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IMAGING

CASE REPORT: HOW WE DID IT

Understanding Cardiac Anatomy and Imaging to Improve Safety of Procedures

The Femoral Artery and Vein: Part 1

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ABSTRACT

We revisit and show comprehensive femoral access site anatomy with a combination of images obtained from detailed cadaveric dissection, fluoroscopy, computed tomography, ultrasound, and 3-dimensional printings. Part 1 focuses on the femoral triangle, femoral bifurcation, fluoroscopic and/or ultrasonographic anatomy, and branches of the femoral artery. Profound understanding of this region is fundamental to facilitate safe procedures and to avoid unnecessary complications. (JACC Case Rep. 2024;29:102807) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Although femoral access is 1 of the most common approaches for percutaneous endovascular procedures, associated complications, including excessive bleeding, retroperitoneal hematoma, vessel laceration or dissection, pseudoaneurysm, arteriovenous or arteriolymphatic fistula, and thrombosis remain significant clinical problems.[1-4] Technical factors as well as wide anatomical variation in this region can contribute to procedural complications. Femoral complications result in patient morbidity, prolonged hospital stays, and increased healthcare costs.[5] To avoid these complications, knowledge of femoral access site anatomy and its variations in relation to corresponding clinical images is essential.[1-10] However, systematic understanding is challenging because of limited resources demonstrating comprehensive anatomical information

TAKE-HOME MESSAGES

- A comprehensive understanding of 3-dimensional femoral access site anatomy is crucial for minimizing procedural complications.
- Detailed cadaveric dissection images with corresponding clinical images offer a unique opportunity to revisit femoral access site anatomy.

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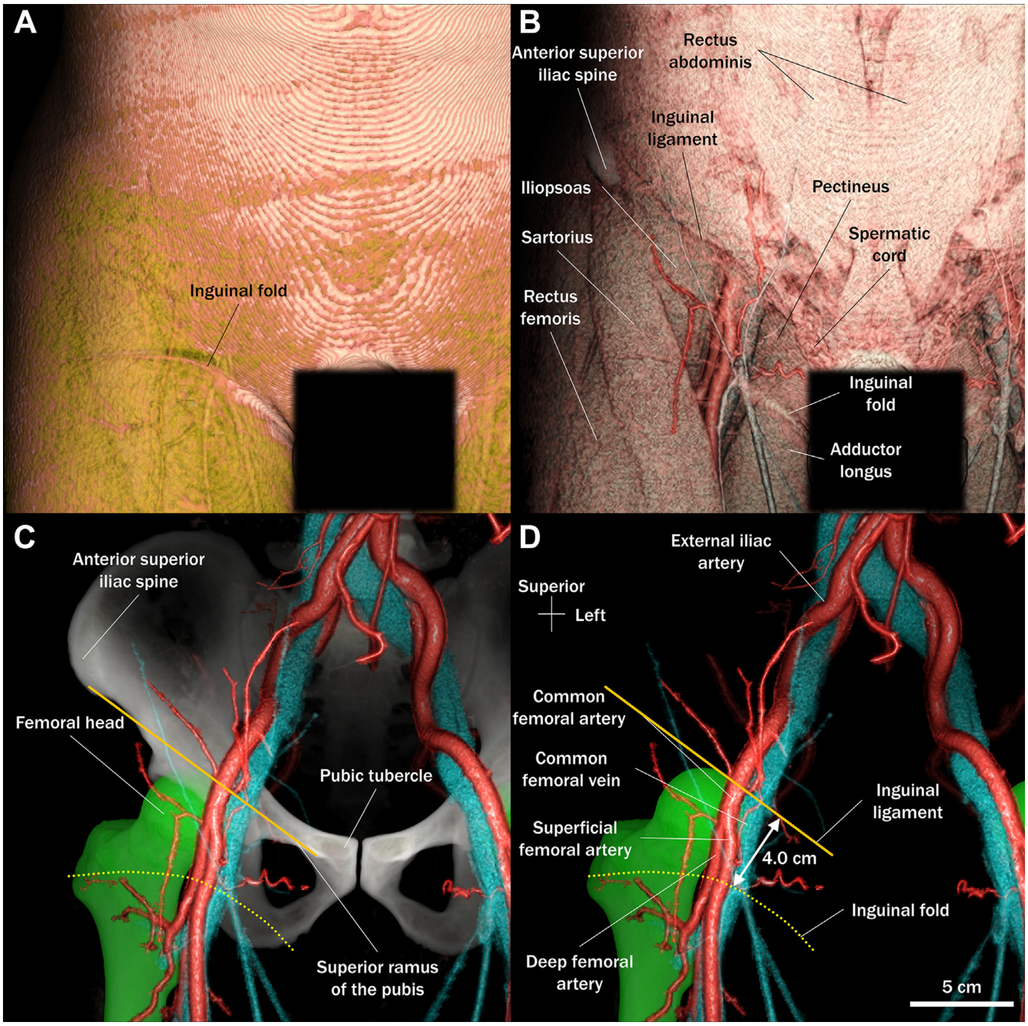
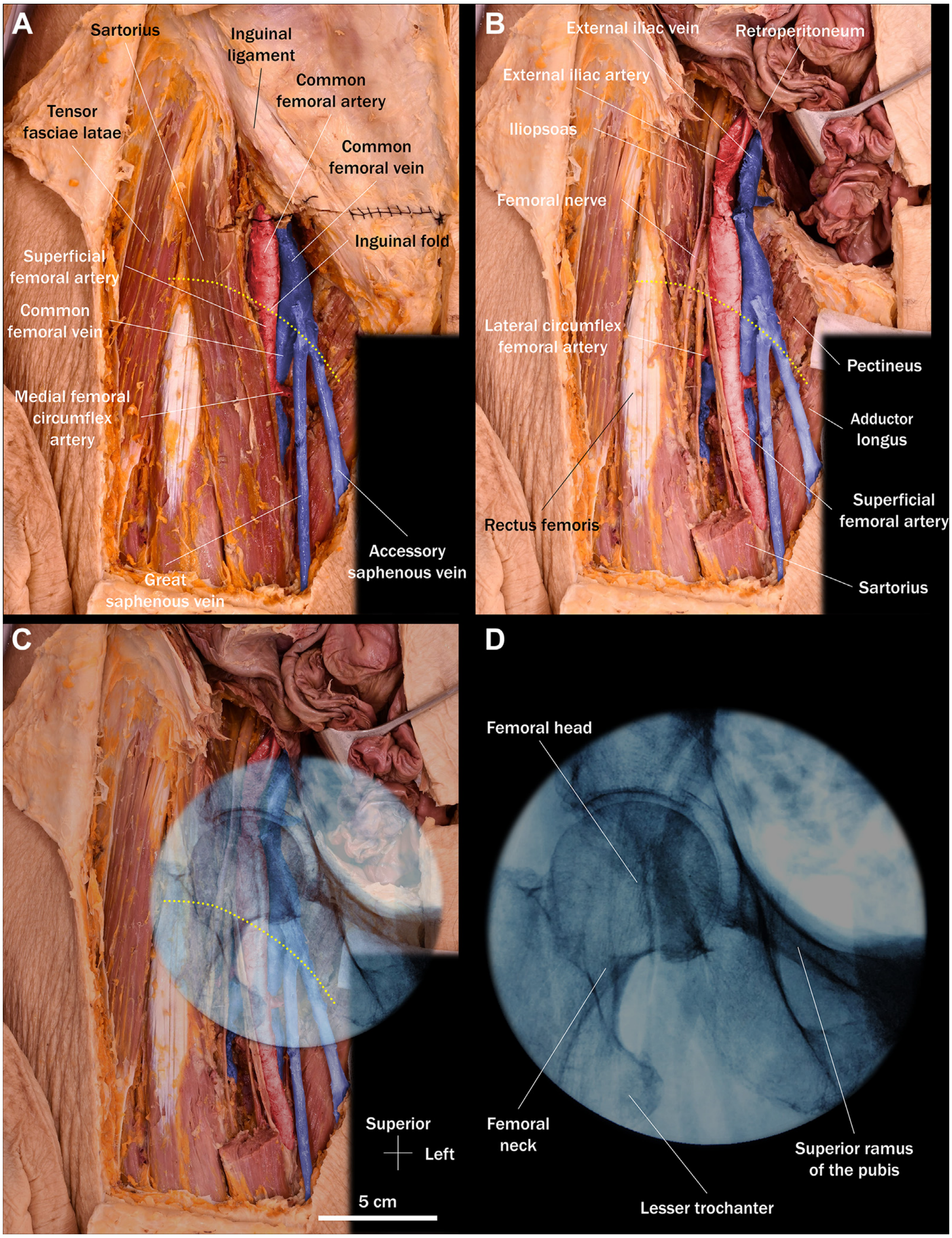
FIGURE 1 Virtual Dissection of the Femoral Triangle



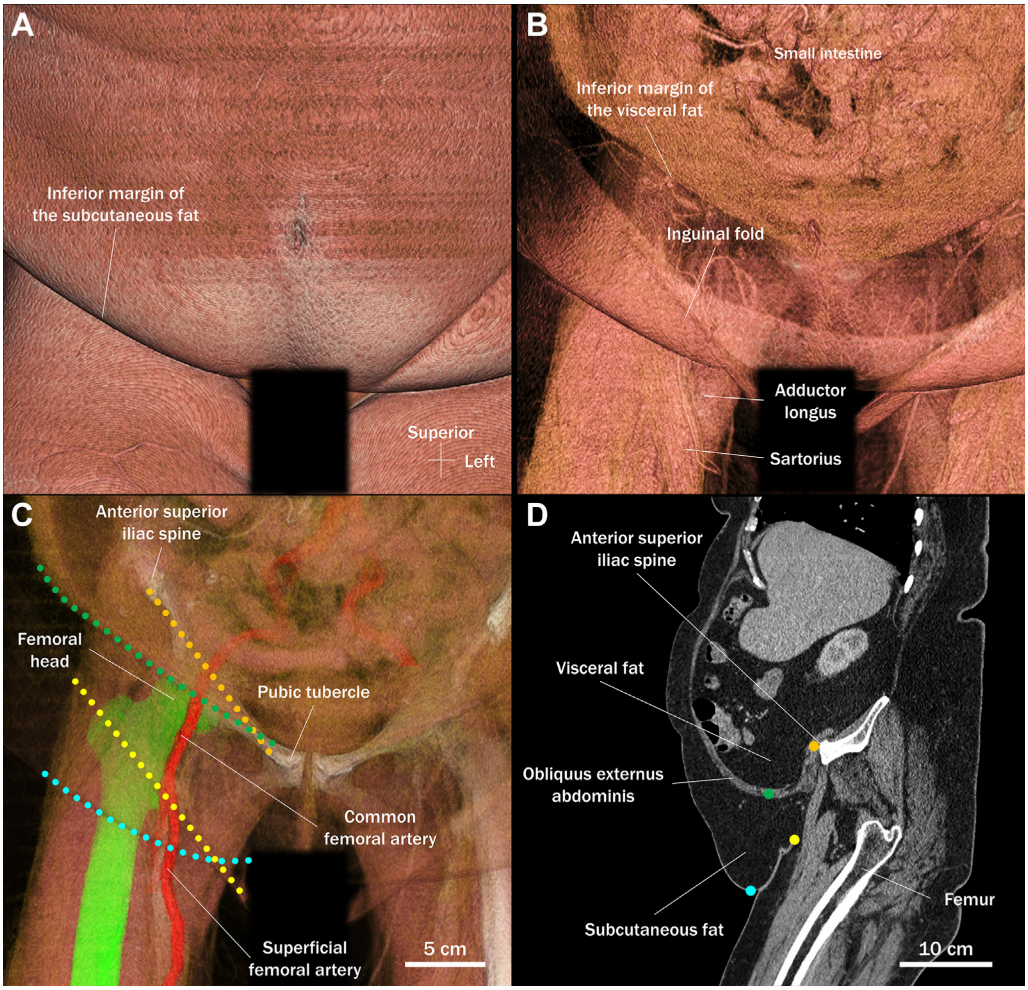
Volume-rendered frontal images of the right inguinal area are reconstructed from computed tomography datasets (as in Figures 3, 4, 6, and 7 in part 1 and Figures 1, 2, 4 to 8, and 10 in part 2[13]). These images confirm that the inguinal fold (yellow dotted lines) is situated 4.0 cm inferior to the inguinal ligament (orange lines) (A-D). Virtual progressive dissection reveals the femoral triangle, bordered by the sartorius, inguinal ligament, and adductor longus (B). Further progressive dissection with (C) and without (D) the pelvis shows the femoral head (4.6 × 4.4 cm in diameters) located between the inguinal ligament and fold, with the femoral vessels overlapping with medial part of the femoral head. Femoral artery bifurcation is generally located at or below the center of the femoral head.[1] In this case, appropriate puncture site of the common femoral artery between the bifurcation and inguinal ligament measures only 2.0 cm. Note that both common and superficial femoral arteries and veins are simply referred to as the femoral artery/vein in anatomical terminology.

FIGURE 2 **Real Dissection of the Femoral Triangle**



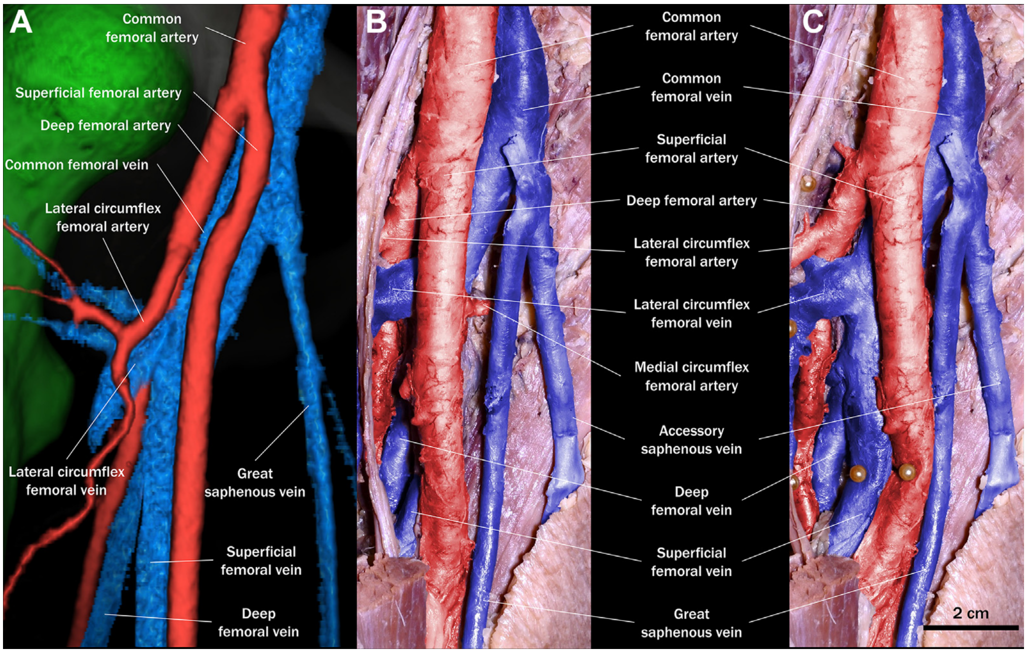
The real dissection image viewed from the frontal direction, corresponding to Figure 1B, shows the femoral artery and vein within the femoral triangle, bordered by the sartorius, inguinal ligament, and adductor longus (A). Arteries and veins are digitally colored red and blue, respectively (as in Figures 4 and 8 in part 1 and Figures 3, 6, and 9 in part 2[13]). Progressive dissection after the removal of the sartorius and inguinal ligament, with the abdominal wall opened, reveals the retroperitoneum between the intestine and external iliac artery and vein (B). Additional fluoroscopic examination of this body with (C) and without (D) overlay reveals the location of the femoral head in relation to the inguinal fold (yellow dotted lines) and femoral vessels. The femoral head is located between the inguinal ligament and fold (Figure 1). The femoral artery bifurcation is at the level of the saphenous vein bifurcation in this case (Figure 4), which is inferior to the femoral head. The common femoral artery and vein overlap with the medial half of the femoral head.

FIGURE 3 **Inguinal Ligament, Inguinal Fold, and Femoral Head in an Obese Patient**



Virtual progressive dissection images of this obese patient (body mass index, 44.3 kg/m^2) viewed from the frontal direction show the relationship between the inguinal ligament or fold (orange or yellow dotted lines), femoral head, and inferior margins of the visceral or subcutaneous fat (green or sky-blue dotted lines). The visceral and subcutaneous fat overlie the inguinal ligament and fold, respectively, that is also demonstrated in a sagittal multiplanar reconstruction image (D). The colors of the dots in D correspond to each color of the dotted line in C. Similar to the nonobese patients (Figures 1 and 2), the femoral head is located between the inguinal ligament and fold (C), serving as the ideal site for femoral access. However, the procedure is complicated because of the thick visceral and subcutaneous fat covering the access site, requiring retraction to establish an ideal window for ultrasound and optimal approach for femoral access.

FIGURE 4 **Virtual and Real Dissection of the Femoral Bifurcation**



Volume-rendered image (A) and the corresponding real dissection images without (B) and with (C) pins to displace the femoral artery, vein, and nerve to visualize the right femoral bifurcation are viewed from the right anterior oblique direction. The femoral artery bifurcation is lower in the case of real dissection (B and C) than in the case of virtual dissection (A). In both cases, however, femoral vein bifurcation is lower than femoral artery bifurcation (8.8 cm in A, 4.2 cm in B and C). At the level inferior to the femoral artery bifurcation, the distal common femoral vein or superficial and deep femoral veins are located behind the superficial femoral artery. Therefore, the appropriate puncture site of the common femoral vein is also situated between the femoral artery bifurcation and inguinal ligament. The lateral circumflex femoral artery and vein branch from the deep femoral artery and common femoral vein, respectively. The lateral circumflex femoral vein is sandwiched between the lateral circumflex femoral artery and deep femoral artery (Figure 6).

of this region. Furthermore, anatomical information solely obtained and visualized from the autopsied body cannot fill the gap between anatomical knowledge required for clinical practice targeting the living individual. Therefore, in part 1, we show femoral access site anatomy with a combination of detailed cadaveric dissection and clinical images (Figures 1 to 8) by using a similar pipeline that we have established for 3-dimensional analysis of the human heart anatomy,[11,12] mainly focusing on the femoral triangle, femoral bifurcation, fluoroscopic and/or ultrasonographic anatomy, and branches of the femoral artery. Revisiting comprehensive anatomical information of this region (parts 1 and 2) may help proceduralists improve their practice, facilitate better outcomes, and avoid unnecessary complications.

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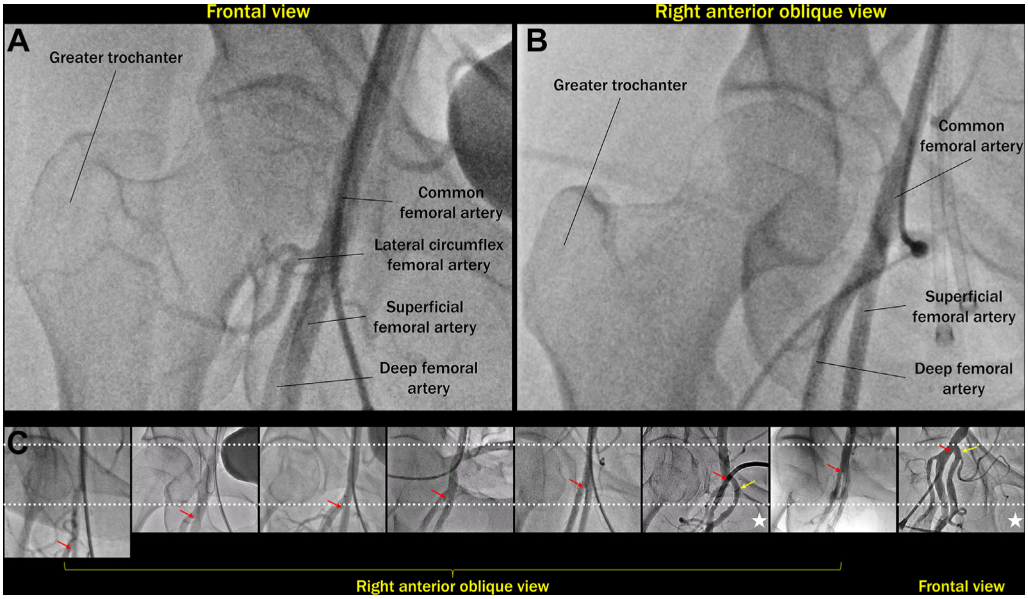
FIGURE 5 Variation in the Location of Femoral Artery Bifurcation Relative to the Femoral Head



In the frontal view (A), the femoral head, neck, and greater trochanter complex is foreshortened, the femoral artery overlaps with medial part of the femoral head, and the femoral artery bifurcation is not separated, limiting detailed anatomical evaluation. In contrast, the right anterior oblique view (B) can show a clear profile of these structures (Figure 1 in part 2[13]). Femoral artery bifurcation is located at or below the center of the femoral head in 98.5% of cases.[1] Wide variation in the location of femoral artery bifurcation (red arrows) relative to the femoral head (between the white dotted lines) is demonstrated (C). All images except the rightmost one (frontal view) are viewed from the right anterior oblique direction. The cases with stars show a rare variant where the deep femoral artery (yellow arrows) branches medially to the superficial femoral artery,[6] indicating the risk of arteriovenous fistula during the approach targeting the common femoral vein (Figure 8 in part 2[13]). High femoral artery bifurcation results in a shorter common femoral artery, complicating arterial access and increasing the risk of inadvertent high puncture. Awareness of these anatomical variants (C) is essential for avoiding complications. Thorough preprocedural evaluation and real-time ultrasound-guided puncture (**Figure 6**) with fluoroscopic support help achieve precise access and reducing associated risks.

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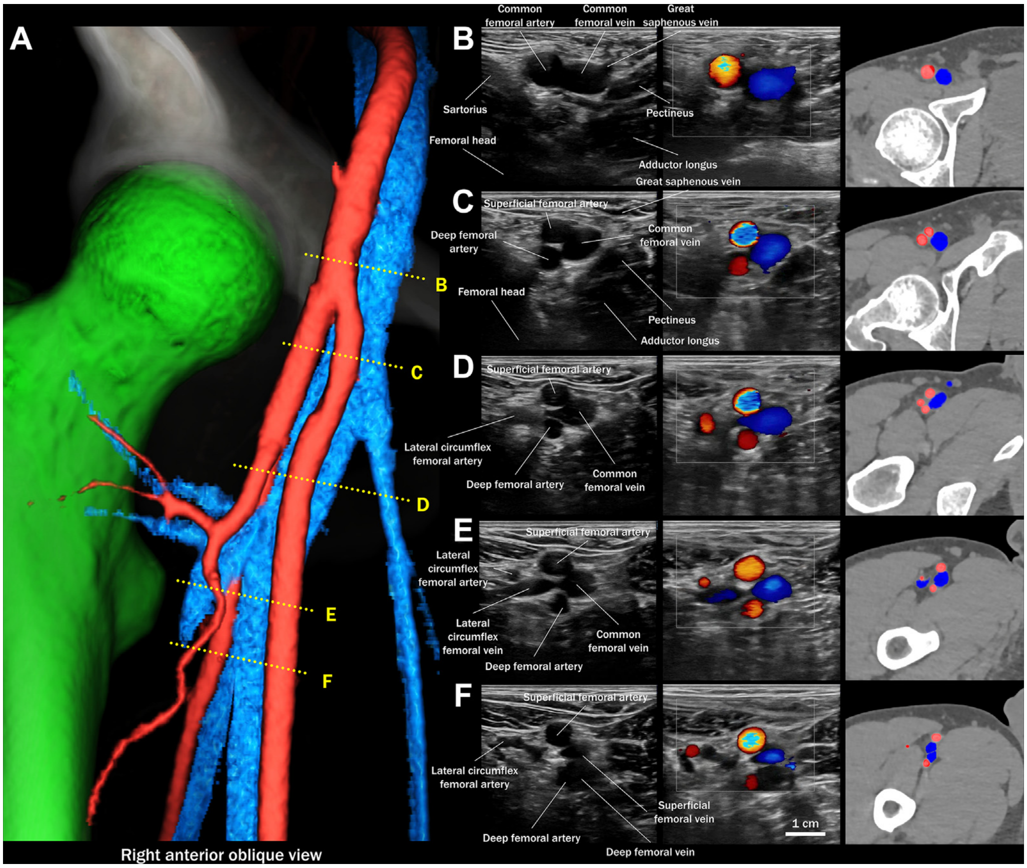
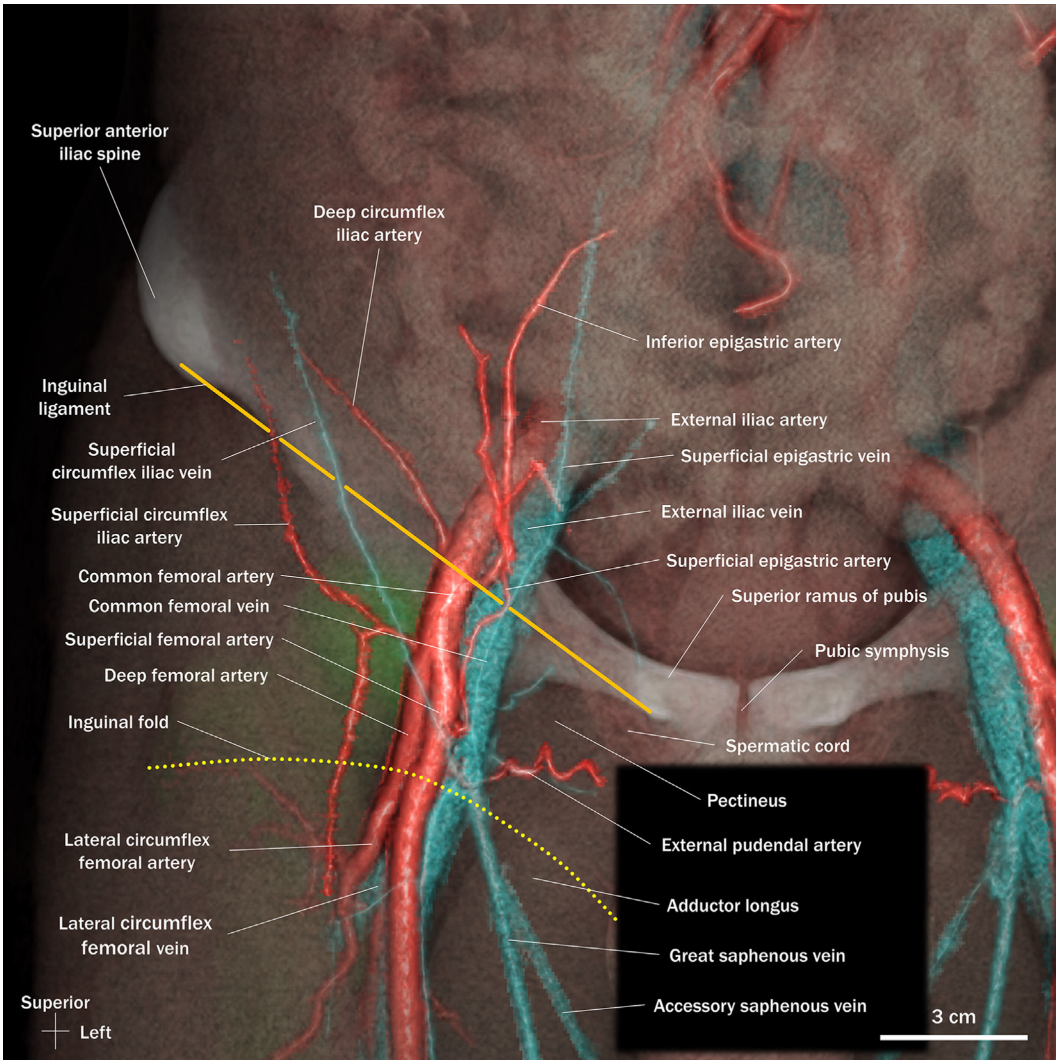
FIGURE 6 Ultrasound and Computed Tomographic Images of the Femoral Access Site



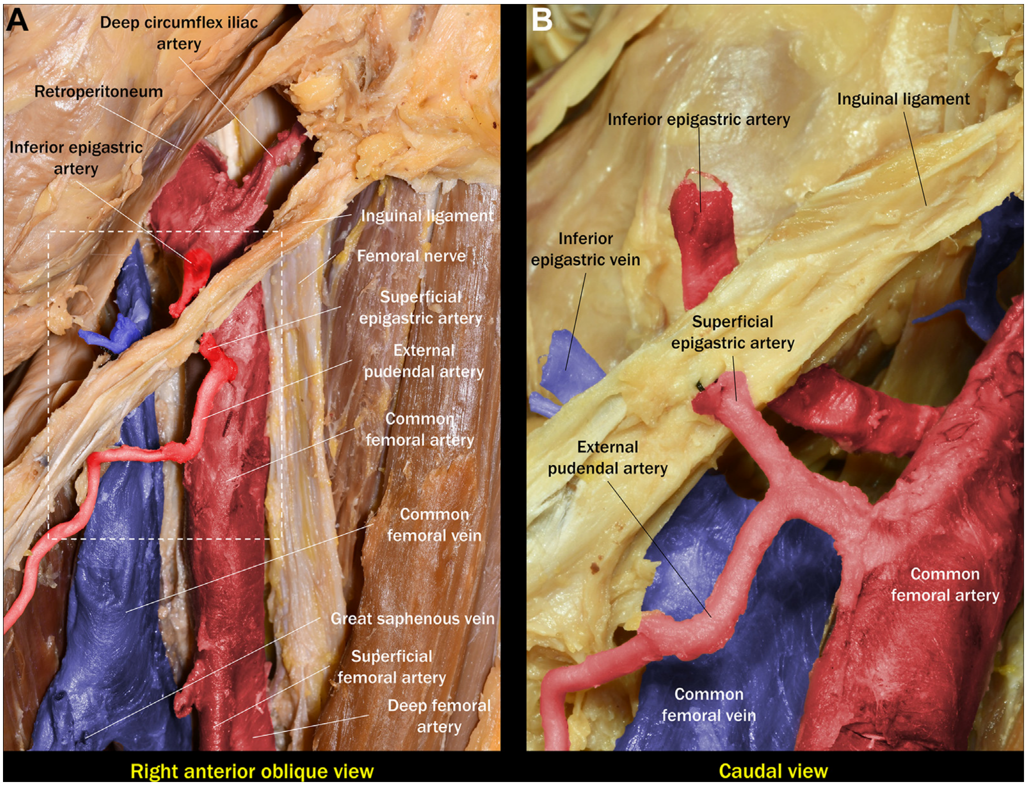
Volume-rendered image (A) of the right femoral artery and vein viewed from the right anterior oblique direction is shown alongside ultrasound and axial computed tomographic images. Yellow dotted lines marked as B through F in A correspond to each sectional plane in B through F in ultrasound, with (B-F, center) and without Doppler (B-F, left), and computed tomographic images (B-F, right). In the computed tomographic images, the arteries and veins are depicted in red and blue, respectively. Only the B level within the upper half of the femoral head identifies the ideal site for femoral access to minimize the risk of procedural complications, where you can also identify the femoral head in ultrasound. Computed tomography and ultrasound are not perfectly identical (origin of the great saphenous vein), because they are obtained from different subjects' datasets. Furthermore, pre-existing vascular pathologies, including atherosclerosis, calcification, and thrombus, can significantly influence procedural outcomes with an increased risk of complications such as arterial dissection or distal embolization. Identifying these factors through preprocedural imaging is essential for performing a safe procedure.

FIGURE 7 **Virtual Dissection of Small Branches in the Femoral Access Site**



Volume-rendered frontal image of the right femoral artery and vein demonstrates small branches found in the femoral access site. The inguinal fold (yellow dotted line) and the inguinal ligament (orange line) are indicated. The superficial epigastric artery or vein and superficial circumflex iliac artery or vein reside anterior to the inguinal ligament. In this case, the superficial epigastric artery, which typically branches off the common femoral artery, originates from the superficial femoral artery. Femoral access has a potential risk of inadvertent injury of these small branches, including the superficial circumflex iliac artery, inferior epigastric artery, superficial epigastric artery, and external pudendal artery. Injury to these branches can cause significant bleeding, which could continue throughout the procedure.

FIGURE 8 Real Dissection of Small Branches in the Femoral Access Site



The real dissection image of the left femoral access site focuses on small branches of the femoral artery and vein (A). The white dotted rectangle in A is magnified and in B, which is viewed from a slightly caudal direction. In this case, the origins of the superficial and inferior epigastric arteries are located inferior to the inguinal ligament, and both arteries are separated by the inguinal ligament (B). The external pudendal artery and superficial epigastric artery branch off the common femoral artery through a shared trunk in this case. The external pudendal artery is located anterior to the common femoral vein, indicating the potential risk of vessel laceration and/or dissection and arteriovenous fistula during common femoral vein approach (Figure 7 in part 2[13]). Importantly, these branches are detectable during ultrasound-guided puncture.

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