

Ultrasound-guided block of sciatic and femoral nerves: an anatomical study

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1 **Abstract**

2 The sheep is a popular animal model for human biomechanical research involving invasive
3 surgeries of the hip or the stifle joint. These painful procedures can only be ethically justified
4 with the application of adequate analgesia protocols. Regional anaesthesia as an adjunct to
5 general anaesthesia may markedly improve wellbeing of these experimental animals during the
6 post-operative period due to a higher analgesic efficacy when compared to systemic drugs and
7 therefore reduce stress and consequently the severity degree of such studies.

8 As a first step fourteen sheep cadavers were used to establish a new technique of peripheral
9 blockade of the sciatic and the femoral nerves under sonographic guidance and to evaluate the
10 success rate by determination of the colorization of both nerves after injection of 0.5 ml of 0.1%
11 methylene blue solution. First, both nerves were visualized sonographically. Then, methylene
12 blue solution was injected and subsequently, the length of colorization was measured by gross
13 anatomical dissection of the target nerves. Twenty-four sciatic nerves were identified
14 sonographically in 12 out of 13 cadavers. In one animal, the nerve could not unequivocally be
15 ascertained and, consequently, nerve colorization failed. Twenty femoral nerves were located
16 by ultrasound in 10 out of 13 cadavers. In 3 cadavers, signs of autolysis impeded the scan. This
17 study provides a detailed anatomical description of the localization of the sciatic and the femoral
18 nerves and presents an effective and safe yet simple and rapid technique to perform peripheral
19 nerve blocks with a high success rate.

20

21 **Introduction**

22 The sheep is a valuable animal model for biomechanical and translational research due to a
23 rather inexpensive husbandry and easy handling ¹⁻⁴. Analogies between various ovine and
24 human joints as well as a high comparability of the ovine bone morphology to the human
25 skeleton enable not only studies concerning the replacement of ligaments but also the treatment
26 of chondral and osteochondral defects ^{5,6}. Many of the surgical procedures are highly invasive
27 and painful thus requiring adequate peri-operative pain management to ensure post-operative
28 well-being ⁷⁻¹¹.

29 The use of loco-regional anaesthesia techniques allows the depth of anesthesia to be reduced
30 during surgery and decreases the need for systemic analgesic drugs during and after surgery
31 due to their long-lasting analgesic efficacy ^{7,12}. In humans, application of such techniques often
32 allows the induction of general anaesthesia to be circumvented. Furthermore, the risk of
33 adverse effects such as vomiting and nausea is minimized during the postoperative phase while
34 pain is reduced and patients can be released from the hospital earlier ¹³⁻¹⁵. In most animals, the
35 need of unconsciousness during orthopedic surgery remains unavoidable due to a lack of
36 compliance.

37 A large variety of regional anaesthesia techniques has been described in dogs and cats ¹⁶⁻¹⁸. In
38 small ruminants, only a few methods have been evaluated so far, spinal administration of
39 analgesic drugs being the technique of choice for surgery on the hind limb ¹⁹⁻²¹. However,
40 bilateral motor blockade can cause severe stress during recovery ^{20,22,23}. The intra-articular
41 administration of analgesic drugs leads to effective analgesia during and after surgery involving
42 stifle joints ^{24,25}. Though, cytotoxic effects of local anaesthetics on articular chondrocytes have
43 recently been demonstrated in vitro ²⁶.

44 The sciatic and the femoral nerves are the main nerves of the hind limb. A peripheral blockade
45 of these nerves allows surgery of the knee and the tibia to be performed and, therefore, is a
46 popular technique in human and small animal medicine ^{27,28}.

47 The innervation of the hip joint is species specific. In the dog, this joint is innervated by the
48 sciatic and the femoral nerves, the latter apparently containing both motor and sensory fibers,
49 and the gluteus cranialis nerve with a pure motor function ²⁹. In humans and horses, the
50 obturator nerve, which is also considered to be purely motor, is involved as well ^{30,31}. As for the
51 ruminants, no species specific information has been published so far.

52 Until now, the neuraxial administration of analgesic drugs was the only technique allowing
53 effective anaesthesia of the hip joint in sheep ²¹ as a very proximal blockade of the sciatic nerve
54 is needed to block sensory afferents from this area. In humans and dogs, the paravertebral or
55 parasacral administration of local anaesthetics to the sciatic nerve leads to an adequate level of
56 peri-operative analgesia of the hip joint ^{32,33}. This approach reduces the potential for
57 cardiovascular side effects such as hypotension and bradycardia and reduces the risk for post-
58 operative complications as compared to epidural anaesthesia ³⁴. As a consequence, post-
59 operative well-being may be improved in animals and humans ^{7,35,36}.

60 Several anatomical landmarks can be used for the perineural administration of local
61 anaesthetics to the sciatic and the femoral nerves. Notwithstanding, the success rate of these
62 blocks could be further increased even with smaller volumes of injected local anaesthetics when
63 using a nerve stimulator ^{17,36}. Lately, the technique has been further developed and perineural
64 injections can now be performed under sonographic guidance. Various ultrasound guided loco-
65 regional anaesthesia techniques have been established in human and small animal medicine ³⁷⁻
66 ⁴¹. To the author's knowledge, however, the blockade of the sciatic and the femoral nerves
67 under ultrasound guidance has not yet been described in sheep.

68 The direct visualization of the needle, of the target nerve as well as of the surrounding
69 anatomical structures such as blood vessels, bone, muscles, tendons and fat tissue allows
70 exact positioning of the needle tip close to the targeted nerve. Due to real-time visualization of
71 the spreading of the local anesthetic, the drug volume can be minimized. A precise localization
72 of the target nerve leads to a faster onset of blockade, longer duration of effect and therefore
73 better quality of nerve blockade ⁴².

74 As a first step in the process of establishing a new technique, it is useful to inject dye into
75 cadavers in order to assess the success rate by staining the target nerves ^{37,38,43}.

76 The aim of this study was to establish the technique of perineural injection of methylene blue
77 close to the sciatic and femoral nerves under ultrasound-guidance in sheep cadavers and to
78 evaluate the distribution of a minimal amount of methylene blue solution at the desired
79 locations. We hypothesized that it would be possible to visualize the sciatic and the femoral
80 nerves by ultrasound in adult sheep cadavers and that the injection of a small volume of
81 methylene blue would lead to a distinct colorization of the target nerves.

82

83 **Materials and methods**

84 **Animals**

85 Fourteen cadavers of adult female Swiss Alpine Sheep with a mean weight of 72 (56-83) kg
86 were used in this study. The animals were euthanized at the end of an experimental
87 cardiovascular trial.

88 Both hind limbs, the pelvis and the lumbar spine were abscised *in toto* before freezing for 2-8
89 weeks. The cadavers were thawed for 36 hours at room temperature before starting the
90 experiment.

91 **Pilot study**

92 In one sheep, the anatomy of the sciatic and the femoral nerves was assessed and compared
93 with the structures previously identified by ultrasound (linear array probe, 6-13 Mhz; MTurbo®,
94 Sonosite, Seattle, USA).

95 **Procedures**

96 After “sternal” positioning of the cadavers, the skin and subcutaneous fat tissue were gently
97 removed as it had become hard and dry due to the freezing process. The sacrum and the tuber
98 coxae were palpated and used as anatomical landmarks. A linear array probe (6-13 Mhz;
99 MTurbo®, Sonosite, Seattle, USA) was positioned on the tuber coxae at an angle of
100 approximately 70° to the long axis of the cadaver and moved in caudal direction until the sciatic
101 nerve could be visualized where it leaves the foramen ischiadicum majus. A needle specifically
102 designed for injections under ultrasound guidance (22 G x 80 mm; SonoTAP cannula®, Pajunk,
103 Germany) was positioned in-plane in latero-medial direction until the needle tip could be
104 detected in close proximity to the nerve (Fig.1). Methylene blue solution (0.5 ml; 0,1%) was then
105 injected under sonographic control. Due to the small volume, the space being occupied by the
106 injected fluid was not visible.

107 In a second step, the cadaver was positioned in supine position. The sartorius muscle at the
108 midpoint of the medial aspect of the thigh was used as an anatomical landmark. The probe was
109 positioned perpendicular to the long axis of the thigh upon the sartorius muscle and was moved
110 in a proximal and caudal direction until the femoral artery, the vein and the nerve could be
111 visualized under the fascia of the sartorius muscle as proximally as possible. The needle was
112 positioned in-plane until the tip of the needle reached the targeted structures (Fig.2). Directly
113 after injection of the methylene blue, the quality of colorization of the target nerves was
114 quantified by measurements of the length of colorization after dissection of both nerves. A photo
115 of the colored tissue with a scale was taken to allow later evaluation (Fig.3, 4).

116

117 **Results**

118 **Pilot study**

119 The **sciatic nerve** was identified sonographically in the foramen ischiadicum majus of the pilot
120 animal (Fig.1). Therefore, the tuber coxae and the tuber ischiadicum served as the most
121 important anatomical landmarks. When a line was drawn from the tuber coxae to the tuber
122 ischiadicum, the injection site could be located in the middle of this line.

123 The sartorius muscle with its triangular appearance and its fascia as the limit between the
124 muscle, nerve and vessels were identified as the most important anatomical landmark for the
125 **femoral nerve** (Fig.2). The nerve was located underneath the fascia but superficial to the
126 femoral artery and vein.

127 **Main study**

128 We were able to identify 24 **sciatic nerves** in 12 out of 13 sheep cadavers using ultrasound.
129 They appeared as oval, hypoechoic structures with a hyperechoic rim (Fig.1). The cadavers
130 were dissected after injection of methylene blue: 10 sciatic nerves could be stained perineurally
131 using methylene blue over a mean length of 4 cm, 8 sciatic nerves were stained either
132 perineurally or the nerve itself over a mean length of 3 cm (Fig.3), and 6 sciatic nerves were
133 stained over a mean length of 4 cm.

134 Twenty **femoral nerves** were identified in 10 out of 13 sheep cadavers underneath the fascia of
135 the sartorius muscle (Fig.2): in 6 femoral nerves adequate scanning and perineural injections
136 were not possible due to signs of autolysis, in 6 femoral nerves, dye was found perineurally over
137 a mean length of 3 cm and in 14 femoral nerves, the mean length of staining was 4 cm (Fig.4).

138 Again, slight neural staining was expected while every effort was made to avoid intraneural
139 injections.

140

141 **Discussion**

142 In an effort to further improve analgesia, we evaluated the sciatic and femoral nerve block under
143 ultrasound guidance with encouraging results. With this study we could demonstrate the
144 feasibility to block the sciatic and the femoral nerves in sheep with a high success rate.
145 Ultrasound guidance was very useful in detecting and staining the sciatic and femoral nerve
146 perineurally. The results of this study promise effective blockade of the sciatic and femoral
147 nerves under ultrasound guidance for orthopaedic surgery in sheep.

148 **Anatomy**

149 The **sciatic nerve** leaves the spine from the segments L6 to S2 of the plexus lumbosacralis and
150 exits the pelvis through the foramen ischiadicum majus. It courses between the gluteus medius
151 and profundus muscles before bending distally between the trochanter major of the femur and
152 the tuber ischiadicum ^{44,45}. The nerve progresses on the caudal side of the thigh. In the middle
153 of the thigh it splits into the tibial and peroneus communis nerves which run caudally to the
154 fossa poplitea ⁴⁶.

155 After leaving the pelvic cavity, the nerve crosses the gemelli muscles between the trochanter
156 major of the femur cranially and the tuber ischiadicum caudally. Along this way, the sciatic nerve
157 sends motor branches to the gluteus profundus muscle, the gemelli muscles and the quadratus
158 femoris muscle. The sciatic nerve is the most important sensory nerve of the hip joint as it
159 dispatches nerve branches to the hip joint capsule ⁴⁶. The nerve passes distally to the plantar
160 side of the thigh, deep to the biceps femoris muscle ⁴⁴. In the middle of the thigh, the sciatic
161 nerve splits into the tibial and peroneus communis nerves ⁴⁶.

162 The desensitization of the hip joint requires a very proximal block of the sciatic nerve in order to
163 block its branches to the hip joint, too ^{33,47}. Between the acetabulum and the sacrum, the sciatic
164 nerve could be visualized sonographically as a hypoechoic structure of oval shape with a

165 hyperechoic rim. Due to the very deep position of the sciatic nerve and the limited depth of
166 penetration of the ultrasound waves, the sciatic nerve can only be visualized near the foramen
167 ischiadicum majus in sheep by using a linear high frequency transducer.

168 For surgery in the area of the stifle joint and more distal structures, an additional blockade of the
169 femoral nerve is required ^{7,40}.

170 The **femoral nerve** originates from the segments L4 to L6 of the plexus lumbalis and reaches
171 the lacuna musculorum in conjunction with the iliopsoas muscle. Distally to these structures, it
172 splits off the saphenous nerve as the main sensory nerve for the stifle joint and exits the
173 abdominal cavity through the lacuna musculorum which is delimited by the ligamentum
174 inguinale and the fascia iliaca. It then enters the quadriceps femoris muscle where it gives off
175 branches innervating the quadriceps femoris muscle ^{45,46}. Close to its origin, the saphenous
176 nerve sends motor branches to the sartorius, pectineus and gracilis muscles and courses in the
177 femoral triangle embedded between the vastus medialis muscle and the sartorius muscle in
178 compound with the femoral artery and vein under the fascia of the sartorius muscle near the
179 caudal margin of the femur between its proximal and middle third ^{7,40,44,45,48}.

180 In this trial, the femoral nerve could not be differentiated from blood vessels due to the lack of
181 blood flow in the cadavers. Consequently, the triad of femoral artery and vein and the
182 saphenous nerve could not be resolved visually from each other.

183 The femoral nerve can be blocked at the paravertebral level (lumbosacral block). With this
184 approach, local anesthetic needs to be injected to the roots of the femoral nerve at three or four
185 injection points ^{18,33}. At the mid-femoral level, the saphenous nerve can be blocked with one
186 single injection ^{7,40,48}.

187 The peripheral blockade of the sciatic and saphenous nerve allows effective desensitization of
188 tissue at the hind limbs, especially at the stifle joint and the tibia ^{7,40}. The decisive factor is the

189 localization of the nerve. Anatomical landmarks to block the sciatic and the saphenous nerves
190 under ultrasound guidance or by use of a neuro-stimulator have been evaluated. In most trials,
191 the sciatic nerve was blocked at the “mid-femur” before the peroneus communis nerve and the
192 tibial nerve diverge near the stifle joint^{38,41}. The femoral nerve was blocked at the medial aspect
193 of the thigh, distally to the pectineus muscle but cranially to the femoral artery and ventrally to
194 the fascia iliaca⁴¹.

195 Rasmussen et al⁴⁹ successfully blocked the common peroneal and the tibial nerves at the
196 caudal thigh in the groove between the biceps femoris and semimembranosus/semitendinosus
197 muscle at the midpoint between the patella and the greater trochanter. The saphenous nerve
198 was blocked at the medial aspect of the thigh at the midpoint between the pectineus muscle and
199 the medial epicondyle of the femoro-tibial joint between the sartorius and gracilis muscle.

200 With the use of a nerve stimulator, the sciatic nerve can be blocked between the trochanter
201 major and the tuber ischiadicum^{7,40,43,50}. The femoral nerve can be blocked at the medial thigh
202 cranial to the femoral artery and caudal to the fascia of the rectus femoris muscle⁵¹ and medial
203 to the sartorius muscle⁴⁰.

204 In this trial, we chose a very proximal approach to the sciatic nerve in order to block the nerve
205 before branches for the hip joint are given off: parasacrally in the foramen ischiadicum majus
206 where the nerve crosses the ilium. The saphenous nerve was blocked between the proximal
207 and middle thirds of the femur, underneath the sartorius muscle and superficial to the femoral
208 vessels. The sciatic and the femoral nerves are the main nerves of the hind limb and, thus, have
209 to be blocked for hip or stifle joint surgery to ensure adequate peri-operative analgesia.
210 Surprisingly enough, no additional analgesic effect could be detected after blocking these
211 nerves in an experimental study in sheep undergoing a surgical procedure on the stifle joint⁵².

212 The systemic administration of a large variety of analgesic drugs besides the block to the
213 animals might explain this result.

214 McNamee et al.⁵³ evaluated the additional obturator nerve block to the sciatic femoral nerve
215 block in humans undergoing total knee replacement. This study showed an improvement in
216 post-operative analgesia by adding the obturator nerve block. In domestic species, the following
217 spinal nerves provide skin sensation at the stifle joint: the iliohypogastric, ilioinguinal,
218 genitofemoral and cutaneous femoral nerve⁵⁴.

219 To the author's knowledge, the additional obturator nerve block has not yet been described in
220 sheep. However, the obturator nerve is described as pure motor nerve with the exception of the
221 stifle joint in horses⁴⁶. Thus, an obturator nerve block is unlikely to improve overall hind-limb
222 analgesia.

223 **Learning curve**

224 After a very short period of adjustments, the anatomical landmarks were easily identified. The
225 sciatic and femoral nerve blocks were feasible and rapidly performed. A person lacking previous
226 ultrasound experience quickly learned how to use the ultrasound technique and improve
227 accuracy and speed in performing the nerve blocks under ultrasound guidance. The possibility
228 to control each injection in necropsy further accelerated the learning process.

229 A steep learning curve of the needle placement under ultrasound guidance has previously been
230 shown for breast cyst aspiration^{55,56}.

231 **Limitations of the study**

232 In two cadavers, the sciatic and the femoral nerves could not be identified because of the
233 limited quality of the cadaveric tissue. Before scanning the cadaver, the skin and the
234 subcutaneous fat tissue of the frozen cadaver had to be removed as it became firm and dry due
235 to the freezing process, thus generating severe artifacts impeding the sonographic view on the

236 underlying structures. When the sciatic nerve was evaluated sonographically in an
237 anaesthetized sheep being involved in another experimental trial, the sciatic nerve could easily
238 be identified.

239 **Use of ultrasound**

240 The necessity of an expensive ultrasound machine might limit the application of such a
241 technique in experimental settings. For this trial, a linear array probe (6-13 MHz) was used to
242 allow the best possible visibility of the sciatic and femoral nerves, but due to the very profound
243 position of the sciatic nerve and the embedding in the muscles, the quality of the ultrasound
244 image was reduced ⁴². The use of probes with lower frequency would have led to increased
245 depth of visualization but also to a loss of detail visibility.

246 The in-plane technique used in the present study offers significant advantages over the out-of-
247 plane technique as the tip of the needle and the shaft can be visualized while advancing in
248 direct proximity to the target nerve.

249 The femoral nerve is lying relatively superficial. Anyway, the identification was difficult due to the
250 lack of blood flow through the femoral vessels and the impossibility to differentiate the neural
251 structures from the vessels.

252 The success rate of peripheral nerve blocks can be significantly increased with the use of
253 ultrasound guidance as compared to the application of a nerve stimulator ^{40,42,57}. Intraneural
254 injections of local anaesthetics can lead to nerve damage and should be avoided ⁵⁸. Therefore,
255 complete neural staining was not expected with the minute volumes used.

256 The use of needles designed for injections under ultrasound guidance with reflector marks allow
257 an even more precise localization of the needle tip. Consequently, with the combination of
258 modern sonographic accessories and the in-plane technique, a successful perineural injection
259 of analgesic drugs can be provided.

260 As intended in this trial, the small volumes of methylene blue usually stained the perineural
261 tissue instead of the nerve itself. Therefore, intraneural injection of methylene blue could be
262 excluded.

263 The experiment described here was a pure cadaveric study. Therefore, the analgesic efficacy of
264 the sciatic and femoral nerve block could not be evaluated. However, the proof of principle of
265 both nerve blocks in dogs, humans and goats to desensitize the stifle joint has been provided
266 before^{7,40,59}. To the author's knowledge, the effectiveness of a single parasacral sciatic block
267 for hip surgery has not been demonstrated so far, neither in humans nor in animals.

268 As a next step it will be necessary to test the described regional anaesthesia techniques in
269 animals undergoing orthopaedic surgery. Even though the duration of effects of local
270 anaesthetics is longer in sheep than in humans, a perineural catheter will be helpful to prolong
271 the post-operative analgesia for several days.

272

273 **Conclusions**

274 With this study we provide an exhaustive anatomical description of the localization of the sciatic
275 and femoral nerve by using ultrasound imaging in sheep. The evaluated technique is simple and
276 rapid to perform and produces precise and clear images of the nerves. *In vivo* studies will be
277 necessary to assess the efficacy of this technique in providing satisfactory perioperative
278 sensory analgesia and motor blockade.

279

280 **Conflict of interest statement**

281 None of the authors of this paper has a financial or personal relationship with other people or
282 organisations that could inappropriately influence or bias the content of the paper.

283

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286

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464 **Figures**

465 **Fig. 1:** Ultrasonographic image of the left sciatic nerve (a) near the greater sciatic foramen.
466 Needle (b) with its reflector mark and the ilium (c).

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468 **Fig. 2:** Ultrasonographic image of the right femoral nerve, the femoral artery and the femoral
469 vein (d). The needle tip can be seen underneath the fascia of the sartorius muscle near the
470 femoral nerve, the femoral artery and the femoral vein. The sartorius muscle with its triangular
471 appearance (a), the femur (b) and the needle (c).

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473 **Fig. 3:** Left pelvis, dorsal view. The sheep cadaver was positioned in sternal recumbency. The
474 left sciatic nerve (a) and the surrounding tissue have been stained with methylene blue.

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476 **Fig. 4:** Right pelvic limb, medial view. The cadaver was positioned in supine position. The left
477 femoral nerve and the surrounding tissue have been stained with methylene blue.

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479 Figure 1:

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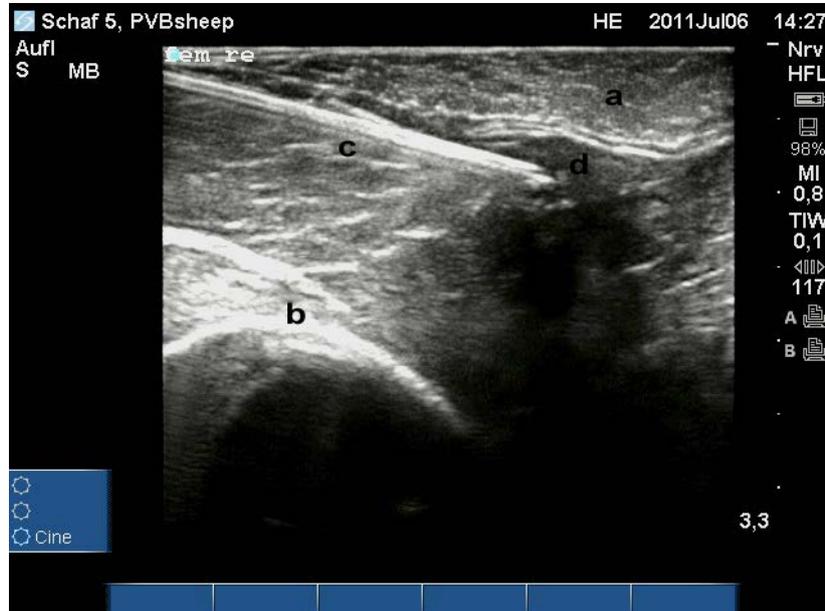
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495 Figure 2:

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497 **Figure 3:**

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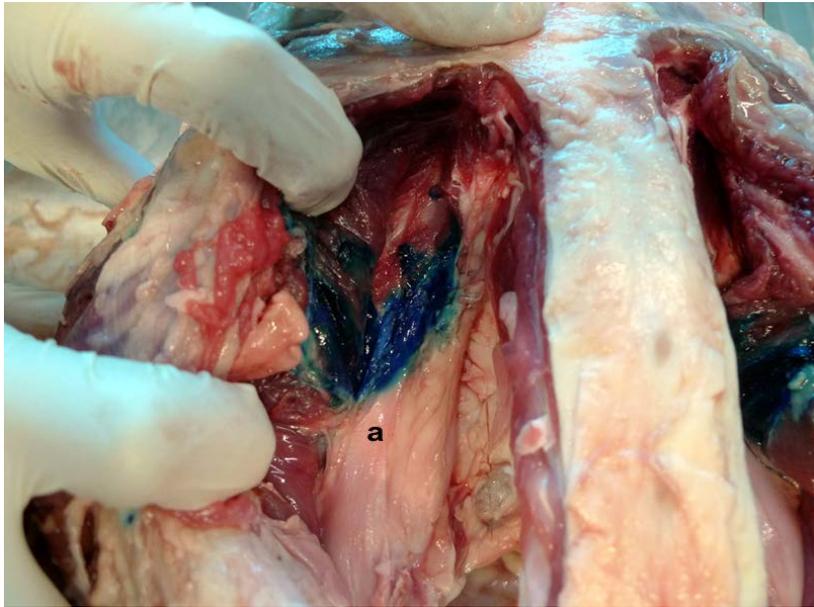


Figure 4:

