications after percutaneous coronary intervention: incidence, predictors, and impact on long-term survival among 17,901 patients treated at the Mayo Clinic from 1994 to 2005. JACC Cardiovasc Interv. 2008;1(2):202-9.
4. Kiemeneij F, Laarman GJ. Percutaneous transradial artery approach for coronary stent implantation. Cathet Cardiovasc Diagn. 1993;30(2):173-8.
5. Kiemeneij F, Laarman GJ, Odekerken D, Slagboom T, van der Wieken R. A randomized comparison of percutaneous transluminal coronary angioplasty by the radial, brachial and femoral approaches: the access study. J Am Coll Cardiol. 1997;29(6):1269-75.
6. Sandhu K, Butler R, Nolan J. Expert Opinion: Transradial Coronary Artery Procedures: Tips for Success. Interv Cardiol. 2017;12(1):18-24.
7. Bertrand OF, Belisle P, Joyal D, Costerousse O, Rao SV, Jolly SS, et al. Comparison of transradial and femoral approaches for percutaneous coronary interventions: a systematic review and hierarchical Bayesian meta-analysis. Am Heart J. 2012;163(4):632-48.
8. Neumann FJ, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, Benedetto U, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J. 2018.
9. Bertrand OF, De Larochelliere R, Rodes-Cabau J, Proulx G, Gleeton O, Nguyen CM, et al. A randomized study comparing same-day home discharge and abciximab bolus only to overnight hospitalization and abciximab bolus and infusion after transradial coronary stent implantation. Circulation. 2006;114(24):2636-43.
10. Cooper CJ, El-Shiekh RA, Cohen DJ, Blaesing L, Burket MW, Basu A, et al. Effect of transradial access on quality of life and cost of cardiac catheterization: A randomized comparison. Am Heart J. 1999;138(3 Pt 1):430-6.
11. Valgimigli M, Gagnor A, Calabro P, Frigoli E, Leonardi S, Zaro T, et al. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomised multicentre trial. Lancet. 2015;385(9986):2465-76.
12. Ando G, Capodanno D. Radial Versus Femoral Access in Invasively Managed Patients With Acute Coronary Syndrome: A Systematic Review and Meta-analysis. Ann Intern Med. 2015;163(12):932-40.
13. Norgaz T, Gorgulu S, Dagdelen S. A randomized study comparing the effectiveness of right and left radial approach for coronary angiography. Catheter Cardiovasc Interv. 2012;80(2):260-4.
14. Sciahbasi A, Romagnoli E, Burzotta F, Trani C, Sarandrea A, Summaria F, et al. Transradial approach (left vs right) and procedural times during percutaneous coronary procedures: TALENT study. Am Heart J. 2011;161(1):172-9.
15. Pancholy SB, Joshi P, Shah S, Rao SV, Bertrand OF, Patel TM. Effect of Vascular Access Site Choice on Radiation Exposure During Coronary Angiography: The REVERE Trial (Randomized Evaluation of Vascular Entry Site and Radiation Exposure). JACC Cardiovasc Interv. 2015;8(9):1189-96.
16. Bertrand OF, Rao SV, Pancholy S, Jolly SS, Rodes-Cabau J, Larose E, et al. Transradial approach for coronary angiography and interventions: results of the first international transradial practice survey. JACC Cardiovasc Interv. 2010;3(10):1022-31.
17. He GW, Yang CQ. Characteristics of adrenoceptors in the human radial artery: clinical implications. J Thorac Cardiovasc Surg. 1998;115(5):1136-41.
18. Deftereos S, Giannopoulos G, Raisakis K, Hahalis G, Kaoukis A, Kossyvakis C, et al. Moderate procedural sedation and opioid analgesia during transradial coronary interventions to prevent spasm: a prospective randomized study. JACC Cardiovasc Interv. 2013;6(3):267-73.

19. Valgimigli M, Campo G, Penzo C, Tebaldi M, Biscaglia S, Ferrari R, et al. Transradial coronary catheterization and intervention across the whole spectrum of Allen test results. J Am Coll Cardiol. 2014;63(18):1833-41.
20. Rose SH. Ischemic complications of radial artery cannulation: an association with a calcinosis, Raynaud's phenomenon, esophageal dysmotility, sclerodactyly, and telangiectasia variant of scleroderma. Anesthesiology. 1993;78(3):587-9.
21. Pancholy SB, Sanghvi KA, Patel TM. Radial artery access technique evaluation trial: randomized comparison of Seldinger versus modified Seldinger technique for arterial access for transradial catheterization. Catheter Cardiovasc Interv. 2012;80(2):288-91.
22. Seto AH, Roberts JS, Abu-Fadel MS, Czak SJ, Latif F, Jain SP, et al. Real-time ultrasound guidance facilitates transradial access: RAUST (Radial Artery access with Ultrasound Trial). JACC Cardiovasc Interv. 2015;8(2):283-91.
23. Dehghani P, Mohammad A, Bajaj R, Hong T, Suen CM, Sharieff W, et al. Mechanism and predictors of failed transradial approach for percutaneous coronary interventions. JACC Cardiovasc Interv. 2009;2(11):1057-64.
24. Kwok CS, Rashid M, Fraser D, Nolan J, Mamas M. Intra-arterial vasodilators to prevent radial artery spasm: a systematic review and pooled analysis of clinical studies. Cardiovasc Revasc Med. 2015;16(8):484-90.
25. Rao SV, Tremmel JA, Gilchrist IC, Shah PB, Gulati R, Shroff AR, et al. Best practices for transradial angiography and intervention: a consensus statement from the society for cardiovascular angiography and intervention's transradial working group. Catheter Cardiovasc Interv. 2014;83(2):228-36.
26. Lo TS, Nolan J, Fountzopoulos E, Behan M, Butler R, Hetherington SL, et al. Radial artery anomaly and its influence on transradial coronary procedural outcome. Heart. 2009;95(5):410-5.
27. Patel T, Shah S, Pancholy S, Rao S, Bertrand OF, Kwan T. Balloon-assisted tracking: a must-know technique to overcome difficult anatomy during transradial approach. Catheter Cardiovasc Interv. 2014;83(2):211-20.
28. Obaid D, Hailan A, Chase A, Dorman S, Jenkins G, Raybould A, et al. Balloon-Assisted Tracking Use Reduces Radial Artery Access Failure in an Experienced Radial Center and is Feasible During Primary PCI for STEMI. J Invasive Cardiol. 2017;29(7):219-24.
29. Abhaichand RK, Louvard Y, Gobeil JF, Loubeyre C, Lefevre T, Morice MC. The problem of arteria lusoria in right transradial coronary angiography and angioplasty. Catheter Cardiovasc Interv. 2001;54(2):196-201.
30. Bertrand OF. Acute forearm muscle swelling post transradial catheterization and compartment syndrome: prevention is better than treatment! Catheter Cardiovasc Interv. 2010;75(3):366-8.
31. Patel T, Shah S, Sanghavi K, Pancholy S. Management of radial and brachial artery perforations during transradial procedures--a practical approach. J Invasive Cardiol. 2009;21(10):544-7.
32. Saito S, Ikei H, Hosokawa G, Tanaka S. Influence of the ratio between radial artery inner diameter and sheath outer diameter on radial artery flow after transradial coronary intervention. Catheter Cardiovasc Interv. 1999;46(2):173-8.
33. Mamas MA, Fath-Ordoubadi F, Fraser DG. Atraumatic complex transradial intervention using large bore sheathless guide catheter. Catheter Cardiovasc Interv. 2008;72(3):357-64.
34. Stella PR, Kiemeneij F, Laarman GJ, Odekerken D, Slagboom T, van der Wieken R. Incidence and outcome of radial artery occlusion following transradial artery coronary angioplasty. Cathet Cardiovasc Diagn. 1997;40(2):156-8.
35. Pancholy S, Coppola J, Patel T, Roke-Thomas M. Prevention of radial artery occlusion-patent hemostasis evaluation trial (PROPHET study): a randomized comparison of traditional versus patency documented hemostasis after transradial catheterization. Catheter Cardiovasc Interv. 2008;72(3):335-40.

36. Dahal K, Rijal J, Lee J, Korr KS, Azrin M. Transulnar versus transradial access for coronary angiography or percutaneous coronary intervention: A meta-analysis of randomized controlled trials. Catheter Cardiovasc Interv. 2016;87(5):857-65.
37. Kiemeneij F. Left distal transradial access in the anatomical snuffbox for coronary angiography (ldTRA) and interventions (ldTRI). EuroIntervention. 2017;13(7):851-7.
38. Pitta SR, Prasad A, Kumar G, Lennon R, Rihal CS, Holmes DR. Location of femoral artery access and correlation with vascular complications. Catheter Cardiovasc Interv. 2011;78(2):294-9.
39. Rapoport S, Sniderman KW, Morse SS, Proto MH, Ross GR. Pseudoaneurysm: a complication of faulty technique in femoral arterial puncture. Radiology. 1985;154(2):529-30.
40. Altin RS, Flicker S, Naidech HJ. Pseudoaneurysm and arteriovenous fistula after femoral artery catheterization: association with low femoral punctures. AJR Am J Roentgenol. 1989;152(3):629-31.
41. Illescas FF, Baker ME, McCann R, Cohan RH, Silverman PM, Dunnick NR. CT evaluation of retroperitoneal hemorrhage associated with femoral arteriography. AJR Am J Roentgenol. 1986;146(6):1289-92.
42. Grier D, Hartnell G. Percutaneous femoral artery puncture: practice and anatomy. Br J Radiol. 1990;63(752):602-4.
43. Rupp SB, Vogelzang RL, Nemcek AA, Jr., Yungbluth MM. Relationship of the inguinal ligament to pelvic radiographic landmarks: anatomic correlation and its role in femoral arteriography. J Vasc Interv Radiol. 1993;4(3):409-13.
44. Fitts J, Ver Lee P, Hofmaster P, Malenka D, Northern New England Cardiovascular Study G. Fluoroscopy-guided femoral artery puncture reduces the risk of PCI-related vascular complications. J Interv Cardiol. 2008;21(3):273-8.
45. Schnyder G, Sawhney N, Whisenant B, Tsimikas S, Turi ZG. Common femoral artery anatomy is influenced by demographics and comorbidity: implications for cardiac and peripheral invasive studies. Catheter Cardiovasc Interv. 2001;53(3):289-95.
46. Mignatti A, Friedmann P, Slovut DP. Targeting the safe zone: A quality improvement project to reduce vascular access complications. Catheter Cardiovasc Interv. 2018;91(1):27-32.
47. Wu SY, Ling Q, Cao LH, Wang J, Xu MX, Zeng WA. Real-time two-dimensional ultrasound guidance for central venous cannulation: a meta-analysis. Anesthesiology. 2013;118(2):361-75.
48. Gedikoglu M, Oguzkurt L, Gur S, Andic C, Sariturk C, Ozkan U. Comparison of ultrasound guidance with the traditional palpation and fluoroscopy method for the common femoral artery puncture. Catheter Cardiovasc Interv. 2013;82(7):1187-92.
49. Sobolev M, Slovut DP, Lee Chang A, Shiloh AL, Eisen LA. Ultrasound-Guided Catheterization of the Femoral Artery: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. J Invasive Cardiol. 2015;27(7):318-23.
50. Soverow J, Oyama J, Lee MS. Adoption of Routine Ultrasound Guidance for Femoral Arterial Access for Cardiac Catheterization. J Invasive Cardiol. 2016;28(8):311-4.
51. Chandrasekar B, Doucet S, Bilodeau L, Crepeau J, deGuise P, Gregoire J, et al. Complications of cardiac catheterization in the current era: a single-center experience. Catheter Cardiovasc Interv. 2001;52(3):289-95.
52. Piper WD, Malenka DJ, Ryan TJ, Jr., Shubrooks SJ, Jr., O'Connor GT, Robb JF, et al. Predicting vascular complications in percutaneous coronary interventions. Am Heart J. 2003;145(6):1022-9.
53. 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):541-5.
54. Schulz-Schupke S, Helde S, Gewalt S, Ibrahim T, Linhardt M, Haas K, et al. Comparison of vascular closure devices vs manual compression after femoral artery puncture: the ISAR-CLOSURE randomized clinical trial. JAMA. 2014;312(19):1981-7.

55. Biancari F, D'Andrea V, Di Marco C, Savino G, Tiozzo V, Catania A. Meta-analysis of randomized trials on the efficacy of vascular closure devices after diagnostic angiography and angioplasty. Am Heart J. 2010;159(4):518-31.
56. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, et al. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention. A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. J Am Coll Cardiol. 2011;58(24):e44-122.
57. Martin JL, Pratsos A, Magargee E, Mayhew K, Pensyl C, Nunn M, et al. A randomized trial comparing compression, Perclose Proglide and Angio-Seal VIP for arterial closure following percutaneous coronary intervention: the CAP trial. Catheter Cardiovasc Interv. 2008;71(1):1-5.
58. Resnic FS, Wang TY, Arora N, Vidi V, Dai D, Ou FS, et al. Quantifying the learning curve in the use of a novel vascular closure device: an analysis of the NCDR (National Cardiovascular Data Registry) CathPCI registry. JACC Cardiovasc Interv. 2012;5(1):82-9.
59. Azzalini L, Tosin K, Chabot-Blanchet M, Avram R, Ly HQ, Gaudet B, et al. The Benefits Conferred by Radial Access for Cardiac Catheterization Are Offset by a Paradoxical Increase in the Rate of Vascular Access Site Complications With Femoral Access: The Campeau Radial Paradox. JACC Cardiovasc Interv. 2015;8(14):1854-64.
60. Hulme W, Sperrin M, Kontopantelis E, Ratib K, Ludman P, Sirker A, et al. Increased Radial Access Is Not Associated With Worse Femoral Outcomes for Percutaneous Coronary Intervention in the United Kingdom. Circ Cardiovasc Interv. 2017;10(2):e004279.