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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.

362 Author contributions :

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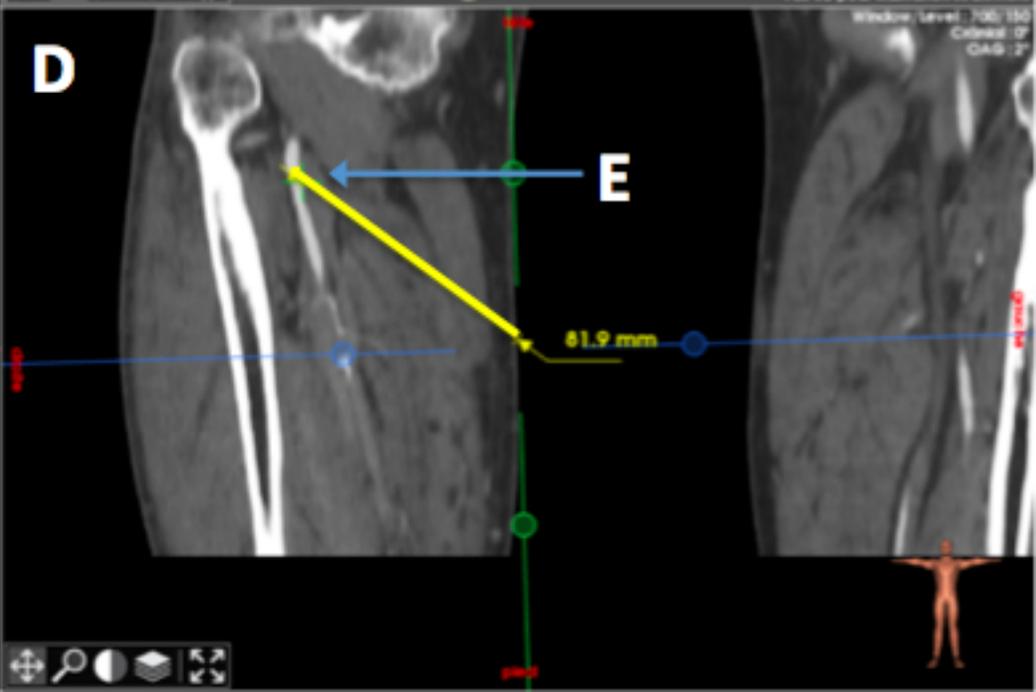
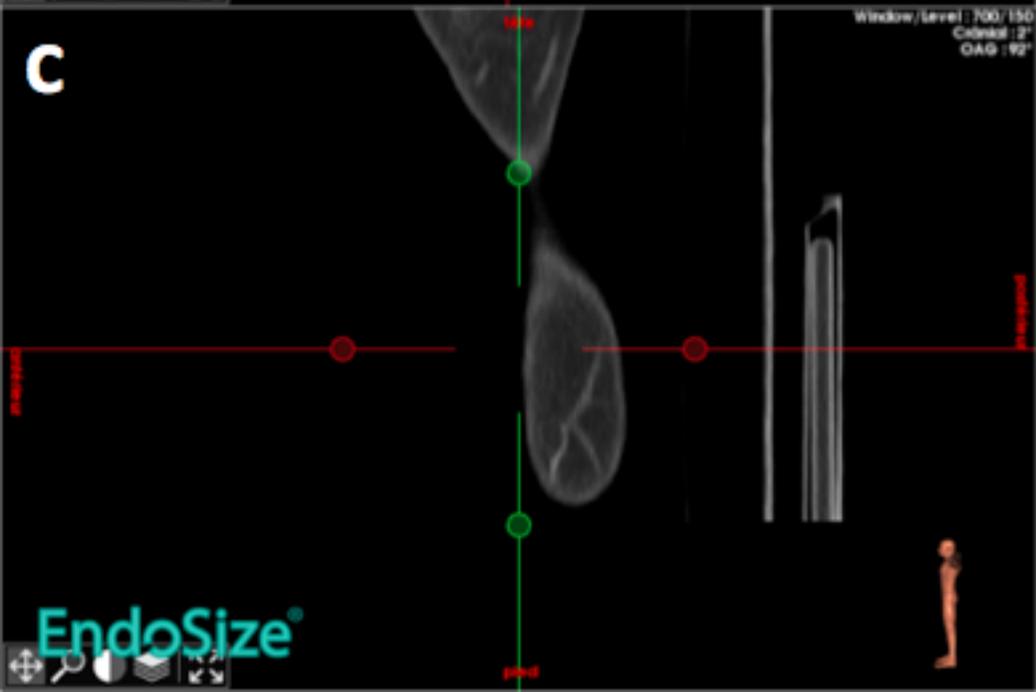
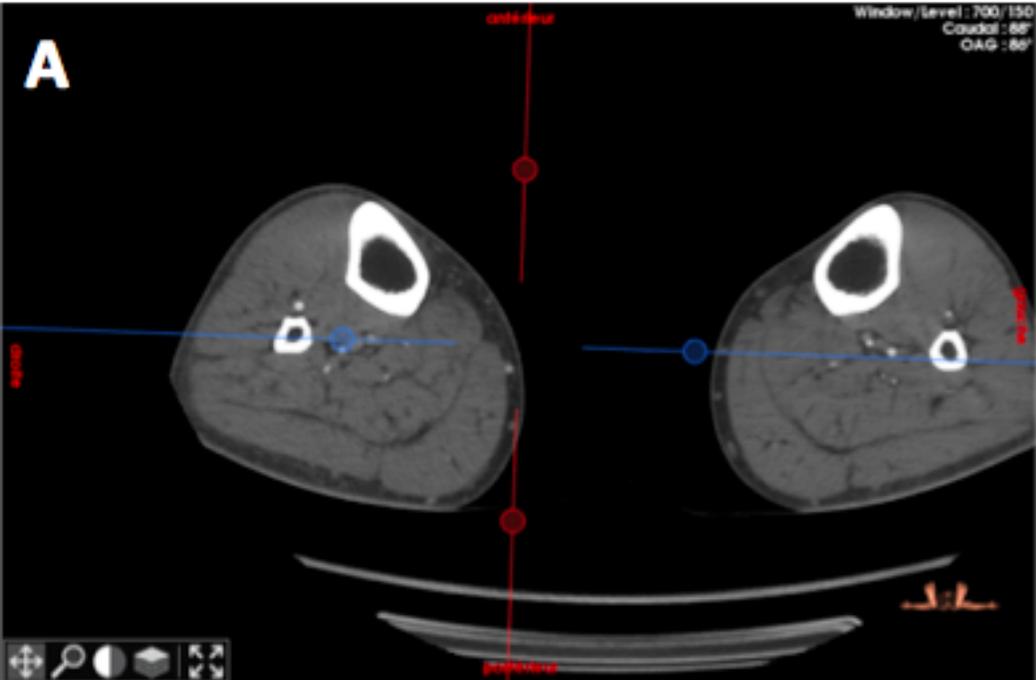
492 **Figure 2. Angiography during cadaver study** (A: guide wire from proximal in the retro  
493 articular popliteal artery, B: IPA puncture site)

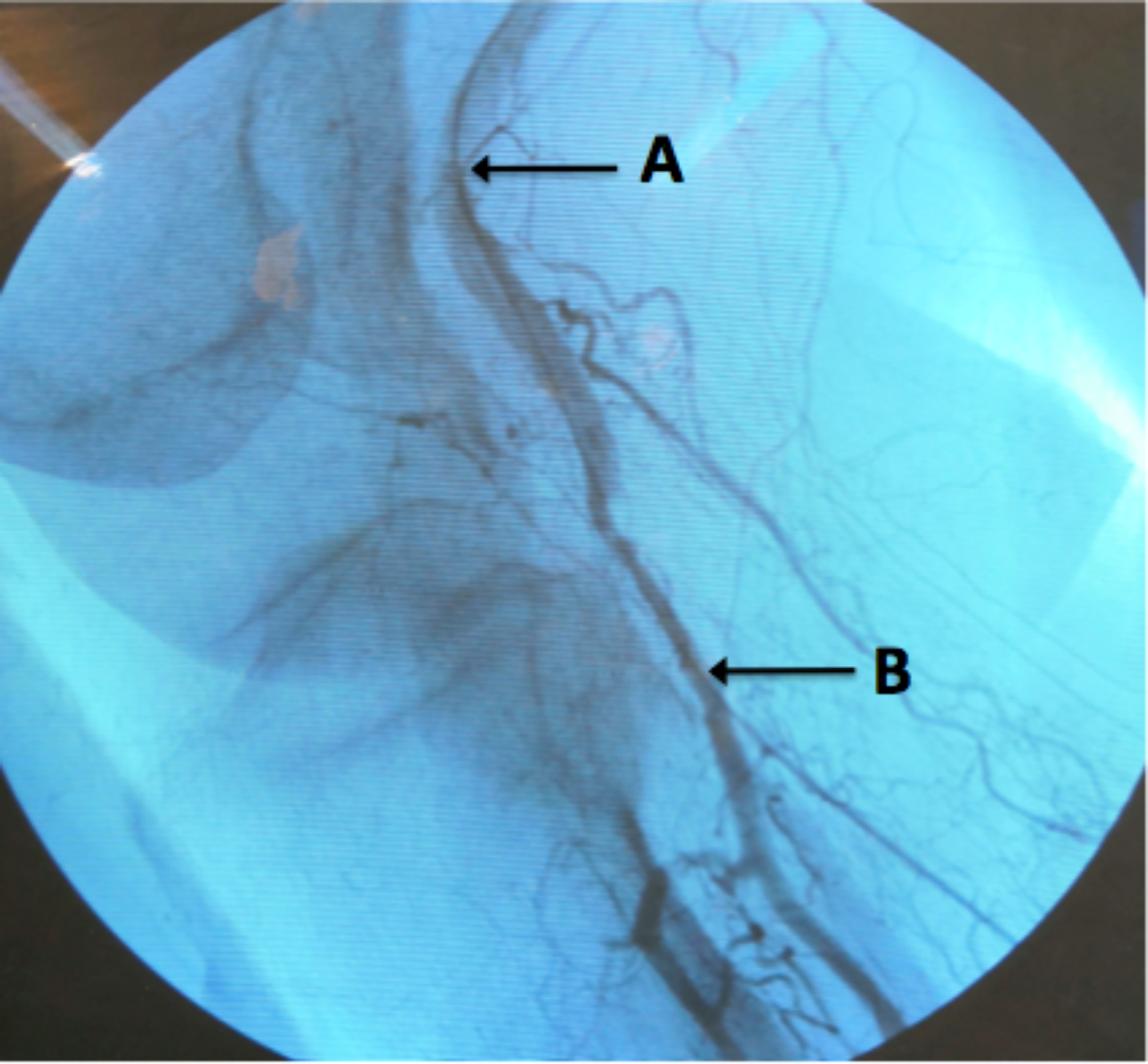
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496 **Figure 3. Dissection showing tibial nerve trauma** (A: IPA, B: tibial nerve transfixing  
497 wound, C: puncture site with puncture path (dotted line))

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← **A**

← **B**

