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A Guide to Femoral Arterial Access for Resuscitative Endovascular Balloon Occlusion of the Aorta

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Arterial access is essential in the resuscitation of trauma and hemorrhagic shock patients and can be effectively used for rapid endovascular treatment such as resuscitative endovascular balloon occlusion of the aorta (REBOA) and interventional radiology (IVR), continuous invasive hemodynamic monitoring, and frequent blood tests. In the REBOA procedure, obtaining arterial access is the first and most critical step. Arterial access can be obtained in three ways: (1) blind/landmark technique, (2) ultrasound-guided technique or (3) surgical cutdown technique. Regardless of which technique is chosen, it is crucial to recognize external landmarks before implementing any technique. In ultrasound-guided puncture, there are two types of techniques: short-axis puncture and long-axis puncture. There are two methods for actual puncture: the single-wall puncture method and the double-wall puncture method. In cases of hemorrhagic shock, the double-wall puncture method is advantageous when it is necessary to obtain arterial access quickly and reliably. The cutdown technique is useful when the femoral artery cannot be identified through ultrasound guidance or cannot be punctured for a long time owing to puncture-induced hematoma or obesity. This technique should be used without hesitation if it is evaluated to be more rapid and reliable than an ultrasound-guided puncture.

Keywords: *Blind/Landmark Technique; Ultrasound-Guided Technique; Surgical Cutdown Technique; Short-Axis Puncture; Long-Axis Puncture; Single-Wall Puncture Method; Double-Wall Puncture Method*

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INTRODUCTION

Obtaining arterial access should be one of the top priorities during resuscitation of patients with trauma or hemorrhagic shock. Access can be used for both REBOA and angioembolization [1–4]. Not only would it lead to quick activation of endovascular procedures, but it would also allow prompt invasive hemodynamic monitoring and repeat blood sampling during resuscitation. Furthermore, the inguinal approach allows quick access to both the artery and vein in a single sterile area. Even when the upper half of the body is occupied with procedures such as endotracheal intubation, thoracotomy, chest compressions, or defibrillation, the groin area should be easily accessible [1,5]. Large-bore venous access can be used for fluid administration or blood transfusion; therefore, the sheath should not be removed, even when it was inadvertently positioned in the vein. Removing the sheath would necessitate compression at the insertion site and cause a delay in the next puncture. Often, you should aggressively try to obtain both arterial and venous access if the patient is in shock.

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Hereby, we review the important aspects of femoral vessel anatomy and our recommended vascular access techniques for optimal REBOA and subsequent endovascular resuscitation in time-critical situations.

Ethical Approval and Informed Consent

Ethical approval was not required. Informed consent was not required.

METHODS OF OBTAINING ARTERIAL ACCESS

Failed attempts to obtain arterial access would lead to more blood loss, more delay in the subsequent intervention, and loss of the option of various endovascular procedures. Therefore, arterial access must be obtained rapidly and securely.

Arterial access can be obtained in three ways: (1) blind/landmark technique, (2) ultrasound-guided technique, or (3) surgical cutdown technique [6–11]. Historically, the blind technique was the mainstay of the puncture method. However, blood vessels are not always located at anatomically predicted locations. In particular, when the artery and vein overlap, there is a possibility of penetrating the vein. For obtaining access and prevention of complications, such as puncture-site hematoma formation, the ultrasound-guided technique is recommended for obtaining an arterial access [7,10].

The blind technique is not usually recommended, but occasionally it is inevitable, in situations where you do not have access to ultrasound, for example. Do not fixate on a single technique. If it does not work, immediately consider moving on to a different technique, including surgical cutdown [8–10].

In obese patients, exploration of the subcutaneous tissue is an option to shorten the distance to the vessels and subsequently confirm the location using ultrasound. Understanding the characteristics of each technique and using these techniques flexibly is essential, but the ultrasound-guided technique should be the standard approach [6,7,10,12].

Ultrasound-guided punctures have been reported to have higher technical success rates, improved secondary outcomes, and lower numbers of punctures and puncture times compared to percutaneous approaches using anatomical landmarks and palpation, although the primary outcomes were not significantly different [6,7,10]. In addition, there are some reports that access-related complications such as bleeding and hematoma are low and others that there is no difference, and no definite opinion has been obtained [6,7,12–19]. However, emergency arterial access is particularly challenging due to several factors. Due to the urgency, there is little time available for the ultrasound anatomical assessment, preparation, and performance of the procedure. Once the pulse is lost, vasoconstriction and loss of pulse make it difficult to identify the artery and confirm it with the ultrasound. In the case of cardiac arrest, chest compressions can result in significant torso movement, making it even more difficult. Patients with hematomas, edema, or obesity may have anatomical changes that interfere with ultrasound visualization. The presence of atherosclerosis or other abnormalities also makes the technique more difficult [4]. A study regarding emergency femoral access for REBOA demonstrated no difference in overall complication rates, incidence of specific complications, and relative risk of complications between echo-guided puncture and blind percutaneous approaches in non-compressible torso hemorrhage (NCTH) patients with shock requiring REBOA [20]. In addition, comparisons of arterial access methods concerning the time factor have revealed no significant differences between percutaneous and surgical cutdown approaches or ultrasound-guided percutaneous access versus blind access [20–22]. In a study on emergency femoral access for REBOA, the results showed that for arterial access in hypotensive NCTH patients requiring REBOA, a percutaneous approach using anatomical landmarks and palpation was used more frequently without increased complications, access attempts, and mortality compared to ultrasound-guided femoral artery access [20].

TIMING OF OBTAINING ARTERIAL ACCESS

After the decision to use REBOA has been made, it still takes at least several minutes to occlude the aorta because procedures such as obtaining an arterial access, inserting the REBOA catheter, and inflating the balloon are to be performed. Therefore, if you recognize any possibility that the patient might require the use of REBOA (which should happen much earlier than the actual decision to use REBOA), you must start the preparation for the procedure as early as possible [1–3,23,24].

Obtaining arterial access is the first and most critical step of the REBOA procedure. In patients with hemorrhagic shock, the femoral artery becomes unpalpable and the lumen of the vessel becomes narrowed [1]. The complication rate of vessel injuries and puncture-site hematoma increases because the technical difficulty of the puncture becomes more challenging. It has been reported that the survival rate decreases by 10% as the time to obtain an arterial access is delayed by 10 min; therefore, early arterial access is essential [1]. The following situations are reasonable indications for early arterial access in trauma: shock, positive Focused Assessment with Sonography for Trauma, suspicion of pelvic fracture, and multiple trauma. Early arterial access would also be helpful in trauma patients when the cause of shock was unclear at first but turned out to be retroperitoneal hemorrhage or, in non-traumatic patients, intrinsic intra-abdominal hemorrhage [1–3,23,24].

When obtaining arterial access in the early stages of trauma care, it may still be uncertain whether REBOA using an 18-G arterial line or small sheaths (4 Fr/5 Fr) is sufficient. The decision to obtain arterial access and the decision to use REBOA should be made separately. Indications for obtaining arterial access should be much broader than indications for initiating REBOA. Using small sheaths as initial access is more common and preferable than using larger profile sheaths compatible with REBOA. As mentioned above, sheaths inserted in the early stages can be used for monitoring invasive hemodynamic, conducting blood tests, and identifying access routes for other endovascular procedures [24]. After the decision has been made to use REBOA for aortic occlusion, the sheath should be upsized to a larger sheath size that supports the insertion of REBOA [13].

In addition, the size of the guidewires packed in the product must be paid attention to. The guidewire size varies among products; some are packed with 0.025-inch guidewires (Rescue Balloon®) and some are packed with 0.035-inch guidewires (Block Balloon®). The guidewire may not pass through the sheath or catheter because of the difference in size. To avoid unnecessary trouble during an emergency procedure, the specifications of the REBOA product going to be used must be known beforehand. In particular, Rescue Balloon® has three different guidewires: 0.035-inch guidewire for sheath insertion, 0.025-inch 145-cm guidewire for femoral artery approach, and 0.025-inch 240-cm guidewire for brachial artery approach.

PRACTICE OF ULTRASOUND-GUIDED PUNCTURE

Preparation

Our recommended items for ultrasound-guided arterial puncture

The items presented here are those we recommend, but some items may be obviated in the event of a time-sensitive emergency arterial access situation.

- Sheath introducer set (4 Fr or 5 Fr)
- Syringe
- Saline or heparinized saline
- Suture kit
- Local anesthesia
- Gauze
- Large surgical drape
- Ultrasound equipment
- Sterile ultrasonic probe cover

Priming Procedure (Figure 1)

(1) Open the stopcock
(2) Flush the sheath introducer (outer cannula) at will with the saline
(3) Close the stopcock
(4) Insert the dilator (inner cannula) into the sheath introducer (outer cannula)
(5) Flush the dilator (inner cannula) with saline

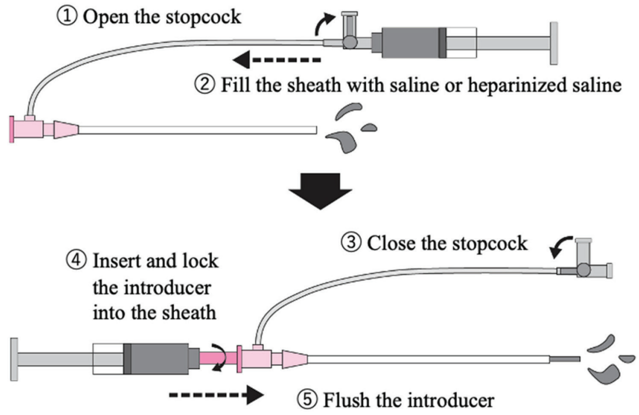


Figure 1 Priming procedure of the sheath.

In the most urgent setting, flushing with saline may be omitted before puncture. The lumen of the sheath introducer will fill with the backflow of the blood and then be flushed with saline.

Puncture Site

The common femoral artery (CFA), brachial artery, and radial artery are used as arterial accesses. In emergency situations, the CFA is commonly selected for several reasons:

(1) Easy to palpate and puncture because of the anatomical location and size.
(2) Manual compression is achieved easily with the femoral head.
(3) The risk of erroneous puncturing is relatively low because the arteries and veins are located in parallel.
(4) May reduce the risk of occlusion due to dissection or spasm.

Simultaneous bilateral femoral access can be considered according to the hemodynamics or subsequent procedures (REBOA, interventional radiology, surgery). The CFA branches into the superficial femoral artery (SFA) and deep femoral artery (DFA). Arterial access must be obtained from the CFA (above the bifurcation). The CFA is found just medial to the midpoint of the inguinal ligament (halfway between the pubic symphysis and the anterior superior iliac spine) in the inguinal crease region [25–28]. When fluoroscopy is available, puncture occurs between the center and one-third level of the femoral head [11]. The CFA and common femoral vein (CFV) do not completely overlap at the level of the inguinal ligament, with the CFA located lateral to the CFV (Figure 2*a*). As these vessels move toward the lower extremity, the CFV is positioned dorsal to the CFA (Figure 2*b*), and at the level of the sartorius muscle, the CFA completely lies on top of the CFV (Figure 2*c*). Therefore, when puncturing at this level, care should be taken because the CFA is collapsed during shock or cardiac arrest, and the needle may penetrate the anterior and posterior walls of the

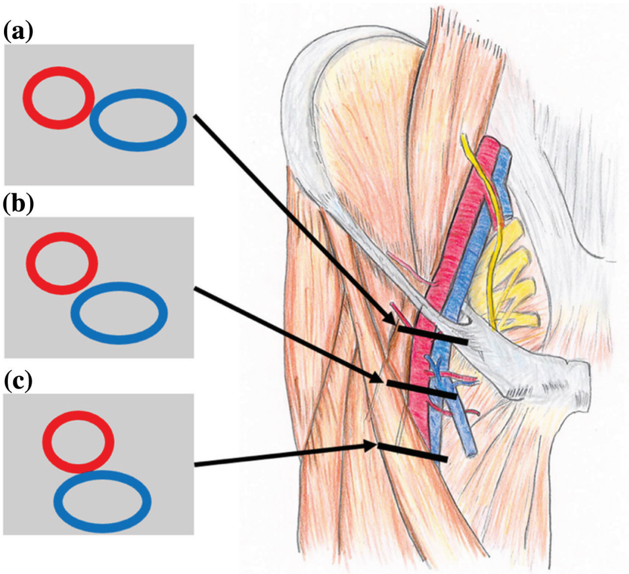


Figure 2 The relative position of CFA and CFV.

CFA and enter the CMV. Because of the above, there is strong support today for the use of ultrasound to visualize the vessel and obtain vascular access to increase success rates and reduce complications. Ultrasound-guided puncture is also strongly recommended for time-critical CFA or CFV access, and we consider it to be of paramount importance for success.

The risk of performing a high-level puncture is intra-abdominal puncture or peritoneal or retroperitoneal hematoma [24,29–34]. On the other hand, a low-level puncture may result in SFA puncture, guidewire migration to the DFA via the SFA, and arteriovenous puncture [24,29–31]. In addition, large-bore arterial access in the SFA could result in leg ischemia. The external landmarks are shown in Figure 3.

In obese patients, the inguinal ligament is located on the cranial side of the inguinal skin crease. It should be noted that obese patients have a more cephalad location of the inguinal ligament and CFA than expected compared to non-obese patients [4]. Therefore, the inguinal ligament should be identified with the pubic symphysis and the anterior superior iliac spine. Furthermore, in obese patients, the distance from the skin to the artery may be very long, and when an echo is performed, it may be difficult to identify the femoral artery within the range of the echo screen. In such cases, the cutdown method described below can be used in combination to reduce the distance from the echo probe to the artery, making identification of the artery on the echo easier [4]. The SFA may be the most palpable if the bifurcation of the CFA is high-level [32,33]. If the puncture position is determined only by the inguinal skin crease or palpation, the position may be inappropriate (often too low). Confirm the puncture site with fluoroscopy (femoral head) or ultrasound (bifurcation) guidance to avoid misplacement [18,29,35,36].

During severe hemorrhagic shock, when a cardiac arrest or the cardiac arrest is imminent, the femoral artery is vasoconstricting and its diameter is smaller than during normotension, making it difficult to obtain arterial access. In addition, in the state of cardiac arrest, the arterial and venous pressure waveforms are the same due to chest compressions for cardiopulmonary resuscitation (CPR), making it difficult to distinguish them reliably. In addition, when normal arterial pressure is lost, the arteries tend to collapse due to surface compression by the echo probe. Furthermore, the movements and vibrations induced by CPR make not only ultrasound imaging but also puncture and access to the artery difficult [4].

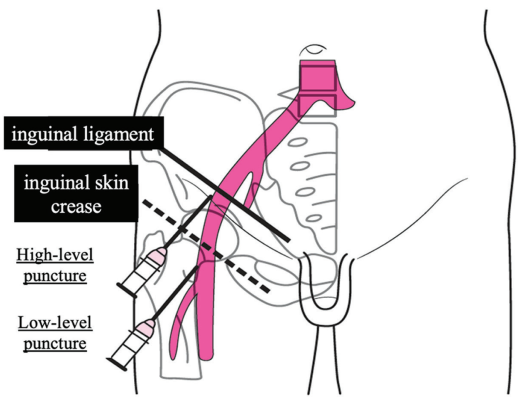


Figure 3 Landmark of the body surface at the time of puncture.

Procedure

There are two types of techniques for ultrasound-guided puncture: short-axis (SA) puncture and long-axis (LA) puncture [37–42].

Short-axis puncture

In the SA puncture method, a probe is applied perpendicularly to the artery to create a short-axis view. With this method, the center of the anterior wall of the artery can be confirmed at the moment of puncture (Figure 4). Therefore, the SA method is preferred as the first choice for an emergency. It is the only possible choice in the case of non-flat skin (obesity) or insufficient space for LA placement (pediatric case or short neck). Because this method does not provide the entire length of the puncture path on a single scanning plane, the operator needs to continue capturing the needle tip according to the advance of the needle [37–42].

To securely capture the needle tip, the probe should be located slightly anterior to the puncture site. Imagine that the needle tip enters the scanning plane. The needle tip should be recognized before the tip reaches the anterior wall of the artery and then the probe should be tilted (alternatively, slide the probe forward) until the tip disappears from the screen. As the needle is advanced slowly,

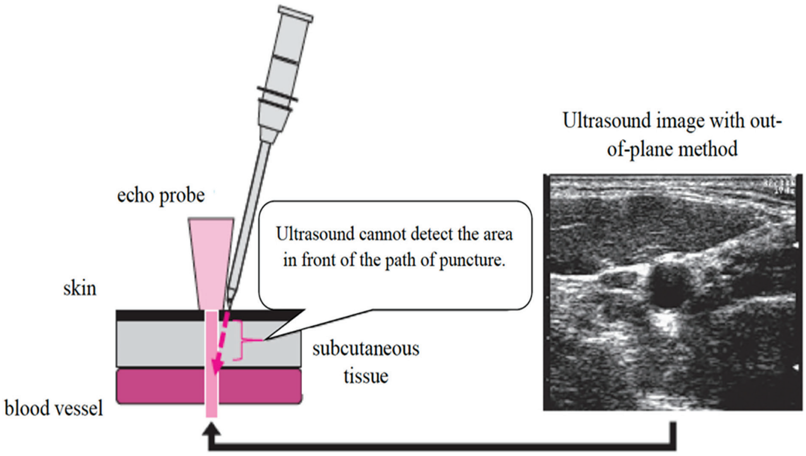


Figure 4 Short-axis puncture (out-of-plane method).

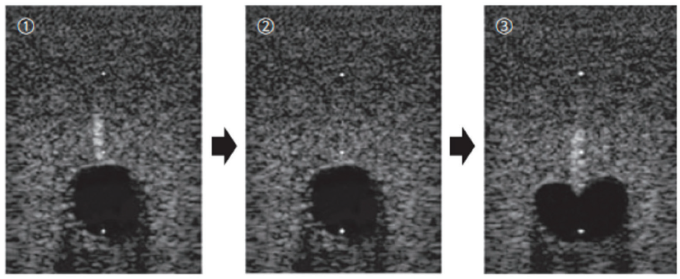


Figure 5 Needle tip visualization in short-axis puncture.

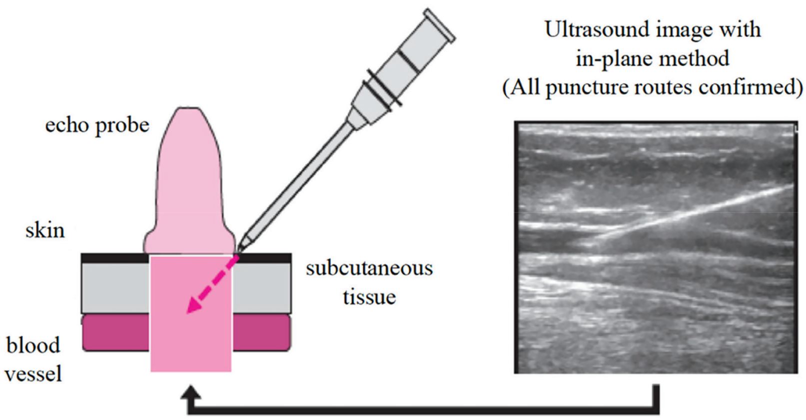


Figure 6 Long-axis puncture (in-plane method).

the tip appears again. These processes are repeated until the tip arrives at the anterior wall (Figure 5) [37–42].

Long-axis puncture

In the LA puncture method, a probe is inserted parallel to and immediately above the artery to create a LA view (Figure 6). This method provides the entire puncture route on a single scanning plane. Since this method does not visualize the center of the anterior wall (unlike the SA puncture method), it concentrates on keeping the probe on the centerline of the artery (Figure 7). The needle guide helps avoid deviation from the puncture route [37–42].

Advantages and Disadvantages of Both Methods

LA punctures can help visualize the entire puncture route, but the probe must be maintained parallel to the

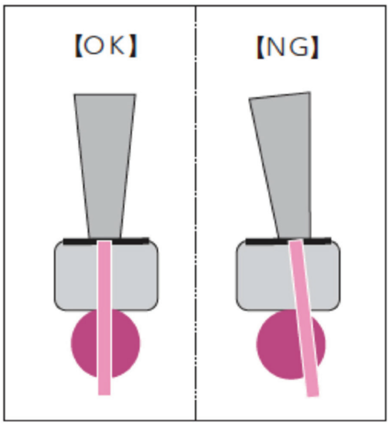


Figure 7 Schema of drawing from the center of a blood vessel with ultrasound guidance (long-axis puncture).

artery. In contrast, SA punctures help visualize the needle tip and the center of the artery. However, the probe must be constantly adjusted (tilted or slid) to recognize the needle tip because the entire puncture route cannot be visualized on a single plane. The advantages and disadvantages of each technique described above must be understood [37–42].

In both methods, we comprehend how and where the arteries run. The three-dimensional anatomy and depth of the target artery via a pre-scan (sweep scan and swing scan technique) should be recognized. After confirming the bifurcation of the CFA to the SFA and DFA, puncture the CFA, the segment cephalad to the bifurcation; sterilize the access area; and provide local anesthesia, as needed [37–42].

We investigated whether emergency arterial access was obtained by the LA or SA method in 15 emergency hospitals and emergency centers in Japan in 2021, and it was revealed that 1 institution performed LA punctures and 14 institutions performed SA punctures.

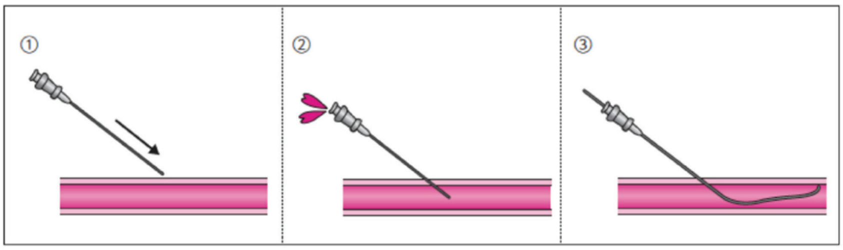
In addition, we performed a literature search in comparing LA puncture versus SA puncture in vascular access. As a result, there was no significant difference in first-pass success rate, mean time to success, mean number of attempts to success, or hematoma incidence between LA and SA punctures in overall vascular access [43,44]. As far as we could search, there were no studies limited to emergency arterial access to the femoral artery in adults comparing LA and SA punctures. In a study of pediatric femoral artery access, the initial puncture success rate was significantly higher for LA, the mean time to successful initial puncture and total catheter insertion time were significantly shorter for LA, and complications were not significantly different [42]. In addition, there were reports of higher success rates, shorter cannulation times, and significantly less posterior wall damage with LA punctures and no difference in radial artery access [45–47]. Regarding venous line access, there are some reports that SA puncture has a higher success rate than LA, others that there is no significant difference, and others that LA puncture has a lower complication rate and fewer punctures [39,48,49]. Therefore, there is no clear consensus on which is superior.

CATHETER (SHEATH) INSERTION PROCEDURE

Puncture with Puncture Needle and Check for the Backflow of Blood

Single-wall puncture method

In this method, the needle is advanced into the lumen of the vessel by penetrating only the anterior wall. The guidewire is advanced while holding the needle when the backflow of blood is confirmed (Figure 8). This method is advantageous for patients with coagulation disorders, including those on anticoagulant or antiplatelet medications. It does not involve a puncture of the posterior wall and thus does not form a hematoma behind the posterior wall. The outer tube must also be firmly inside the blood vessel when using a puncture needle with an inner and outer tube. If the momentum of the backflow is insufficient after removal of the inner tube (similar to a metal needle), the needle tip may not have entered the artery. When only a slow backflow is observed, the needle tip may be within the anterior wall. There is a risk of arterial dissection or extravascular implantation if the guidewire is advanced in this condition [34,50].



① Advance the needle into the lumen of the vessel, ② when it is confirmed that the tip of the needle has entered the lumen of the vessel, ③ advance the guidewire.

Figure 8 Schema diagram of the single-wall puncture.

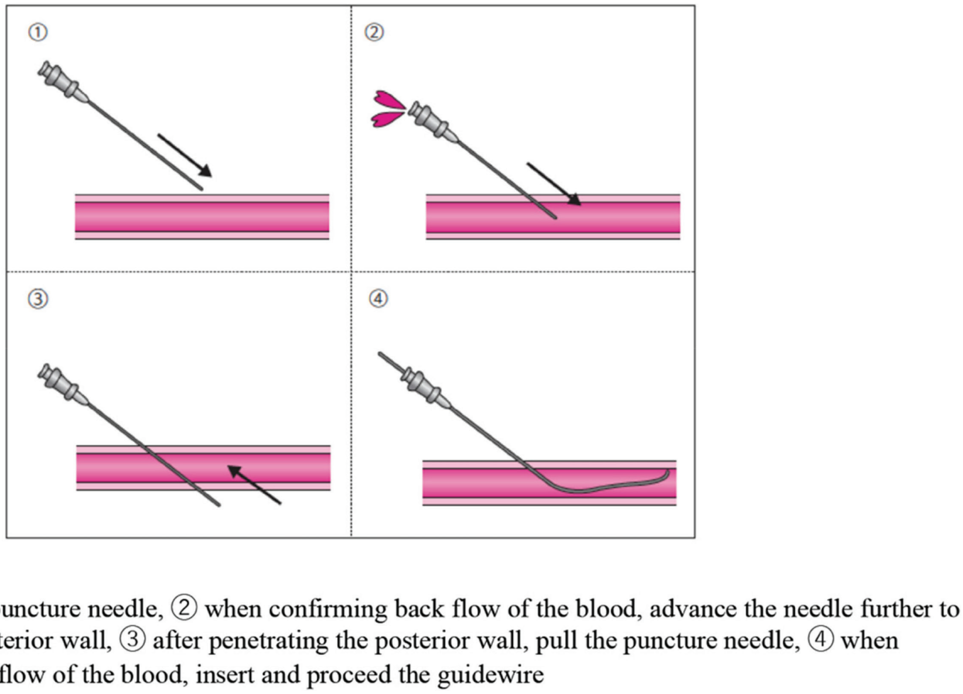


Figure 9 Schema diagram of the double-wall puncture.

In addition, using a small-diameter puncture needle (e.g., micropuncture kit) makes it easier to puncture the anterior wall because of the minor collapse of the lumen by the puncture pressure. The micropuncture kit generates slow backflow, even when placed correctly. In addition, the small-profile guidewire does not provide “unpleasant” resistance when the wire is advanced in the dissection or extravascularly. Thus providers may feel it is challenging to recognize the difference between correct and incorrect placement.

Furthermore, in patients with hemorrhagic shock, vessel diameter changes are smaller. The lumen collapses more easily under puncture pressure. As a result, a single-wall puncture may become challenging and unreliable.

Double-wall puncture method

In the double-wall puncture, the puncture needle is first advanced into the lumen, which is confirmed by the backflow; then, the needle is advanced further until the backflow disappears. Next, the inner tube is removed in the case of a puncture needle with an inner and outer tube. Furthermore, the outer tube is pulled out slowly while lying down until the backflow is reliably observed. Finally, the guidewire is advanced while the backflow is maintained (Figure 9) [34,50].

The double-wall puncture method confirms the backflow of blood by applying a pulling force, unlike a pushing force in the single-wall puncture method, and the lumen can be captured more reliably. Therefore, the double-wall puncture is more effective than the single-wall puncture if the puncture needle is placed securely in the blood vessel. The risk of posterior hematoma is usually negligible. The high-level puncture should be avoided; otherwise, the retroperitoneal hematoma may spread owing to ineffective compression.

How to Advance the Guidewire

First, when advancing the guidewire, the hand that grasps the outer tube (or metal needle) should be fixed to the patient and not moved. After confirming the backflow of blood, the outer tube should be held firmly, and the guidewire should be advanced. If fluoroscopy is available, the tip of the guidewire should be checked visually by the operator while simultaneously feeling resistance to advancing.

When the guidewire is inserted correctly, the resistance felt from the guidewire will be minimal. If any resistance is met, particularly at the beginning of guidewire advancement, it is an indication that the tip was not positioned in the vessel. In such a case, the backflow should be rechecked. Particular attention should be paid when micropuncture kits are used. When resistance is felt after advancing the wire smoothly, the wire may have strayed into a branch vessel instead of the correct route of the external iliac artery. This may occur in low-level punctures, especially in obese patients. The angle of the puncture needle becomes steep, and the wire may enter through the SFA to the DFA. The solution is to reinsert the guidewire from the beginning or check the guidewire route using fluoroscopy or portable X-ray. When advancing a guidewire under non-fluoroscopic guidance in an emergency room or resuscitation room, it is essential to concentrate entirely on the resistance felt on advancing because this cannot be checked in real-time.

Confirmation of guidewire advancement is performed using a combination of fluoroscopy, portable X-ray, and ultrasound. Ultrasound-guided confirmation of the guidewire in the target vessel before dilation is a safe method that is recommended during central venous catheter insertion. The same procedure is also helpful in arterial puncture; however, it recognizes the risk of hematoma at the puncture site. The entire length of cannulation of the outer tube along the guidewire may decrease the hematoma when using an inner/outer tube-type puncture needle.

In addition, during the advanced guidewire procedure, it is sometimes observed that the puncture needle is dislodged from the vessel's lumen. In that case, the entire puncture needle and guidewire system should be removed and the puncture site should be firmly compressed.

How to Advance a Sheath Catheter Using the Over-The-Wire Method

When removing the outer tube of the puncture needle and advancing the catheter sheath, the puncture point is compressed firmly to prevent hematoma formation. When advancing the catheter sheath system into a blood vessel, first ensure that the guidewire is coming out of the back end of the catheter sheath. The catheter sheath is then advanced while grasping the straightened guidewire to prevent it from straying into the blood vessel. When the catheter sheath system is advanced, resistance is always checked with the hand holding the catheter sheath system. If resistance is present, insertion of the catheter sheath should be discontinued. If the catheter sheath is 4 Fr or 5 Fr, a skin incision is often unnecessary. However, if there is resistance in the skin when inserting the catheter sheath, a skin incision facilitates dilatation with a dilator.

Flush the inside of the catheter sheath with saline or heparinized saline and secure it

The catheter sheath should be flushed with saline or heparinized saline and secured to the skin to prevent it from slipping. Since the patient may then be moved to another location, the catheter sheath should be firmly secured to the skin with sutures. In such a case, the catheter sheath and its hub should be sutured and secured to the skin.

Catheter Sheath Management

After obtaining the arterial catheter sheath, flush with saline or heparinized saline. The sheath is then used for REBOA or endovascular treatment etc. When used for bleeding control, avoid flushing with heparinized saline as much as possible. After endovascular treatment is completed or REBOA is no longer needed, it should be removed as soon as possible due to the risk of thrombosis. For some reason, if the sheath is to be preserved, it should be used as an arterial pressure line or flushed intermittently or continuously with saline or heparinized saline [51–60]. When used as an arterial pressure line or for continuous flushing, it is often administered at 3 ml/h [51–60]. Studies comparing the efficacy of saline and heparinized saline flushes as flush solutions on arterial line patency have shown no difference in patency (or pressure waveform changes), with some reports indicating that the addition of heparin does not reduce the incidence of thrombosis [51–53,55–59,61], and others indicating that saline shortens the life of the arterial line due to occlusion [54,60]. However, when used as an arterial line for a long duration, heparinized saline has been reported to have better patency, lower flush frequency, and no side effects such as heparin-induced thrombocytopenia (HIT) [51]. Studies comparing continuous versus intermittent flushing of arterial lines have, as far as we have been able to investigate, been performed in transfemoral cerebral angiography, and there were no significant differences in the development of new embolic signals between the groups [62].

In conclusion, it is advisable to remove arterial sheath catheters as soon as possible, but if the sheath is left in place, intermittent or continuous saline flushing may be sufficient for a short period of time. However, if the sheath is to be used for a long-term period, such as a continuous arterial pressure line, it is recommended that heparinized saline be used.

CUTDOWN

Indication

In the case of obesity and thick, soft tissues, for example, it is technically challenging to perform ultrasound-guided puncture and the blind method while palpating the femoral artery pulse. Differences in the proficiency of the ultrasound-guided puncture technique itself may occur among practitioners. The cutdown method also requires a certain level of proficiency in surgical techniques, and individual differences in proficiency among practitioners may occur. The operator should not hesitate to use the cutdown method if the operator determines that it can be faster or more reliable than an ultrasound-guided puncture. There are no absolute indications for the cutdown method of securing the artery, but rather relative indications based on the patient's condition and the surgeon's skill level. Specifically, the following are typical scenarios that require cutdown procedures: both femoral arteries are punctured several times, but the artery is not hit; failure to identify the femoral artery by ultrasound guidance due to puncture-induced hematoma or obesity; and inability to puncture for a long time. When an operator is proficient in the cutdown, the method should change at the scene [4,8,9].

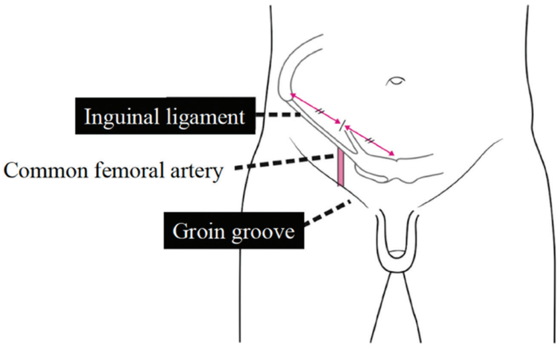


Figure 10 Body surface landmarks during skin incision.

Advantages and Disadvantages

The cutdown method can be more reliable than the ultrasound-guided puncture method if the femoral artery is exposed and punctured under direct vision. It can be performed under local anesthesia. In addition, the technique is such that it that can be performed by non-vascular surgeons with appropriate training. The disadvantage is that it may not be as quick as an ultrasound-guided puncture. It can be performed faster with more experience but requires more surgical training than other methods. It is recommended that cutdown items be set up in advance to save time. Since this is a surgical procedure, there is a risk of bleeding, infection, and secondary injuries. When securing the femoral artery by puncture is challenging, the femoral artery is sometimes exposed to cutdown. The catheter sheath is obtained by the direct puncture method, which requires time for fixation and wound closure after catheter sheath placement. For fixation, puncturing the blood vessel after penetrating the skin with a puncture needle provides better fixation after inserting the catheter sheath [4,8,9,63,64].

Anatomy and Landmark

Landmark

The landmark of the skin incision is the inguinal ligament. However, the inguinal groove between the abdomen and thigh is sometimes mistakenly thought of as the inguinal ligament, resulting in a skin incision made lower on the extremity than expected. It should be noted that the inguinal ligament is located between the superior anterior iliac spine and the pubic symphysis, and 3–5 cm cephalad of the inguinal groove between the abdomen and thigh (Figure 10) [8,9,11].

Type of skin incision

There are two main skin incision methods for cutdown: oblique and longitudinal incisions. A vertical incision is preferred for emergency cases because it allows the wound to be extended and the surgical field to be developed easily. The oblique incision provides better wound healing after closure and less visible wound scarring than the longitudinal incision. However, it is not suitable for emergency cases because it requires time to expose the blood vessels.

Anatomy of the femoral artery and the pathway to reach the femoral artery

After emerging from the inguinal ligament, the CFA branches posteriorly lateral to the DFA, approximately 4 cm caudal to the SFA (Figure 11). Since it is rare to find a vascular branch in the anterior surface of the CFA, after detachment of the anterior surface of the vessel and incising the vascular sheath, the anterior wall of the vessel is exposed, and the detachment proceeds to cranial and caudal while maintaining that layer. Suppose the detachment proceeds without exposing the anterior wall

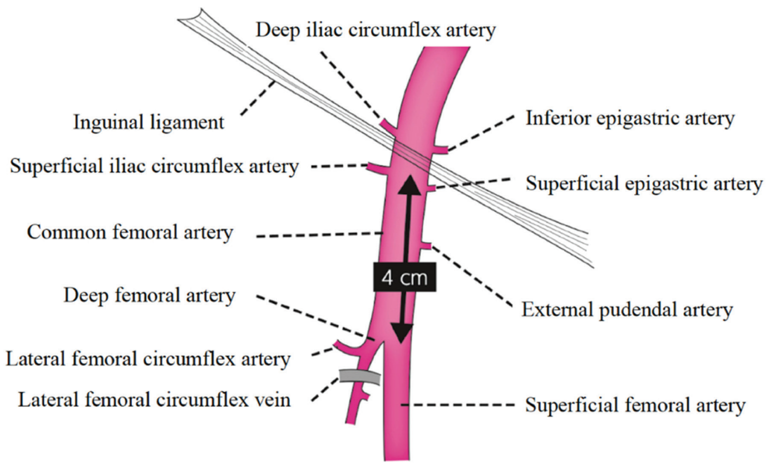


Figure 11 Branch vessels of the CFA.

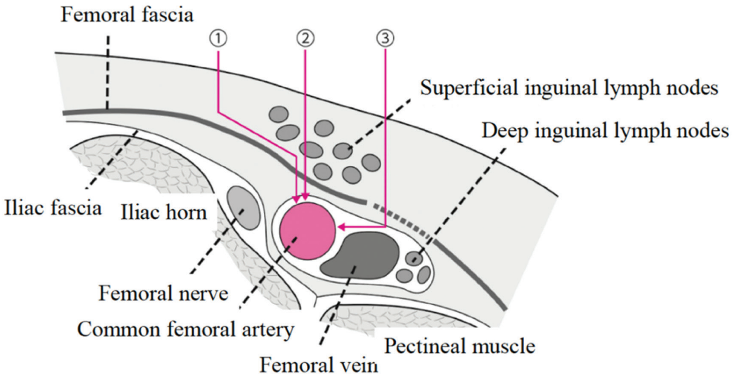


Figure 12 Pathway to reach the vascular sheath.

of the blood vessel. In such cases, it may injure the blood vessel branches and take a long time to detach the vessel, resulting in a delay in securing the blood vessel. Another way to reach the vascular sheath is from the medial or lateral side, avoiding the superficial inguinal lymph nodes in the subcutaneous tissue just above the vessels. However, this is not suitable for emergencies. Reaching the femoral artery vertically at the shortest possible distance from just above the femoral artery pulsation is a shorter exposure time (Figure 12) [26,27,36,65].

Procedure

Skin incision

When palpating the femoral artery pulsation, the skin incision should be assumed directly above the pulsation, longitudinally across the inguinal ligament, one-third to the head, and two-thirds to the lower extremities. To avoid a lower puncture, a skin incision should be made at a height that exceeds the inguinal ligament. If the pulsation is not palpable, the skin incision should be performed from the midpoint of the superior anterior iliac spine and pubic tubercle to the cranial and caudal, assuming a vertical length of about 10 cm (Figure 13). The area from the lower umbilicus to the knee should be sterilized and covered with a drape, and local anesthesia should be administered to the assumed site. As described above, oblique incisions provide good wound healing. However, in emergency cutdowns, longitudinal incisions are advantageous because of the ease of wound extension and because they run in the same running directions of the blood vessel [4,8,9].

Subcutaneous tissue to the femoral fascia

When the subcutaneous tissue is incised with electrocautery, it reaches the femoral fascia (Figure 14). Subsequently, the superficial abdominal wall arteries and veins and the superficial iliac circumflex arteries and veins may be visible, but in that case, ligation and hemostasis are performed. When the femoral artery is reached

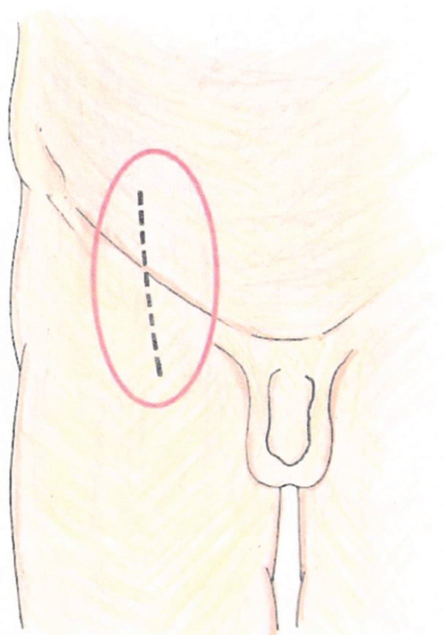


Figure 13 Skin incision.

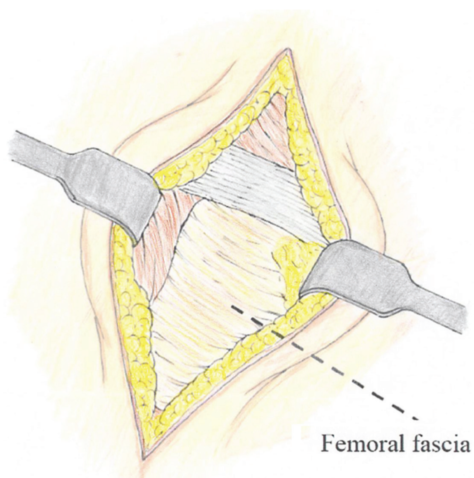


Figure 14 Exposure of the femoral fascia.

at the shortest distance, there are superficial inguinal lymph nodes that should be ligated or electrocauterized as much as possible to avoid postoperative lymphatic fistula or lymphocele. If there is not enough time, it can be performed after securing the catheter sheath. These maneuvers are performed using a wound retractor or a muscle hook by an assistant to expand the wound and develop the surgical field. However, if these preparations are not available and an assistant is not present, the surgeon should spread the wound using the index finger and the middle finger of the left hand [4,8,9].

Exposure of the femoral artery

When the femoral fascia is reached, the pulsation can be felt more clearly than through the skin, and puncture in this state may be an option. In addition, the ultrasound-guided puncture is more reliable in this state and may be helpful in obese patients. Puncture at this stage is advantageous in terms of speed. However, since the puncture is performed without taping the vessel, there is a risk of hematoma formation, persistent bleeding, and inability to perform a second or subsequent puncture if the double puncture method is used because there is not enough tissue around the vessel and compression is not effective. The point is to puncture without advancing the peeling too profoundly.

An incision through the femoral fascia reveals the vascular sheath. When the vascular sheath is incised sharply, the CFA is exposed (Figure 15). Exfoliation of the vascular sheath proceeds to the cephalic and caudal sides. On the caudal side, the bifurcation of the SFA and the DFA is exposed. Once the CFA is exposed, it should be taped and punctured while raising it using traction (Figure 16).

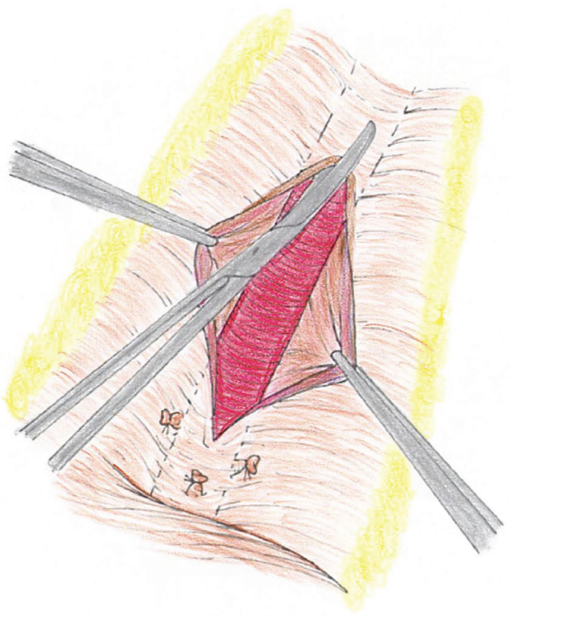


Figure 15 Exposure of the CFA.

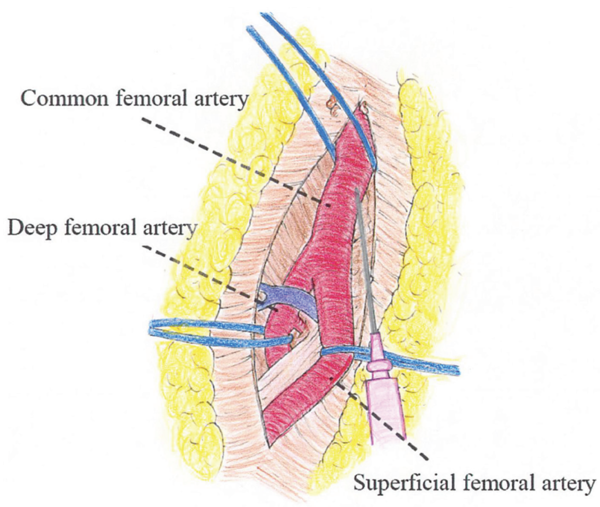


Figure 16 Taping and puncture of the CFA.

This avoids puncture of the posterior wall, facilitates the capture of the vessel lumen, and helps control bleeding in cases of puncture failure. Taping of the SFA and DFA would further ensure bleeding control. However, it may not be a priority in the emergency vascularization phase (taping all vessels is necessary when suturing vessels to remove large sheaths or cannulas). When taping, it is vital to incise the vascular sheath, expose the anterior wall of the artery, exfoliate the posterior wall from both lateral walls, carefully pass behind the posterior wall with vascular detachment forceps, and secure it with taping tape. Forcibly passing the detachment forceps from the outside of the vascular sheath without incising it, unintentionally passing the forceps to the posterior wall of the artery without ensuring that the lateral wall to posterior wall is exfoliated, pushing the forceps directly into the artery despite resistance to the forceps, and carelessly pointing the forceps tip upward without passing the forceps to the opposite side are avoided because they may cause posterior wall damage and branching damage to the artery (especially damage to the DFA), which may take more time and make hemostasis more difficult.

Insertion of the catheter sheath

After the CFA is exposed, the catheter sheath is inserted through the anterior wall of the vessel. The method of inserting the catheter sheath is the same as that for percutaneous insertion. However, suppose that the double-wall puncture method is performed when the artery is completely exposed. In such a case, it will be difficult to control bleeding from the posterior wall of the artery; consequently, this procedure is avoided as much as possible. To prevent bleeding around the insertion site, a purse-string suture is performed with a polypropylene (Prolene®) around the planned insertion site before inserting the catheter sheath, and the suture is ligated or tightened with a tourniquet after insertion of the catheter sheath. However, these procedures may be performed in emergencies after catheter sheath insertion because there is no time to spare. If the tourniquet is used, the suture can be used directly for ligation and closure of the insertion site when the catheter sheath is removed. Once the catheter sheath is obtained, the REBOA catheter insertion procedure is initiated.

Wound closure and catheter sheath fixation

Since the catheter sheath obtained by cutdown is much easier to dislodge than by percutaneous puncture, it should be firmly secured outside the wound once the wound is temporarily closed. If a Nelaton® catheter is used as a tourniquet, the Nelaton® catheter and mosquito pen are placed in the wound, and the wound is closed with sutures.

When there is a tendency to bleed due to coagulopathy, temporary closure by packing gauze around the sheath and inside the wound is helpful for wound closure. In addition, puncturing the blood vessel after penetrating the skin with a puncture needle during puncture may provide better fixation after sheath placement. This is especially useful when an oblique incision is used [4,8,9].

SUMMARY

The critical first step in establishing REBOA is access to the vessel itself, a time-critical procedure. Access to the femoral artery is the most practical method. Without rapid vascular access, effective REBOA and subsequent hemostasis will be difficult to achieve. Since time-critical REBOA and hemostasis can be lifesaving, the time required for initial vascular access has a significant impact on the outcome. The practitioner should be familiar not only with the anatomy of femoral vascular access, but also with vascular access techniques such as ultrasound-guided percutaneous puncture, femoral vascular cutdown, and sheath catheter insertion.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

Yosuke Matsumura was a clinical advisory board member of Tokai Medical Products (2015–2017). None of the other authors have any conflicts of interest to declare.

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Author Contributions

FN was responsible for drafting, editing, and submission of the manuscript. YM critically appraised the manuscript. YM, KY, TS, KI, and TM contributed to the critical revision of the manuscript for important intellectual content and provided intellectual input to the research and manuscript. All authors read and approved the manuscript.

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