Evaluation of three approaches for performing ultrasonography-guided anesthetic blockade of the femoral nerve in calves

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Objective—To develop a practical ultrasonography-guided injection approach to anesthetic blockade of the femoral nerve in calves and to assess the method’s accuracy.

Animals—13 cadavers of 4-week-old male Holstein Friesian calves.

Procedures—Detailed topographic and anatomic cross-sectional evaluation of the relevant topography in 3 cadavers was performed to identify optimal injection approaches to the femoral nerve. Three approaches (ventral paravertebral, dorsal paravertebral, and ileal) were evaluated by simulated ultrasonography-guided perineural injection of methylene blue dye in 10 cadavers. Ultrasonographic image quality, number of needle redirections required for correct needle positioning, and injection success as defined through a 3-point grading system were recorded.

Results—The dorsal paravertebral approach yielded the best results, compared with the ileal and ventral paravertebral approaches, to properly and adequately stain the targeted nerve.

Conclusions and Clinical Relevance—The dorsal paravertebral injection technique appeared to be the best choice for performing a femoral nerve block in calves, although this technique will need to be further evaluated in live calves to determine its effectiveness and clinical usefulness. Diagnostic perineural anesthesia of the femoral nerve in cattle might be helpful in identifying quadriceps muscle involvement in those with complex spastic paresis.


The typical clinical manifestation of spastic paresis in cattle is involuntary spastic contractions of the gastrocnemius muscle when the cattle are standing. In contrast, a variant manifestation in Belgian Blue calves is mainly characterized by quadriceps femoris muscle involvement in spasticity of the hindquarters. To the authors’ knowledge, involvement of the quadriceps muscle in spastic paresis in cattle still needs to be confirmed.

Spastic paresis of the gastrocnemius muscle or quadriceps muscle in calves is differentiated through the evaluation of posture and gait. Calves with spastic paresis of the gastrocnemius muscle have spastic hyperextension of the affected hind limb in a caudal direction, whereas those in which the quadriceps muscle is affected primarily have cranially directed hyperextension of the limb. In recent years, a higher than usual incidence of mixed spastic paresis involving both muscles has been observed in Belgian Blue calves. Spasticity of gastrocnemius, quadriceps, and probably other muscle groups of the hind limb causes repetitive hyperextension of the affected limb. Depending on the dominant spastic muscle, this hyperextension is variably directed cranially, caudally, or laterally, complicating definitive diagnosis.

Standard treatment for spastic paresis includes tectectomy or surgical denervation (partial neurectomy of the tibial nerve) of the gastrocnemius muscle bellies; however, no treatment has been described for mixed spastic paresis. Partial tibial neurectomy to denervate the gastrocnemius muscle is contraindicated when the quadriceps muscle is the major contributor to the spasticity. The overactivity of quadriceps and gastrocnemius muscles can keep the affected limb in a neutral, although spastically hyperextended, position. When the influence of a contributing muscle is removed, as would occur with partial neurectomy of the gastrocnemius muscle, spastic contractions originating from the other contributing muscles become dominant and possibly exaggerated. This situation can cause an inability to remain standing. When the gastrocnemius muscle is
the primary contributor to the spasticity, surgical intervention can ameliorate pain and improve growth in an affected calf; however, a calf with mixed spastic paresis will continue having spastic contractions. For the aforementioned reasons, it is important to be able to differentiate among the various types of spastic paresis. Differentiation through clinical examination alone is challenging, and findings are often inconclusive. Anesthetic nerve blocks targeted to affect the spastic muscles can temporarily relieve signs and may aid in identification of the contributing muscle groups, and this procedure is used for that purpose in humans, such as those who have had a traumatic brain injury or stroke.6–8 In humans, the clinical effects of anesthetic blocks are useful in determining appropriate therapeutic interventions such as neurolysis, botulinum toxin injection, or neuroectomy.6,9

In veterinary medicine, nerve blocks are commonly performed for diagnostic purposes such as lameness examination in horses9 or for anesthetic purposes before, during, and after surgical interventions (eg, paravertebral anesthesia for laparotomy in cows).9 Given that the quadriceps muscle activity is solely regulated by the femoral nerve, a diagnostic anesthetic technique for blocking femoral nerve conduction might help in differentiating the muscles involved in cattle with spastic paresis. Femoral nerve blockade has been performed in dogs to provide preemptive analgesia for orthopedic procedures.10–12 Comparable techniques for use in cattle have not been reported. The purpose of the study reported here was to explore various approaches for a practical ultrasonography-guided injection of the femoral nerve in calves, to assess the accuracy of the techniques, and to identify the superior technique so that it might be evaluated further in live cattle.

Materials and Methods

Animals—The study involved 2 phases. In the first, the topographic anatomy of the femoral nerve was evaluated in the cadavers of 2 calves (a 78-kg Belgian Blue calf [age, 6 weeks] and a 52-kg Holstein calf [age, 4 weeks]), and the cross-sectional anatomy was evaluated in an additional Holstein calf (50 kg; age, 4 weeks). All calves had been euthanized for reasons unrelated to any pathological changes involving their neuromusculoskeletal structures.

In the second phase, ultrasonography-guided approaches to injection of the femoral nerve were evaluated in the cadavers of 10 healthy 4-week-old male Holstein-Friesian calves with a median body weight of 50 kg (range, 45 to 55 kg). These calves had been used in ultrasonography studies that required euthanasia. The protocol for both phases of the present study was approved by the Ethical Committee for Animal Research of Ghent (EC No. 2011-057).

Topographic and cross-sectional anatomic evaluation of the femoral nerve—Topographic anatomy of the femoral nerve was reviewed with the aid of anatomy textbooks.11–14 Dissection of the 2 calf cadavers was performed within 4 hours after euthanasia. Initially, the cadavers were positioned in dorsal recumbency for dissection of the medial thigh and inguinal region. Afterward, the calves were positioned in lateral recumbency for dissection of the lumbosacral region and the hindquarter musculature. Anatomic landmarks relevant for ultrasonography of the regions of interest were recorded, and possible approaches for needle insertion were identified.

For the cross-sectional evaluation, the spinal cord and musculature of the back of the third cadaver were removed within 2 hours after death and frozen for 48 hours at –18°C. Consecutive 2-cm-thick transverse sections were subsequently cut from L2 to C2. High-resolution photographs were obtained of each side of the frozen transverse sections15 on a photography table. Topographic relationships of important structures were studied on the photographs for comparison with corresponding ultrasonographic images. Ultrasonography of the regions of interest was performed with a 3-MHz curved linear array transducer and ultrasonography machine1. The focus was set in accordance with the depth of the landmarks.

Ultrasonography-guided injection of the femoral nerve—This portion of the study was performed immediately after calves were euthanized. All procedures were performed by the same operator (CDV), who had limited experience with ultrasonography-guided injections. Each cadaver was positioned in lateral recumbency to mimic the clinical situation for anesthetic nerve blockade. The skin overlying the predetermined injection sites was clipped of hair and washed. Relevant anatomic landmarks were first identified by means of ultrasonography.

Three ultrasonography-guided approaches to anesthetic blockade of the femoral nerve were evaluated: dorsal paravertebral in 5 cadavers, ventral paravertebral in the remaining 5 cadavers, and ileal in all 10 cadavers. With ultrasonographic guidance, a 90-mm, 19-gauge spinal needle6 was used to inject 5 mL of 20% methylene blue solution into the nerve, with the position of the injection differing among approaches. The dorsal and ventral approaches were not combined on the ipsilateral side of the cadaver because both approaches targeted the same portion of the femoral nerve. A more distally located portion of the femoral nerve was stained during injection via the ileal approach, which allowed this technique to be combined with 1 of the other 2 techniques on the ipsilateral side (Figure 1). After nerve injection, the spinal and hindquarter musculature was dissected to expose the femoral nerve and verify the accuracy of dye deposition around the nerve. Forty injections were performed in 10 cadavers, including 10 via the ventral paravertebral approach, 10 via the dorsal paravertebral approach, and 20 via the ileal approach.

Several variables were recorded to assess the outcome of each injection technique, including ultrasonographic image quality, number of needle redirections required for correct needle positioning, and injection score. Ultrasonographic image quality was scored as follows: 1 = excellent (landmarks clearly identified as 2 hyperechogenic lines [ventral paravertebral approach and dorsal paravertebral approach] or as 2 hypoechogenic spots [ileal approach]; needle clearly identified as a continuous hyperechogenic line); 2 = acceptable...
When a needle was inaccurately positioned, it was slightly withdrawn and reinserted at a corrected angle, which was defined as a repositioning attempt. The deposition of the dye in relation to the femoral nerve was scored on a 3-point scale. An injection score of 1 was given when the nerve was stained (epineural) or 2 when the nerve was not stained but dye was found in the perineural tissues, < 5 mm away from the femoral nerve (perineural). When dye was found > 5 mm away from the femoral nerve, an injection score of 3 was given (peripheral). Injection was considered successful when the nerve was stained (injection score 1).

Statistical analysis—Statistical and graphic analyses were performed with statistical software. The Kendall $\tau$ nonparametric correlation coefficient was calculated to correlate ultrasonographic image and dye injection scores. Statistical differences in both types of scores between the 3 ultrasonography-guided techniques (ventral paravertebral approach, dorsal paravertebral approach, and ileal approach) were evaluated via the Kruskal-Wallis test. The Jonckheere-Terpstra test was used to evaluate whether a trend existed in the scores obtained after injection and to test the hypothesis that a learning effect existed for the injection techniques (ie, better injection scores for femoral nerves injected at the end of the experiment). A value of $P < 0.05$ was considered significant for all analyses.

Results

Topographic and cross-sectional anatomy of the femoral nerve—The femoral nerve was found to originate from several branches at L4 through L6. These branches were surrounded by connective tissue and located near the vertebral bodies of L5 and L6, ventral to the transverse processes of these vertebrae and medial to the psoas major muscle (Figures 2 and 3). More distally, the nerve continued ventrally in a caudoventral direction, toward the wing of the sacrum (ala ossis sacri) and medial to the shaft of the ileum, and passed between the tendon of the psoas minor and iliopsoas muscles, where it was accompanied by the external iliac artery and vein. At the level of the pecten pubis, the femoral nerve branched off the saphenous nerve, which turned medially and spread sensory branches to the
When the cadaver was positioned in dorsal recumbency, the nerve was located deep in the inguinal region, surrounded by several important blood vessels, which might become damaged when an inguinal approach is used. Therefore, 3 possible routes to reach the femoral nerve by injection were proposed for study: 2 targeting the nerve near its origin in the paravertebral area (dorsal and ventral paravertebral approach) and 1 aimed at the mid–ileal shaft region (ileal approach).

Dorsal paravertebral approach—The ultrasonography transducer was placed in an axial, transverse plane at the level of the sacrum and advanced in a cranial direction along the spinal axis to identify the space between the spinous processes of L5 and L6, which are the bony landmarks for this approach. Then the transducer was rotated 90° to a longitudinal plane and repositioned 2 to 3 cm lateral to the axis of the spinal process to make visible the space between the transverse processes of L5 and L6. A 90-mm, 19-gauge spinal needle was inserted through the skin lateral to the transducer (Figure 4) and advanced in a caudomedial direction toward the cranial border of the transverse process of L6. Once the needle tip reached a position < 1 cm lateral to the vertebral body of L6, it was further advanced for a maximum 1 cm under the transverse process, where the dye solution was injected.

Ventral paravertebral approach—The space between the transverse processes of L5 and L6 and the bony contours of these vertebrae were identified as described. With the transducer aimed at the lateral edge of the transverse processes of both vertebrae (bony landmarks), the spinal needle was inserted perpendicular to the longitudinal axis of the spinal cord, 0.5 cm ventral to horizontal plane of the lumbar transverse processes and in the middle of the space between the transverse processes of L5 and L6 (Figure 5). As soon as the needle was identified in this region, it was oriented toward the contralateral tuber ischiadicum. During this procedure, the needle could be followed ultrasonographically until it reached the cranial border of the transverse process of L6. Further insertion made the needle disappear beneath the transverse process until it touched the body of L6. Before dye solution was injected, the needle was withdrawn a few millimeters.

Ileal approach—For this approach, the cranial femoral nerve was targeted at the point where it coursed ventral to the ileal shaft and was accompanied by the femoral artery and vein, which were used as landmarks. The transducer was positioned 3 to 4 cm caudoventral to and parallel with the longitudinal axis of the tuber coxa and perpendicular to the skin and moved in a caudoventral direction until both blood vessels were identified as 2 hypoechogenic spots (Figure 6). The spinal needle was inserted cranial to the transducer and oriented toward the blood vessels. Once the tip of the needle was identified near this location, the dye solution was injected.
Simulated anesthetic blockade of the femoral nerve—A significant \( P < 0.05 \) correlation was identified between the injection score and ultrasonographic image score for the ventral paravertebral approach \( (\tau = 0.66) \) and the ileal approach \( (\tau = 0.62) \) but not for the dorsal paravertebral approach \( (\tau = 0.40; \text{Figure 7}) \). The median number of times the needle required repositioning in the dorsal approach was 5 (range, 2 to 11). For the ventral and ileal approaches, this number was 2.5 (range, 1 to 9) and 4.5 (range, 1 to 10), respectively.

The femoral nerve was stained in 8 of 10 performances of dorsal paravertebral approach, in 5 of 10 for the ventral paravertebral approach, and in 8 of 20 for the ileal approach. The proportion of injections that achieved an injection score of 1 was highest in the dorsal paravertebral approach, compared with in the other approaches. However, these proportions were not significantly \( (P = 0.53) \) different. No significant differences in injection scores \( (P = 0.13) \) nor in ultrasonography scores \( (P = 0.65) \) were observed among the approaches. Although the injection scores improved the more injections were performed for each approach, this trend was not significant \( (P > 0.10) \).

Discussion

This preliminary cadaver study showed that simulated ultrasonography-guided injection of a dye adjacent to the femoral nerve in calves is possible. The success rates of the 3 techniques could be considered equally efficient for performance of femoral nerve block in cadavers.

Ultrasonography is the most appropriate imaging technique to guide injection of peripheral nerves. It allows continuous visibility of the needle tip, which increases the safety of the technique by avoiding inadvertent IV or intraneural injection.\(^1\text{5,16}\) The success rate of peripheral nerve blocks performed with ultrasonographic guidance is considered superior to success rates for techniques that do not allow structures to be seen.\(^1\text{7}\) Ultrasonographic guidance also allows identification of bony landmarks, which is important for correct needle positioning when the injection target is specific or deeply located anatomic areas or structures. This characteristic is of major importance in well-muscled beef cattle, in which bony landmarks are not as readily palpable as they are in thinner breeds. Holstein calves were...
used in the present study mainly because of economic considerations and availability. Their body conformation facilitated the application of the approaches by a moderately experienced operator.

In humans and dogs, a femoral nerve block is performed through a medial, inguinal region approach.10,11,17 The topographic and cross-sectional anatomic evaluation in the present study showed that an inguinal approach to nerve injection was highly impractical, mainly because of the large muscle volume often encountered in beef calves and the high risk of inadvertent blood vessel damage. Clinical application of this approach would also require deep sedation of a calf to allow a safe approach, followed by sedative reversal for subsequent gait evaluation, which would further complicate the procedure. Lateral approaches were deemed more efficient than an inguinal approach because of the more superficial location of the femoral nerve and the proximity of specific anatomic landmarks such as the transverse processes of certain lumbar vertebrae, the tuberculum coxa, and important adjacent vascular structures. However, in the paravertebral approaches, the femoral nerve was not directly visible because of the nerve’s location close to the lumbar bony vertebral column. With the dorsal paravertebral approach, the needle tip could be accurately advanced to the cranial border of the transverse process of L6. With the ventral paravertebral approach, ultrasonography was only useful to identify the correct position for needle insertion. Further insertion was performed without the needle tip visible and guided by external characteristics such as the contralateral tuber ischiadicum. This complication might explain the lower success rate associated with the ventral technique. The ventral paravertebral approach targets a slightly more caudal area of the femoral nerve than does the dorsal paravertebral approach, which might overlap with the origin of the obturator nerve in some calves. Deposition of local anesthetic in this region could cause paralysis of quadriceps and adductor muscles, which might complicate clinical evaluation of the nerve block. For this reason, the least amount of anesthetic should be used when the ventral approach is used.

The main difficulty encountered with the ileal approach was the correct identification of the cranial femoral artery and vein. In several situations, these vascular structures were not clearly outlined on the ultrasonographic images, mainly because of the absence of blood flow in the cadavers, which precluded the use of Doppler techniques to enhance their detection. The inability to clearly see these landmarks in cadavers may have contributed to a lower image quality score for the ileal versus other approaches. Use of the ileal approach in live calves might provide better visibility of the landmarks and therefore better results than those obtained in this cadaver study. That said, the ileal approach enabled nerve identification and allowed needle guidance to the perineural level. Furthermore, injection of a dye solution could be seen as it spread along the nerve and vascular structures. A disadvantage to use of the ileal approach with Doppler techniques is that it would require more sophisticated equipment, increasing the financial burden of the procedure.

We considered the dorsal paravertebral approach to be the most user-friendly of the 3 techniques evaluated and believe that moderate experience in ultrasonography would be sufficient to obtain a high success rate for staining the targeted nerve. No sophisticated equipment was required, and the portion of the injection path that could not be seen was small. However, the small number of calves used is a limitation to the study. Clinical application of these ultrasonographic approaches in healthy cattle would be essential for confirming the suitability of the described injection techniques. From a clinical perspective, the potential of the dorsal paravertebral technique to enable identification of quadriceps muscle involvement in the spastic paresis syndrome warrants further investigation.

References

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