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

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1 **Anatomical considerations of infrageniculate popliteal artery puncture: alternative**
2 **pathway for retrograde access after failed re-entry.**

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81 Abstract:

82 Aims:

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

87 Methods and results:

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

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

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

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

101 Conclusion:

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

105

106 Keywords: popliteal puncture - superficial artery recanalization - lower limb

107

108 Introduction

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

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

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

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

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

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

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

139

140 Method

141 The local ethical committee previously accepted the study protocol.

142 CT angiography study

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

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

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

161 Cadaver study

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

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

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

171 First method: non injected cadaver

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

178

179 Puncture of the IPA using a C-arm: The operator was positioned at the opposite side of the
180 studied limb. The catheter used for the puncture was a 21 G needle (Surflo® W I.V. Catheters
181 18 G, 1.30 x 64 mm, green). In accordance with the standard surgical approach for distal IPA,
182 puncture was made 1 cm posterior to the medial edge of the tibia and 8 cm below the edge of
183 the medial femoral condyle with an angle of circa 45° toward the top. A C-arm and the guide
184 wire already in the artery were used to locate the IPA. When access was obtained, a second
185 guide wire was introduced toward the superficial femoral artery to verify the success of the
186 puncture.

187

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

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

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

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

201

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

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

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

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

211 **Statistical analysis**

212 Categorical variables were presented as percentage.

213

214 Results:

215 CT angiography study

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

219 Twelve CT angiography simulations were included in the study from 8 (67%) males and 4
220 (33%) females. Punctures reached the IPA respecting needle length and skin puncture site. All
221 puncture models went through the inner head of the gastrocnemius muscle.

222 An injury of one element of the popliteal pedicle was found in all punctures: there were 9
223 (75%) popliteal vein and 2 (17%) tibial nerve transfixing wound.

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

225 Cadaver study

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

232

233

234

235

236 Discussion:

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

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

248

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

256

257 Medial IPA retrograde approach with patients remaining supine would allow anterograde and
258 retrograde interventions with the same patient position for the entire procedure. Tonnesen et
259 al (10) first described this technique but it has not been developed because of access-site
260 complications. More recently, punctures of the PA in the supine position, by lifting the heel
261 or by gently flexing and medially rotating the knee, have been described (15). Furthermore,
262 authors have found an increased risk of AVF. Others studies evaluated IPA puncture which
263 patients in the supine position (16–18). Technical success was almost 100%, there was 0 to
264 7.3% AVF complication, but major complications later appeared: a large hematoma appeared
265 several hours resulting in a deficit and a pseudoaneurysm requiring open surgical repair and 2
266 cases of popliteal hematomas that they were not able to walk properly for 2 and 3 months in
267 spite of normal ankle pressures due to tenderness and edema of the foot(10,19).

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

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

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

281 We found lesions of tibia nerve during cadaverous dissections and CT scan simulation. The
282 tibial nerve is anatomically posterior and slightly medial in the neurovascular sheath at leg

283 level. This element is pulled backwards and it is never injured during a surgical approach.
284 During an endovascular procedure, there is no change in popliteal pedicle configuration that
285 could explain some nerve punctures.

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

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

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

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

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

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

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

322
323 Although our study was based on anatomical dissections and CT angiography simulation, we
324 may consider IPA puncture as an alternative in case of femoro popliteal occlusion without
325 antegrade re-entry. This approach would allow the patient to be in supine position; it is a
326 similar approach to traditional surgery and is an easy way to treat potential AVF. Further
327 studies will be needed to determine best puncture site.

328 Ultrasound guidance could identify elements of the popliteal pedicle in order to find the
329 optimal puncture site. Techniques used by the anesthetists to locate the nerve could be used to
330 adapt site and path puncture. It could also identify target site based on vascular lesions
331 (19,20).

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

334 Limits:

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

338
339 Simulations were done on CT angiographies. The large nerve trunks are often well visible on
340 CT angiographies. MRI allows a better visualization of nerve structures (28,29). However, it
341 is performed less frequently in clinical practice, especially during arterial exploration. CT
342 angiographies are an imaging exam which allow to highlight the nerves and thus to perform
343 puncture simulations.

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

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

356

357 Conclusion

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

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376 Disclosure

377 None

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

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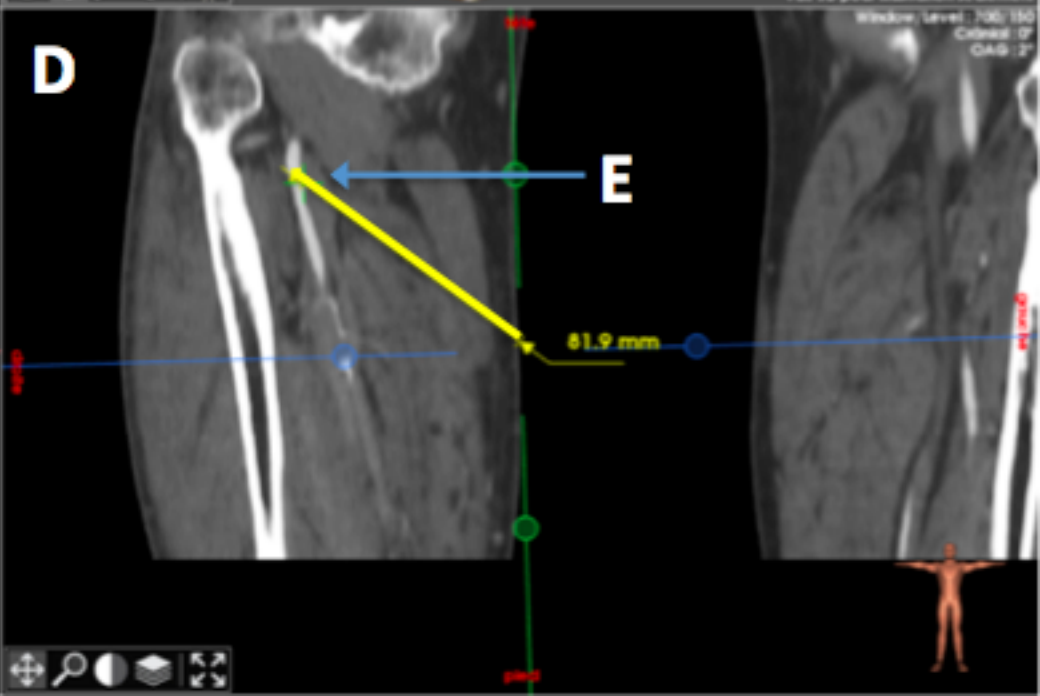
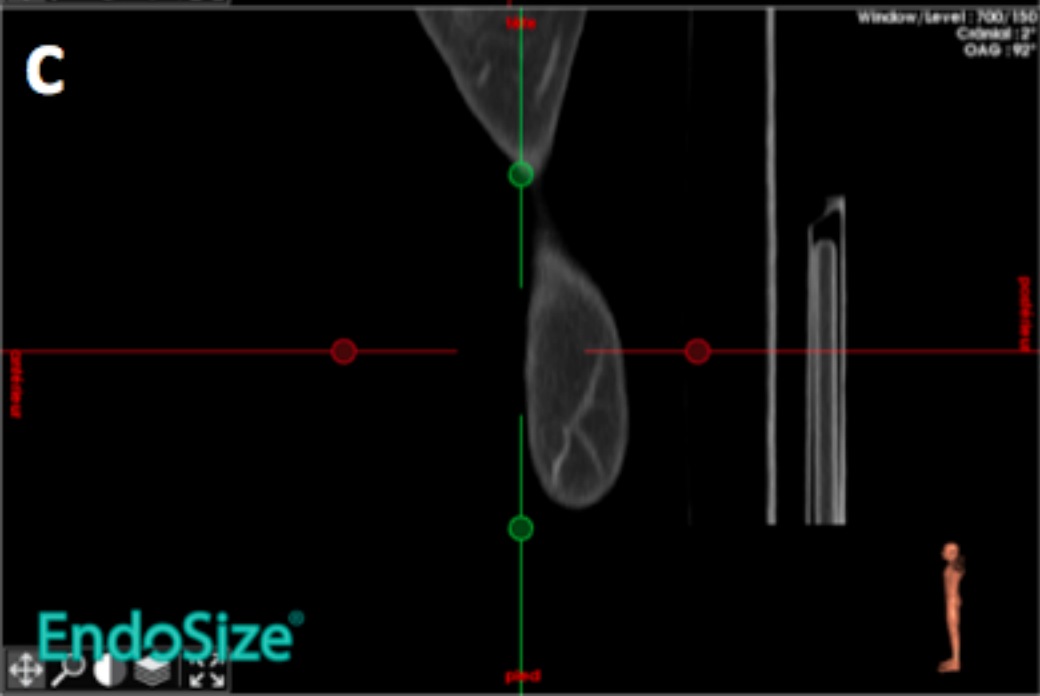
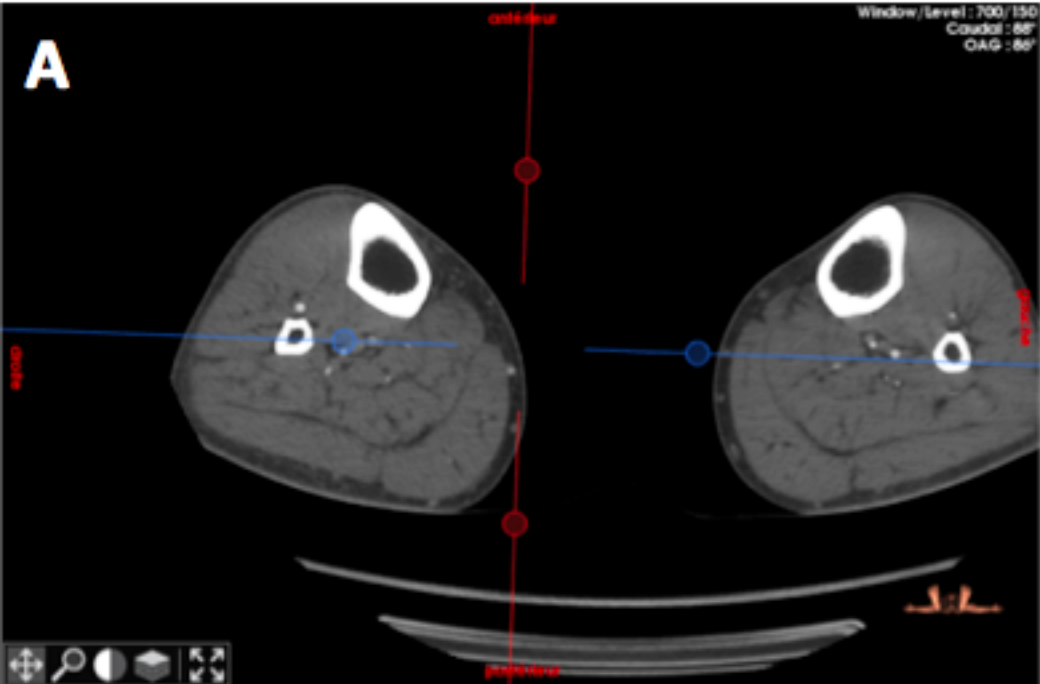
492 **Figure 2. Angiography during cadaver study** (A: guide wire from proximal in the retro
493 articular popliteal artery, B: IPA puncture site)

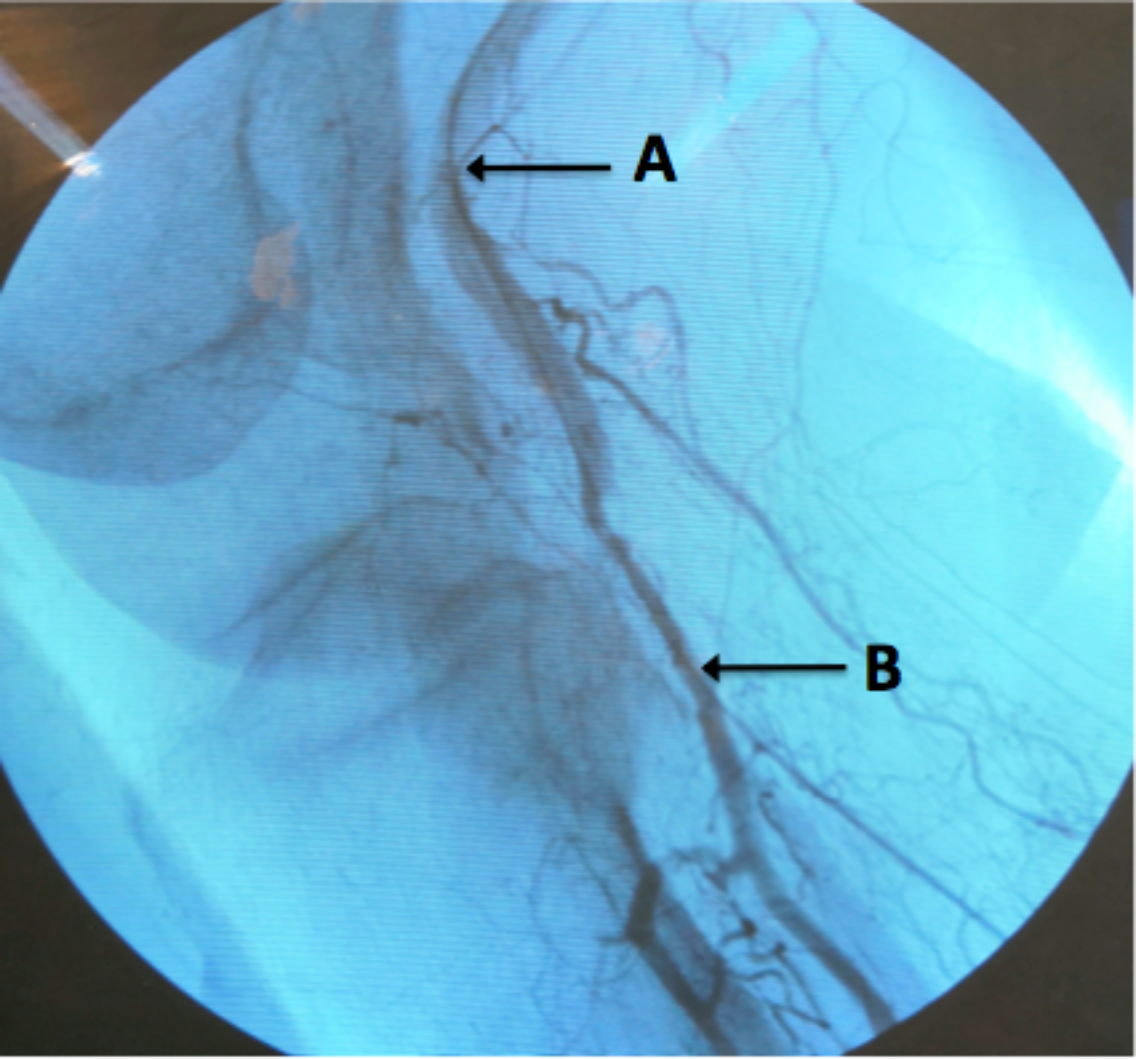
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496 **Figure 3. Dissection showing tibial nerve trauma** (A: IPA, B: tibial nerve transfixing
497 wound, C: puncture site with puncture path (dotted line))

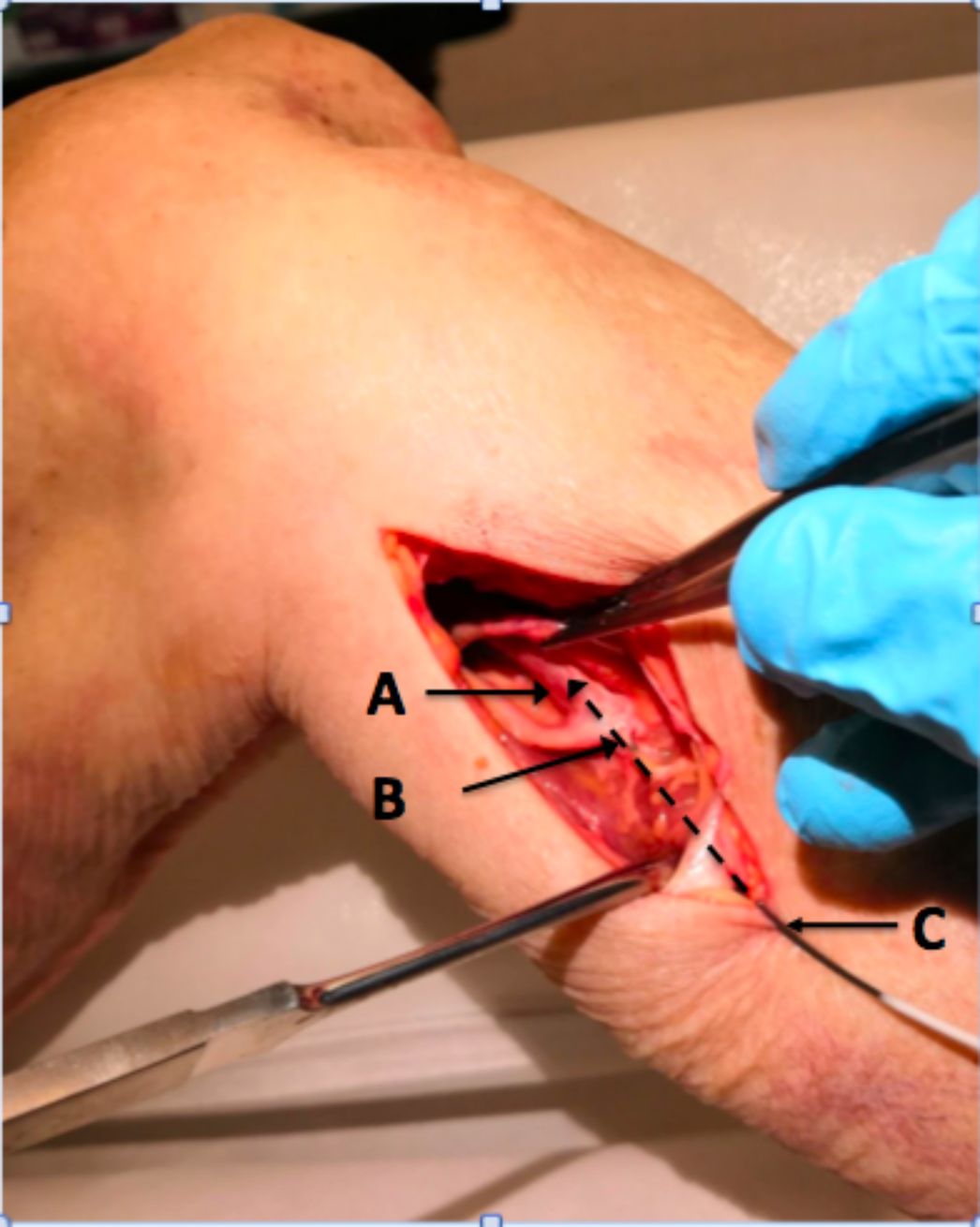
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← **A**

← **B**



A

B

C