Anesthesia of the paralumbar fossa and abdominal wall is necessary to perform common surgeries in standing cattle and can be induced by local anesthetic techniques such as incision line infiltration; inverted L nerve block, proximal or distal paravertebral nerve block, or epidural block; and thoracolumbar subarachnoid anesthesia. 

For laparotomy, the PPNB or DPNB is preferred. Both the PPNB and DPNB desensitize a relatively larger body area, compared with that achieved by the infiltration technique, and are performed by palpating the transverse process of the T13, L1, and L2 vertebral bodies. However, identification of the anatomic landmarks for the PPNB or DPNB may be difficult in obese and heavily muscled animals or impaired because of variation in anatomic pathways of the nerves, and the risk of damaging blood vessels associated with nerve blocks is high. Thus, the success rate of blockade techniques performed without a method of imaging the spinal nerves is variable. Advantages of ultrasound guidance when performing nerve blockade include identification of neural and adjacent anatomic structures, detection of anatomic variations, assessment of the spread of the local anesthetic, and reduction in the volume of local anesthetic required.

In cattle, the use of ultrasound guidance for needle placement as part of the PPNB has been described, with an anesthetic success rate similar to that obtained with the blockade technique performed with unguided needle placement. However, the articular processes of the vertebral segments and not the paravertebral nerves were identified. The purpose of the study reported here was to determine whether ultrasound-guided identification of the T13, L1, and L2 spinal nerves for needle placement would improve blockade effectiveness, compared with that achieved with the PPNB and DPNB, in calves. We hypothesized

Comparison of paravertebral blockade techniques with and without ultrasound guidance in calves

Michela Re PhD
Javier Blanco-Murcia PhD
Alejandra Villaescusa PhD
Ignacio De Gaspar PhD
Ignacio A. Gómez de Segura PhD

OBJECTIVE
To compare the effectiveness of an ultrasound-guided paravertebral nerve blockade technique (UGPNB) with distal and proximal paravertebral nerve blockade techniques without ultrasound guidance (DPNB and PPNB, respectively) in calves.

ANIMALS
4 calf cadavers and 7 healthy calves.

PROCEDURES
A suitable acoustic window was identified to facilitate access to the T13, L1, and L2 spinal nerves in cadavers and live calves. In cadavers, nerves were injected with dye under ultrasound guidance. In calves, the UGPNB, DPNB, and PPNB were performed in random order at 10-day intervals by injection of an anesthetic solution containing 2% lidocaine hydrochloride. Nociceptive withdrawal responses were assessed to determine the effects of the blockades.

RESULTS
In cadavers, nerve staining success rates (ie, ≥2-cm-long dye path) achieved with ultrasound guidance were 88% (T13 ventral branch), 75% (T13 and L1 dorsal branches and L1 and L2 ventral branches), and 38% (L2 dorsal branch). The nerves were each identified as a hyperechoic band in a longitudinal plane. In calves, the UGPNB, DPNB, and PPNB reduced the withdrawal response to the noxious stimulus, mainly in the dorsal-cranial, dorsal-caudal, and ventral-cranial areas of the flank. Overall, the UGPNB resulted in a better nociceptive cumulative score, administering only one half of the local anesthetic dose, compared with findings for the DPNB and PPNB. However, time to perform the UGPNB was longer.

CONCLUSIONS AND CLINICAL RELEVANCE
The UGPNB evaluated may be an improved alternative to the DPNB and PPNB for provision of anesthesia for flank surgery in calves. However, effectiveness of the UGPNB should be evaluated in a clinical setting and in adult cattle. (Am J Vet Res 2016;77:1187–1193)
that even when a lower dose of an anesthetic solution is administered, the effectiveness of the UGPNB would be greater than that of either the PPNB or DPNB.

**Materials and Methods**

To determine a suitable acoustic window for the ultrasound-guided needle placement in live animals, an experiment was carried out in calf cadavers. Subsequently, healthy calves were used to compare the UGPNB with the PPNB and DPNB. The study was approved by the Complutense University of Madrid Institutional Animal Care and Use Committee (Reference No. 101/2012).

**Anatomic assessment and simulated UGPNB in cadavers**

For the anatomic dissection and simulated UGPNB of the left and right T13, L1, and L2 spinal nerves, 4 cadavers of calves were used. The calves had terminal diseases and were sedated with xylazine hydrochloride (0.1 mg/kg, IV) prior to euthanasia (via overdose of embutramide, mebezonium iodide, and tetracaine hydrochloride injectable solution, bIV). At the time of death, the mean ± SD age of the calves was 46 ± 29 days and mean weight was 42 ± 12 kg. The nerves were examined ultrasonographically with a 6- to 10-MHz linear transducer. On each side of the body, the 13th rib was used as the landmark; the probe was placed perpendicular to that rib and the transverse processes of the thoracic and lumbar vertebrae. A suitable acoustic window located at the corresponding paravertebral space was selected to perform the blockade of these nerves. To identify the T13 spinal nerve, the probe was placed in the intertransverse space located between the last rib and the L1 vertebra, at the level of the proximal half of the transverse process and parallel to the spinal cord. Once the T13-L1 intervertebral space was identified, the probe was rotated 90° over the intervertebral space (parallel to the transverse process), and tilted to visualize the dorsal and ventral branches of the T13 nerve. To visualize the L1 and L2 spinal nerves, the probe was placed in a similar manner at the intertransverse space between the transverse processes of L1 and L2 and of L2 and L3, respectively (Figure 1).

An out-of-plane approach was used where only the tip of the needle (attached to a syringe) was observed. The 20-gauge, 90-mm-long spinal needle was advanced perpendicular to the skin plane at the distal part of the transverse process. Once the tip of the needle was approximately 1 mm from the ventral and dorsal branches of each nerve, as determined with the ultrasound device, they were each injected with 0.1 mL of methylene blue dye/kg (1%). The dye was injected in the right nerves when cadavers were placed in left lateral recumbency and in the left nerves when cadavers were placed in right lateral recumbency. On each side of the body, the area located caudal to the last rib and cranial to the crista iliaca, and between the longissimus lumborum muscle, medially, and the medial edge of iliacostalis lumborum muscle, laterally, was immediately dissected for macroscopic verification of the stained area, and the length of the stained portions of the dorsal and ventral branches of each nerve were measured and recorded (in mm). Skin incisions were made close to the lateral border of the longissimus lumborum muscle. The skin was removed medially and laterally to expose the fascia thoracolumbalis. Then, the fascia and the longissimus muscle were removed to expose the lateral dorsal cutaneous branch (dorsal branch) and the ventral branch of each spinal nerve. Muscular branches from the dorsal branch were removed together with the longissimus muscle.

**Nerve blockade in live calves**

Seven healthy university-owned calves (4 Friesians and 3 beef cattle crossbreeds) were used. The mean age of the calves was 6 ± 1 months and mean weight was 234 ± 17 kg. For 2 weeks before the start of the experiment, the calves were acclimated to the restraining device in a standing position with their head fixed for 1 hour daily. The left and right flanks of each calf were blocked in the same experimental session with the PPNB, DPNB, or UGPNB in a random order; there was a 10-day washout period between procedures. In this washout period, the calves were restrained in the device twice.

Each calf was not sedated before the experiments to prevent masking of the analgesic effects of the paravertebral blockades. The anatomic areas of interest were clipped and cleaned with alcohol, and acoustic gel was applied when required. Although nonsterile gel was used, gel at the puncture site was removed with a gauze soaked in alcohol before introducing the needle to prevent potential infection. The anesthetic solution used contained 2% lidocaine hydrochloride, 0.002% epinephrine, and 0.2% chlorobutanol hemihydrate. During experiments with the PPNB and DPNB, 20 mL of anesthetic solution was administered at each nerve location; given the 3 nerve locations, the total volume of anesthetic solution injected on either body side was 60 mL. For the PPNB, 20 mL of the anesthetic solution was injected for desensitization of each of the T13, L1, and L2 spinal nerves where they emerged from the intervertebral foramina. For the DPNB, a 10-mL volume of the anesthetic solution was injected at each branch (dorsal and ventral) of the T13, L1, and L2 spinal nerves. During experiments with the UGPNB, the total volume of anesthetic solution administered on either body side was 50 mL. This volume was half that used for the PPNB or DPNB; the intention was to further demonstrate the increased effectiveness of the UGPNB. For the UGPNB, a 5-mL volume of the anesthetic solution was injected at each branch (dorsal and ventral) of the T13, L1, and L2 spinal nerves.

The PPNB and DPNB were performed by an experienced operator (JB) according to a published description of the techniques. In the present study, the UGPNB was performed on each occasion by the same operator (JB) according to a published description of the techniques.
2 investigators; the first operator (IDG) held the ultrasound probe while the second operator (MR) introduced the needle. The transducer was placed on the acoustic window previously defined in calf cadavers. The depths at which the nerves were located and the time required to perform the blockade of the 3 spinal nerves (T13, L1, and L2) on each side were recorded. Time required to perform the block was considered the interval from positioning of the ultrasound probe or identification of the anatomic landmarks by palpation to the end of local anesthetic injection.

To evaluate analgesia following each of the nerve blockades, the nociceptive withdrawal response was assessed through application of pinpricks with a 21-gauge needle (noxious stimulus) by the same investigator that performed the nerve blockade. The

![Figure 1](https://example.com/figure1)

**Figure 1**—Photographs to illustrate the UGPNB and representative ultrasonographic images used to facilitate the procedure in calves. **A**—Positioning of the ultrasound probe for visualization of the T13 spinal nerve in a calf placed in a restraining device. The anatomic areas of interest were clipped and cleaned with alcohol, and nonsterile acoustic gel was applied when required. Gel at the puncture site was removed with gauze soaked in alcohol before introducing the needle to prevent potential infection. The probe was placed in the intertransverse space located between the last rib and L1, parallel to the transverse process of L1. The anatomic locations of the T13, L1, L2, and L3 vertebrae are drawn in yellow. **B**—Ultrasonographic image of the dorsal and ventral branches (arrows) of the L1 spinal nerve. **C**—Positioning of the ultrasound probe and the needle approach to the T13 spinal nerve for injection of anesthetic solution. **D**—Ultrasonographic image of the anesthetic solution (outlined by dotted lines) that has spread dorsal (Dr) and ventral (Vn) to the ventral branch of the L1 spinal nerve (arrow). Cd = Caudal. Cr = Cranial.
nociceptive withdrawal response (single nociceptive score) was assessed with a 3-point score system as follows: 0 = positive, normal response; 1 = reduced response due to partial nociceptive blockade; and 2 = negative response, indicative that the nociceptive blockade was complete. A positive response was equivalent to the response to the noxious stimulus at baseline (immediately before administration of the last injection of each blockade). A reduced response was considered a response that was clearly diminished, compared with the normal response. A negative response was considered an absence of response to the stimulus. Five anatomic areas were evaluated: cranial-dorsal, cranial-ventral, caudal-dorsal, and caudal-ventral aspects of the flank and the lateral aspect of the stifle region. For each body side of each calf treated with each of the blockade techniques, a cumulative nociceptive withdrawal response (cumulative nociceptive score) was determined as the summation of the baseline value and all single nociceptive scores determined at 10-minute intervals during the first hour after administration of the last injection of the blockade and every 30 minutes thereafter until return to baseline values.

Statistical analysis
A descriptive statistical analysis of the quantitative variables was performed with the data expressed as mean ± SD or median (range) when appropriate. Within each anatomic area and blockade technique, the single nociceptive score at every time point was compared with baseline values by use of the Friedman test for related (repeated) samples. The cumulative nociceptive score for each blockade technique was calculated as the mean of the cumulative nociceptive scores obtained from all 5 evaluated body areas at all time points (baseline, 5, 10, 20, 30, 40, 50, 60, 120, 180, and 240 minutes) for both body sides of all calves. The mean cumulative nociceptive scores for the techniques were then compared with the general linear model procedure, repeated-measures ANOVA, and the Duncan post hoc test. A value of P < 0.05 was considered significant. All analyses were performed with statistical software.

Results
Anatomic assessment and simulated UGPNB in cadavers
The gross dissection of the T13, L1, and L2 spinal nerves and the simulated nerve blockade with ultrasound guidance were easily performed in all cadavers. Each of the 3 nerves exited the intervertebral foramen and immediately divided into 2 branches (dorsal and ventral) in a lateral-caudal direction. The dorsal branch crossed over the transverse process in a caudal direction. The ventral branch extended under the transverse processes and the iliocostalis muscle to reach the superficial surface of the tendon of origin of the transverse abdominal muscle.

Each branch of the nerves was identified ultrasonographically as a hyperechoic band in a longitudinal plane. Once the dye was administered, the liquid spread from the puncture site in a distal direction and appeared as an anechoic space dorsal to the dorsolateral surface of the nerve branches in all cadavers (Figure 1). Of the 48 dorsal and ventral branches of the T13, L1, and L2 spinal nerves on both body sides in the 4 cadavers, 34 (71%) were stained; additionally, there was a cranial-caudal distribution of the dye following the deep fascia of the fascia iliaca. For the T13 spinal nerve, 6 of the 8 dorsal branches and 7 of the 8 ventral branches were stained; for the dorsal and ventral branches, the mean ± SD length of nerve staining was 2.3 ± 0.5 cm and 2.7 ± 0.8 cm, respectively. For the L1 spinal nerve, 6 of the 8 dorsal branches and 6 of the 8 ventral branches were stained; for the dorsal and ventral branches, the mean ± SD length of nerve staining was 2.7 ± 0.8 cm and 3.4 ± 1.4 cm, respectively. For the L2 spinal nerve, 3 of the 8 dorsal branches and 6 of the 8 ventral branches were stained; for the dorsal and ventral branches, the mean ± SD length of nerve staining was 2.7 ± 1.2 cm and 2.9 ± 0.8 cm, respectively.

Nerve blockade in live calves
During the blockade procedures on both sides of the body in the 7 live calves, the 3 spinal nerves and needle were easily identified with ultrasonography, as in the cadavers, and the local anesthetic solution spread dorsal to the dorsolateral surface of each nerve. For each of the nerve blockade techniques, the initial insertion of the needle through the skin (to place the tip subcutaneously) was performed rapidly, with only a slight discernible movement of the animals. Response to needle insertion through the muscular planes was negligible. The mean ± SD time required to perform the UGPNB (7.4 ± 2.6 minutes) was significantly (both P < 0.001) longer than the time required to perform the DPNB (3.2 ± 1.2 minutes) or PPNB (3.4 ± 1.5 minutes). With the UGPNB, the depths of the dorsal branches of the T13, L1, and L2 nerves where the needle was directed were 2.2 ± 0.5 cm, 2.0 ± 0.6 cm, and 1.9 ± 0.6 cm, respectively; the depths of the ventral branches of the T13, L1, and L2 spinal nerves where the needle was directed were 2.4 ± 0.6 cm, 2.2 ± 0.6 cm, and 2.1 ± 0.6 cm, respectively.

Overall, the UGPNB provided a significantly (ANOVA, P = 0.04) higher cumulative nociceptive score, compared with that achieved with either the PPNB or DPNB. A lack of response to the noxious stimulus (median value of single nociceptive scores = 2) was observed with the DPNB in the dorsal-cranial flank area at 30 minutes and in the dorsal-caudal flank area at 50 to 60 minutes after administration of the last injection of the blockade (Figure 2). With the PPNB, this lack of response was observed only in the dorsal-cranial flank area at 10 to 50 minutes. Finally, the UGPNB resulted in a median value of single nociceptive scores of 2 in the dorsal-cranial, dorsal-caudal, and ventral-caudal flank areas starting at the 5-minute time point and lasting until the 90-minute,
A median single nociceptive score of 0 was recorded for the lateral aspect of the stifle region for all techniques evaluated. With the exception of the lateral aspect of the stifle region, the total duration of at least partial blockade (median value of single nociceptive scores, 1 or 2) among the assessed flank areas in the 7 calves was 20 to 85 minutes with the DPNB, 40 to 115 minutes with the PPNB, and 55 to 115 minutes with the UGPNB, although there were differences depending on the anatomic area considered (Figure 2). At 240 minutes after administration of the last injection of the anesthetic solution with any of the 3 blockade techniques, all calves were fully recovered (nociceptive score, 0).

Discussion

In the study reported here, blockade of paravertebral nerves performed with ultrasound guidance in calves was evaluated, and the analgesic effectiveness of that UGPNB was compared with that achieved with the PPNB and DPNB. Ultrasonographic visualization of the T13, L1, and L2 spinal nerves for needle placement increased the effectiveness of the paravertebral nerve blockade. Furthermore, the dose of anesthetic solution used with the UGPNB was half that used with either the PPNB or DPNB. Thus, compared with the standard blockade techniques, the UGPNB was not only more effective but also likely safer, given the reduced drug dose.

In the present study, the use of ultrasonography for the identification of the T13, L1, and L2 spinal nerves in calves was found to be relatively easy. Ultrasound guidance facilitated injection of the nerves with anesthetic solution, and the deposition of the drug around the surface of the nerves could be visualized. In other studies of paravertebral nerve blockade in cows, ultrasonography has been used to identify
the intervertebral joints but not the spinal nerves; in those studies, nerve blockade performed with ultrasound guidance was not more effective than nerve blockade performed without ultrasound guidance. This previous finding further supports the importance of accurate needle placement and deposition of anesthetic solution specifically around the nerve surfaces.

For the calf cadavers used in the present study, lateral recumbency was considered to be the position in which needle insertion would be easiest. On the basis of our clinical experience, the cadavers’ position does not appear to have influenced probe positioning and needle advancement, given that identical ultrasonographic images were obtained in live calves and cadavers. The experiments involving dye injection and subsequent nerve staining in cadavers simulated the UGPNB to ensure proper site administration and confirm that a portion of each nerve would be affected by anesthetic solution following the procedure in live calves.

In addition to the concentration and relative potency of the local anesthetic used, the length of the nerve in contact with the anesthetic agent is considered a major factor contributing to successful nerve blockade. Contact with anesthetic agent along at least 2 cm of the length of a nerve has been considered evidence of adequate blockade in dogs. In various other studies of paravertebral anesthesia involving cadavers, the volume of dye administered was highly variable and ranged from 1 mL in adult cows and 2 mL in horses at the intervertebral foramen up to 3.3 to 4.4 mL (mean volume of 0.3 mL/kg) within the brachial plexus in dogs. In the present study, the volume of dye injected into cadaver calves at each nerve site was 0.1 mL/kg (mean volume, 4.2 mL) because a previous pilot study from the authors in which twice that volume of dye had been used revealed that nerves were highly stained (nerve length > 6 cm). In the present study, 71% of the 48 dorsal and ventral branches of the nerves of interest were stained. In a previous study in 20 cattle wherein a lower volume of dye (1.0 mL) was administered at the intervertebral foramen at the level of T13, L1, and L2 spinal nerves, a success rate of 41% for staining both dorsal and ventral branches of the 3 nerves (49/120 dorsal and ventral nerve branches) was determined.

For all flank areas in the live calves used in the present study, the UGPNB had not only better nociceptive scores but also a longer duration of anesthesia. The time required to perform the UGPNB was more than double that required to perform the PPNB or DPNB but was < 10 minutes in all instances. However, the maximum anesthetic effect was achieved faster with the UGPNB (5 minutes vs 10 to 30 minutes with the other 2 techniques) and it generally lasted longer. Among the evaluated anatomic areas, anesthetic effect was generally slowest to develop in the ventral-caudal flank area, and this observation may suggest additional innervation of this flank region other than that of the ventral branches of the lumbar nerves. Ultrasound guidance during administration of local anesthetics allows optimal distribution of the drug around the nerves, which is considered a key requirement for successful regional anesthetic blockade. With the UGPNB, the potential advantage of faster onset time combined with longer duration of the blockade is improved overall quality of the blockade.

With regard to local and regional anesthesia, the duration of anesthetic effect depends on several factors including the drug and dose (concentration) used or the coadministration of epinephrine. In the present study, the total volume of anesthetic solution per kilogram of body weight used to perform the PPNB or DPNB was 0.26 mL/kg (three 20-mL volumes); this dose was slightly greater than that commonly used in adult cattle. However, the dose of anesthetic solution was twice that used with the UGPNB (mean dose, 0.13 mL/kg). The use of a fixed volume of injectate regardless of weight was justified by the similar weight of all the calves (SD, 17 kg). Also, the use of a fixed volume of injectate may also better mimic the clinical setting. Given that the UGPNB provided better nociceptive scores with half of the anesthetic solution dose used in the PPNB and DPNB, the likelihood of development of anesthetic-related toxic effects was reduced. It remains unclear whether the anesthetic solution dose can be further reduced while maintaining the beneficial effects, thereby reducing the potential for toxic effects even more.

The results of the present study were obtained with a solution containing 2% lidocaine although similar results may be expected with the UGPNB applied with other local anesthetics (eg, 2% procaine), depending on their pharmacodynamics and pharmacokinetic properties. Procaine, but not lidocaine, is licensed for use in cattle in Europe; however, procaine has a shorter duration of action, which should be considered in any comparison of paravertebral anesthesia with these drugs.

Limitations of the study reported here included the use of calves instead of adult cows, particularly obese and heavily muscled animals, and the absence of surgical or other painful procedures as nociceptive stimuli. Although not objective, the nociceptive scoring system was selected because it was a simple and easy method to apply to the various anatomic areas of interest in comparisons of the 3 paravertebral nerve blockade techniques. More objective alternatives, such as mechanical threshold devices, have a high degree of intraindividual variation or have been designed to be applied to specific anatomic areas such as the distal portions of limbs. Needle puncture is a noxious stimulation, which can be prevented by application of a small dose of local anesthetic to the skin and subcutaneous tissue planes. However, in the present study, topical administration of local anesthetic prior to introduction of the paravertebral block needle was not deemed necessary. Moreover, topical administration of local anesthetic might have biased the
results of the present study. The lidocaine solution used included chlorobutanol hemihydrate 0.2%, a preservative with antibacterial-antifungal properties but also local analgesic effects. This drug might have contributed to the findings of the present study, so the use of anesthetic solutions with differing composition might have different results. The UGPNB was performed by 2 investigators, although this situation is unlikely to occur in clinical practice. Finally, the investigator assessing the response to the noxious stimulus was not blinded to the treatments or techniques used, which is a major limitation to the study. Although nonblinded evaluation may influence the results, the response to the noxious stimulus identified relevant differences between paravertebral nerve blocks performed with and without ultrasound guidance. Overall, results of the present study indicated that the UGPNB is relatively easy to perform in calves and that the resultant anesthetic effect in the flank is superior to that provided by the PPNB or DPNB. Further studies are required to demonstrate the improved effectiveness of the UGPNB in adult cattle in clinical settings.

Acknowledgments
Presented in abstract form at the 19th International Bovine Medicine Congress of ANEMBE, Oviedo, Spain, June 2014.

Footnotes
a. Xilagesic 2%, Calier, Barcelona, Spain.
b. T61, MSD, Salamanca, Spain.
c. Logiq Book XP, GE Medical Systems, Milwaukee, Wis.
d. Becton Dickinson, Madrid, Spain.
e. Anesvet, Ovejero, León, Spain.
f. IBM SPSS Statistics for Windows, version 19.0, IBM Corp, Armonk, NY.
g. SAS, version 9.4, SAS Institute Inc, Cary, NC.

References