Anatomical Considerations of Infrageniculate Popliteal Artery Puncture: Alternative Pathway for Retrograde Access After Failed Re-entry

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Abstract:

Aims:

A distal approach in endovascular procedures for revascularization of lowers limbs can be considered in case of no re-entry in subintimal recanalization. The aim of this study is to evaluate the feasibility of a medial approach to the infrageniculate popliteal artery (IPA) using existing CT scan simulation and punctures performed on cadavers.

Methods and results:

CT angiographies of lower extremities were used to simulate IPA puncture and puncture trajectory. Tissues damaged during the trajectory between the puncture site and the access related injuries were analyzed.

Anatomical punctures on cadaverous model were also performed. Corpses were placed in supine position, the hip in slight flexion (40°) and abduction (external rotation of 60°). A 16G needle was used for the IPA puncture.

Twelve CT angiography simulations were made. Out of these 12 simulations, 9 revealed an isolated lesion of the popliteal vein, 2 isolated lesions of the tibial nerve. A lesion of the tibial nerve and the popliteal vein on the same simulation was once observed. Damage to the medial gastrocnemius muscle could not be avoided in each case.

Ten punctures were performed on cadavers with technical success. There were 6 popliteal vein lesions, 3 tibial nerve lesions and 1 case without lesion. In all cases, damage to the medial gastrocnemius muscle was seen.

Conclusion:

This medial approach was feasible and is accompanied by trauma of elements of the popliteal pedicle. Preoperative CT angiography could anticipate best site of puncture and potential access related injury.

Keywords: popliteal puncture - superficial artery recanalization - lower limb

Introduction

Open surgery with venous bypass represents the gold standard for TransAtlantic Inter-Society Consensus (TASC) C and D lesions (1) of the SFA and popliteal artery but often involve patients with severe comorbidities(2). Endovascular revascularizations offer the possibility of extensive femoro-popliteal occlusion treatment and are less invasive but lesions remain a technical challenge. They are proposed, despite length of lesions, to reduce morbidity of open surgery especially in elderly patients(2).

Bolia et al (3) had first described subintimal angioplasty for revascularization of superficial femoral artery occlusion. These techniques have extended indications of endovascular procedures but the risk of not being able to reenter the popliteal artery or a leg artery exists. IPA re-entry is not necessary in all cases and can be higher up according to technical success.

Retrograde access in the IPA can be chosen in order to avoid rotating the patient into a prone position.

Unfortunately, re-entry the distal true lumen is not successful in 13-25% of long recanalizations (4). Inability to re-enter can extend the length of the lesion. It can be done using a device specifically dedicated for this purpose, such as *reentry devices*: Outback™ (Cordis Corporation, Miami, FL; USA) (5), Pioneer™ (Medtronic, Inc, Minneapolis, Minn) (6) and Enteer™ (Medtronic, Minneapolis, MN) catheter(7). These reentry devices also have a failure rate of 10% and risk of bleeding complication due to extensive puncture with the Outback needle (5). This highlights the benefit of IPA puncture.

Distal puncture of leg arteries (tibial, peroneal or foot artery) has been used to ensure arterial continuity but severe complications were reported (8,9).

Popliteal artery access with a posterior puncture requires prone position and complicates the endovascular procedure. IPA puncture were described but no anatomical model was used(10). Guntz et al.(11) studied puncture path in sciatic nerve block in the popliteal fossa using cadaverous models. In addition, imaging studies were used to determine feasibility of lateral approach to the sciatic nerve and common range of needle-insertion angles for sciatic popliteal nerve block.

We describe a medial trans popliteal approach on cadaverous model and CT angiography reconstruction in this study. The aim of the study is to evaluate feasibility of this access to allow the patient to remain in the supine position.

Method

The local ethical committee previously accepted the study protocol.

CT angiography study

CT angiographies of the lower extremities of patients undergoing imaging for evaluation of peripheral arterial disease were retrospectively analyzed. Slice thickness values were from 1 to 2,5mm, 120 to 140 ml of contrast injection (350 mg iodine/ml) were used. Image acquisitions were obtained from patients in the supine position. Multiplanar reconstructions (MPR) with Endosize ® by (Therenva SAS, Philadelphia PA, USA) were used to localize puncture site (figure 1), needle trajectory and to identify traumatized tissue.

Exclusion criteria were absence of IPA visualization necessary to perform simulation: absence of contrast injection, IPA occlusion, and presence of anatomic distortion (path anomaly of popliteal artery or suspicion of trapped popliteal artery) or obscuring artifacts.

Puncture site was defined as 8cm below tibia in axial view and 1 cm below the lower edge of the tibia in frontal view according to standard surgical approach and length of puncture needle. In sagittal view, a visible mark was made on the skin. The trajectory was drawn from puncture site to popliteal artery between 40° and 50° to the horizontal plane. Angles could change to correct difference in size of the patient and to always keep a puncture length shorter than the needle length. Trauma of the inner head of the gastrocnemius or popliteal pedicle was sought: especially to the popliteal vein and tibial nerve. Measurements were made by authors using the Endosize ® radiology software program. A vascular surgeon reviewed all measurements to minimize interobserver variability.

Cadaver study

Ten SAFEBALMⓇ fixed cadavers were used for this study in an anatomy lab. Corpses used were those available at the anatomy lab. Exclusion criteria were: corpses with scars in region studied, corpses with signs may suggest vascular bypass (vascular approach, saphenous vein harvest) and corpses with femoral artery found to be occluded (lesion of lower extremity artery disease (LEAD) seen during dissection without possibility to advanced the guide into the IPA or highlighting of an occluded SFA after injection of contrast agent).

The corpse was placed in supine position, with the hip in slight flexion (40°) and abduction (external rotation of 60°) (5).

Corpses were not perfused; two methods were used to visualize their arteries.

First method: non injected cadaver

Guide introduction: The superficial femoral artery was approached through a medial incision at the anterior side of the thigh. An incision was made on the lateral edge of the sartorius muscle which was then lowered in order to find the superficial femoral artery still in its vascular sheath. The artery was separated from its vascular sheath and a transversal arteriotomy was made in order to introduce a guide wire (Radifocus® 260 cm Guidewire M Stiff type) down to the IPA.

Puncture of the IPA using a C-arm: The operator was positioned at the opposite side of the studied limb. The catheter used for the puncture was a 21 G needle (Surflo® W I.V. Catheters 18 G, 1.30 x 64 mm, green). In accordance with the standard surgical approach for distal IPA, puncture was made 1 cm posterior to the medial edge of the tibia and 8 cm below the edge of the medial femoral condyle with an angle of circa 45° toward the top. A C-arm and the guide wire already in the artery were used to locate the IPA. When access was obtained, a second guide wire was introduced toward the superficial femoral artery to verify the success of the puncture.

Second method: cadaver injected with barium sulfate (Micropaque® 500mL oral/rectal suspension diluted with a dilution factor of 5):

Difficulties of puncture of an artery without lumen led us to use a second method to locate and inflate the IPA.

Injection of the contrast agent: The injected contrast agent was the “Micropaque® 500mL oral/rectal suspension” diluted with a dilution factor of 5. An arched incision was made along the medial edge of the sartorius muscle between the anterior superior iliac spine and the pubic tubercle which led directly to the vascular sheath of the femoral superficial artery. The artery was then isolated and a transversal arteriotomy was performed in order to inject 25 mL of the prepared solution with a 50mL syringe. The success of the injection was verified with the C-arm.

Puncture of the infrageniculate popliteal artery and position of the operator were the same as first method.

Dissection of the region of puncture: The incision started 1 cm behind the protrusion of the medial femoral condyle and followed the line heading to the puncture site for 8 cm. It was enlarged if needed (5).

The vascular sheath was dissected to re-evaluate the success of the puncture.

Each element of the popliteal pedicle was analyzed for access related injury: the popliteal vein and tibial nerve in particular. An access related injury was defined as any transfixing wound of an element. Technical success was defined as intra luminal puncture, objectified during dissection, and progression of the guide wire to the retro articular popliteal artery (figure 2).

Data were anonymously recorded in Excel 2016 (Microsoft, Richmond, WA, USA).

Statistical analysis

Categorical variables were presented as percentage.

Results:

CT angiography study

Two medical students underwent CT angiography reconstructions. A senior vascular verified each reconstruction during an independent session. In a one case, a third measurement was made jointly because of results mismatch.

Twelve CT angiography simulations were included in the study from 8 (67%) males and 4 (33%) females. Punctures reached the IPA respecting needle length and skin puncture site. All puncture models went through the inner head of the gastrocnemius muscle.

An injury of one element of the popliteal pedicle was found in all punctures: there were 9 (75%) popliteal vein and 2 (17%) tibial nerve transfixing wound.

The tibial nerve lesion was associated with one (8%) of the popliteal vein lesions.

Cadaver study

Ten dissections were performed on the cadavers. A C-arm was then used with a guide wire for 2 dissections (2 non-injected cadavers) and with injected contrast agent for 8 dissections to locate the IPA. Technical success was 100%. All punctures were made through the inner head of the gastrocnemius muscle, causing it damage in the process. An injury of one element of the popliteal pedicle was found in 9 punctures: there were 6(60%) popliteal vein and 3(30%) tibial nerve (figure 3) transfixing wound.

Discussion:

In this study, IPA puncture is feasible. Dissections of cadaverous models and CT scans showed comparable results with high number of popliteal vein trauma.

Anterograde femoral artery approach is commonly used for endovascular treatment of femoropopliteal occlusion. It can be limited by patient habitus, surgical scars or proximal occlusion without stump on superficial femoral artery (SFA). Contralateral approach provides less pushability. Retrograde approach was described in case of failure of anterograde intra luminal re-entry (2). Techniques usually involved punctures of distal arteries or posterior approach of IPA, but the rate of technical failure or small vessel trauma is non-negligible. Vessel injury can be minimized when performed with ultrasound guidance(9). Posterior approach needs a change in prone position and serious complications were related as arteriovenous fistula (AVF) (2%) or popliteal hematoma (4%) (10,12).

Distal puncture of leg arteries (tibial, peroneal or foot artery) has been used to ensure arterial continuity in case of failure to cross femoropopliteal occlusion by anterograde approach like subintimal arterial flossing with antegrade-retrograde intervention (SAFARI) technique(8). Those punctures can lead to small artery dissection and can be dangerous if it is the only remaining patent artery. Infrageniculate popliteal artery (IPA) puncture is possible thanks to its anatomy below the knee(13). Puncture can be posterior, external or medial as surgical approach (14).

Medial IPA retrograde approach with patients remaining supine would allow anterograde and retrograde interventions with the same patient position for the entire procedure. Tonnesen et al (10) first described this technique but it has not been developed because of access-site complications. More recently, punctures of the PA in the supine position, by lifting the heel or by gently flexing and medially rotating the knee, have been described (15). Furthermore, authors have found an increased risk of AVF. Others studies evaluated IPA puncture which patients in the supine position (16–18). Technical success was almost 100%, there was 0 to 7.3% AVF complication, but major complications later appeared: a large hematoma appeared several hours resulting in a deficit and a pseudoaneurysm requiring open surgical repair and 2 cases of popliteal hematomas that they were not able to walk properly for 2 and 3 months in spite of normal ankle pressures due to tenderness and edema of the foot(10,19).

Gunz (11) showed the interest of anatomical model studies. It allows to study each element encountered during the dissection of cadaverous models.

Ye(16), who had not reported venous trauma, performed a higher popliteal puncture on popliteal fossa, elaborated also on the high frequency of venous anatomical variations(20) . He found only two (10.5%) hematomas. IPA punctures chosen over the traditional medial approach are more at risk of venous trauma; popliteal vein is more medial on the leg (13). Development of an AVF can appear.

Small AVF close spontaneously most of the time (21). Authors have shown that by simple compression with an ultrasound probe, post-catheterization vascular complications such as pseudoaneurysm or small AVF can be eliminated (22). This treatment is likely to be successful in cases of IPA puncture with the use of micropuncture kit(23). An ultrasound exam should be performed at the end of the procedure because of the frequent occurrence of venous complication.

We found lesions of tibia nerve during cadaverous dissections and CT scan simulation. The tibial nerve is anatomically posterior and slightly medial in the neurovascular sheath at leg level. This element is pulled backwards and it is never injured during a surgical approach. During an endovascular procedure, there is no change in popliteal pedicle configuration that could explain some nerve punctures.

This study cannot evaluate neurologic consequences but post-puncture trauma is unlikely to lead to complete motor paralysis due to absence of a complete section as found on dissection of cadaverous models.

Making a path through the gastrocnemius muscle was systematic and unavoidable. Using a thin needle or a micropuncture set would not always lead ta a hematoma. This may not be a limiting factor for IPA puncture due to low muscle trauma with slight tissue tearing.

During anterograde recanalization, reentry at the right level can be difficult and guidewire can succeed in passing the intima to a lower level. The interest is to reenter to the right level without losing the supra-genicular or retro-articular popliteal artery in case these are still patent. Isolated SFA lesions occur in a minority of patients with Chronic Limb Threatening Ischemia (2). Patients with femoro- popliteal disease and no aorto iliac involvement reported improvement in the claudication distance after treatment with supervised exercise(24). In case of patency of popliteal artery, symptoms are generally isolated claudication and since the risk of dissection or complication is high in certain cases the retro-articular popliteal artery should not be punctured.

In case of successful femoral recanalization, distal access is only nedded to create passage therefore puncture size can be small. Balloons or stents may be placed from above to limit the widening of the puncture site. If the homo lateral anterograde approach cannot be used, the length of the devices can be chosen accordingly to be placed with a contralateral puncture.

Artery puncture should not be extended by endovascular devices. It increases risk of hematoma or fistula complications. At the end of the procedure, an arterial breach or a fistula can be systematically sought. Ye et al.(16) recommend intraluminal balloon dilatation with mild manual compression at the puncture lesion as soon as the catheter or sheath is pulled out from the popliteal approach for hemostasis.

Simulations on CT angiography have confirmed the risk of venous wound and nerve damage. Those complications can be anticipated on pre operative CT angiography with a procedure planning. If trauma is probable we can search for the best site of puncture to avoid the tibial nerve.

Imaging software can provide CT angiography reconstructions on all 3 planes and to study the anatomy in all these plans for each patient. Imaging exams were used by anesthetists to locate the nerve and to determine needle puncture in a modified posterior approach for popliteal sciatic nerve block. Imaging simulations identified puncture site for this new approach(25,26). Revascularization could be prepared as aneurysm endovascular treatment to anticipate material, complication and strategy(27). These reconstructions could be used to anticipate best puncture site to avoid trauma of popliteal pedicle element and to ensure success of the endovascular revascularization.

Although our study was based on anatomical dissections and CT angiography simulation, we may consider IPA puncture as an alternative in case of femoro popliteal occlusion without anterograde re-entry. This approach would allow the patient to be in supine position; it is a similar approach to traditional surgery and is an easy way to treat potential AVF. Further studies will be needed to determine best puncture site.

Ultrasound guidance could identify elements of the popliteal pedicle in order to find the optimal puncture site. Techniques used by the anesthesists to locate the nerve could be used to adapt site and path puncture. It could also identify target site based on vascular lesions (19,20).

A personalized approach could be offered to each patient, and this could make it possible to leave popliteal vein, tibial nerve and other vessels.

Limits:
The most important limitation of this study was the small number of cadavers (n=10). It reflects lack of corpses availability in the anatomy laboratory. Several studies were in progress at the same time in the anatomy laboratory.

Simulations were done on CT angiographies. The large nerve trunks are often well visible on CT angiographies. MRI allows a better visualization of nerve structures (28,29). However, it is performed less frequently in clinical practice, especially during arterial exploration. CT angiographies are an imaging exam which allow to highlight the nerves and thus to perform puncture simulations.

Position of the lower limbs was not exatly the same at the time of the CT scans compraed to the position at dissection. Moreover position of the feet was not standardized for the CT angiographies. Orientation of the feet was done according to natural external rotation in rest poistion. Hip roation is unlikely to affect position of popliteal artery. Cadaverous had a slight external rotation whereas, patients are in supine position on CT angiographies. We did not find any change in the anatomical configuration of the popliteal pedicle between the CT angiographies and the dissections.

Utilization of ultrasound-guided arterial access was shown to be safe and effective even in cases of LEAD or lack of pulse for medium and small arteries(30). This technique decreases the number of attempts and risk of venipuncture. Other elements of vasculo nervous pedicle are well seen with routine use of ultrasound for vascular access and nerve block. Ultrasound-guided puncture could improve IPA access(31,32).

Conclusion

This medial approach was feasible, but results showed trauma of elements of popliteal pedicle. This technique seems to be an efficient approach in case of failed popliteal artery re-entry but more studies will be required to show low-invasiveness of popliteal puncture. Preoperative CT angiography could anticipate best site of puncture and potential access related injury.

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Writing the article: T Mennecart, A Normand, P Tresson
Critical revision of the article: P Lermusiaux, N Della Schiava, A Millon
Final approval of the article: P Tresson
Statistical analysis: n/a
Obtained funding: n/a
Overall responsibility: P Tresson, P Lermusiaux

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Disclosure

None

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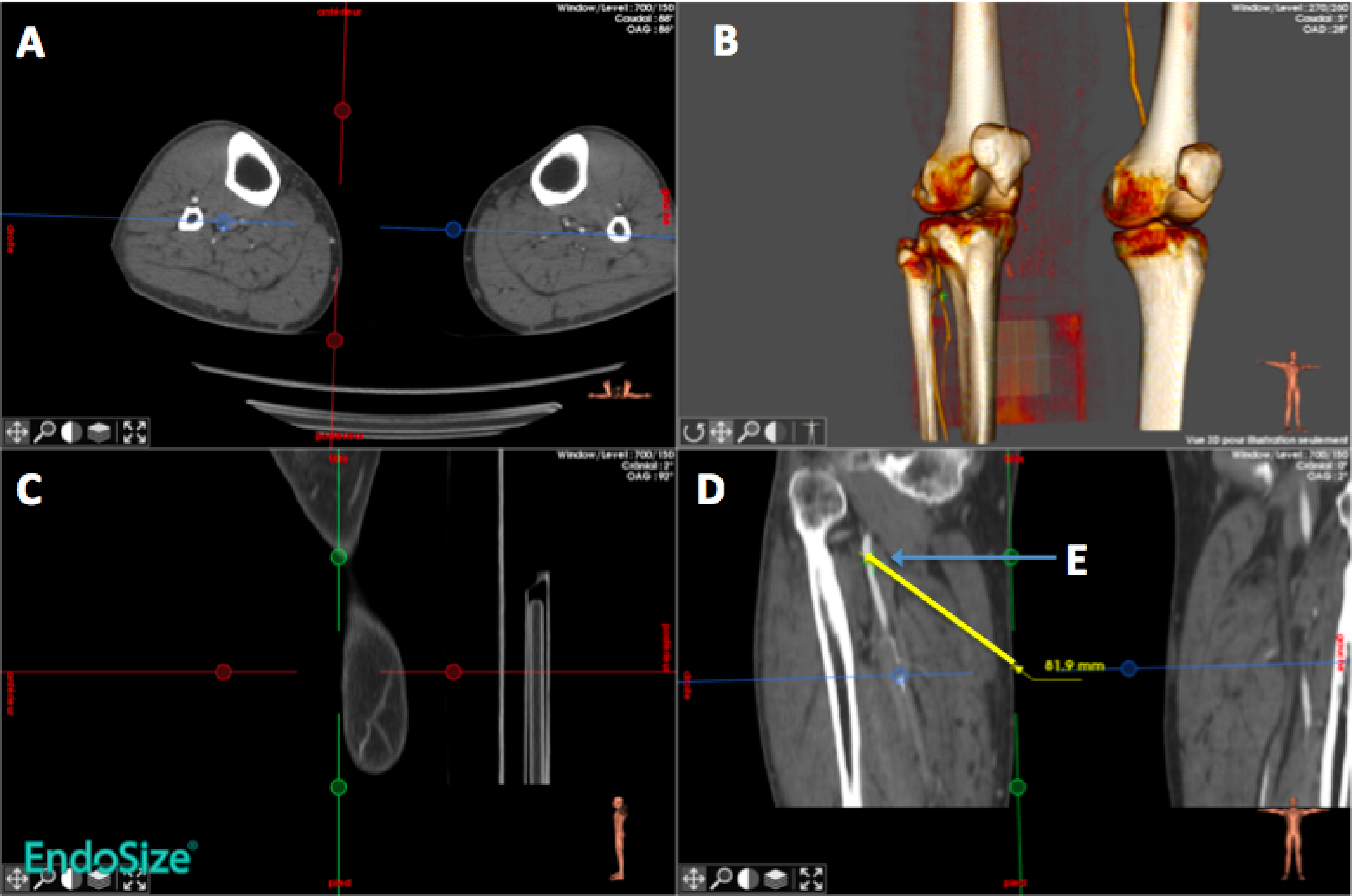
Figure 1. Multiplanar reconstructions of the IPA puncture simulation showing popliteal vein trauma. (A: axial view, B: 3D reconstruction, C: sagittal view, D: coronal view, yellow arrow represents the needle, E showing popliteal vein transfixing wound)

Figure 2. Angiography during cadaver study (A: guide wire from proximal in the retro articular popliteal artery, B: IPA puncture site)

Figure 3. Dissection showing tibial nerve trauma (A: IPA, B: tibial nerve transfixing wound, C: puncture site with puncture path (dotted line))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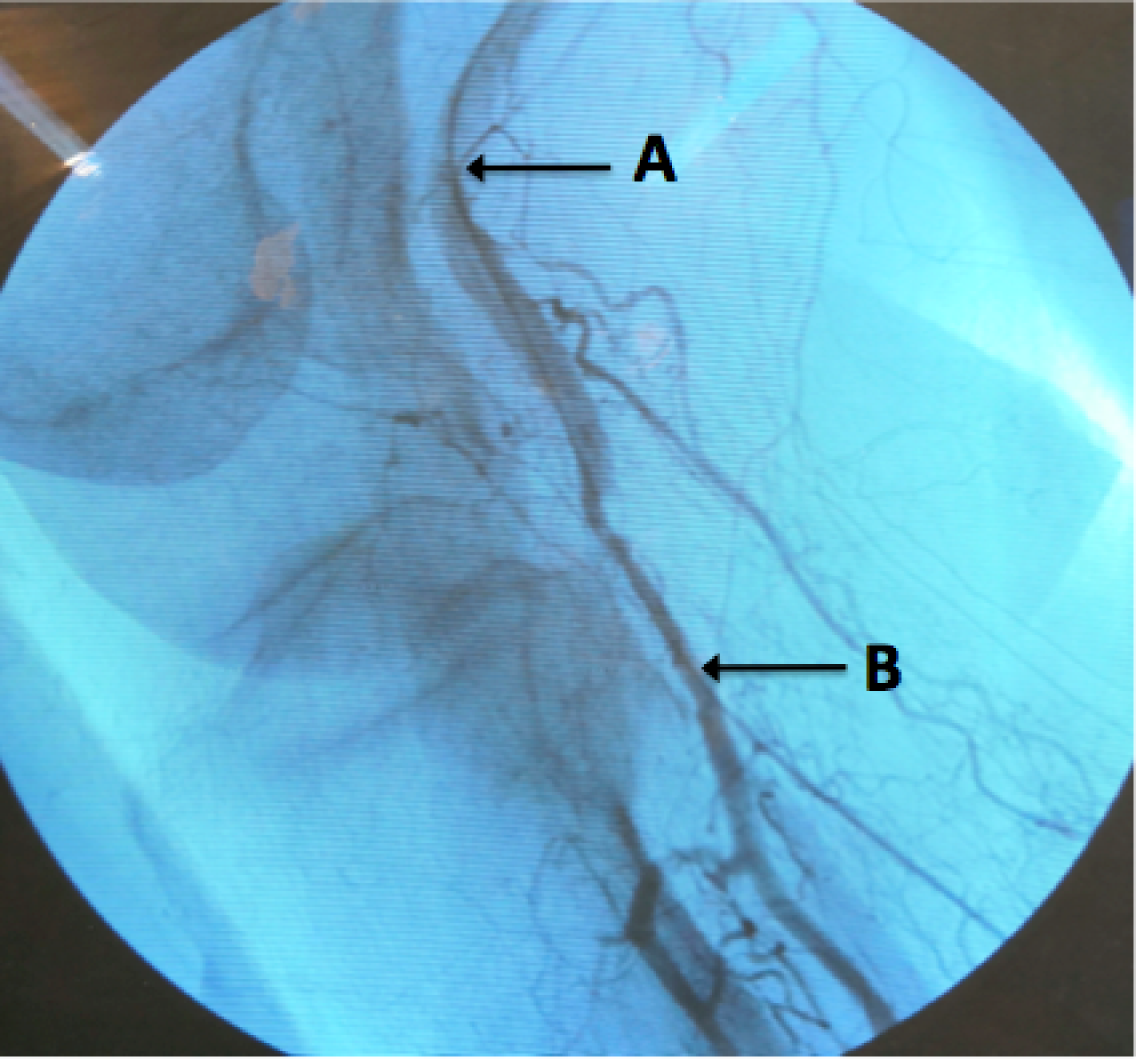
A
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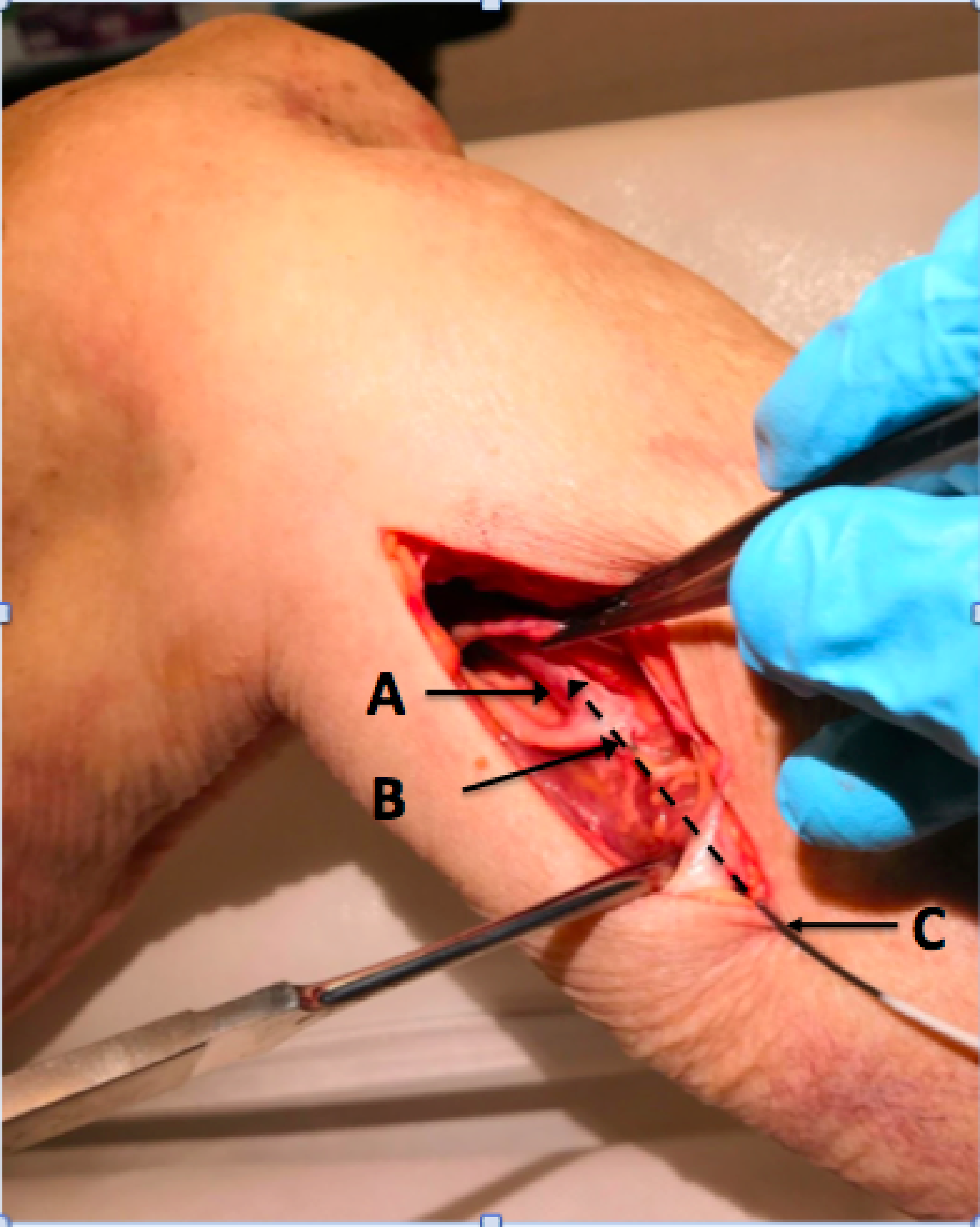
A
B
C