'Evaluation of electrical nerve stimulation to confirm sacrococcygeal epidural needle placement in dogs'

Authors Natali Verdier[a,b], Fernando Martinez-Taboada[c], Pablo E. Otero[a], José Ignacio Redondo García[d], Andrea C. Zaccagnini[a], Alejo A. Costoya[a], Lisa Tarragona[a], Diego A. Portela[e]

[a]Department of Anesthesiology and Pain Management, Facultad de Ciencias Veterinarias, Universidad de Buenos Aires, Buenos Aires, Argentina
[b]Department of Anesthesiology and Perioperative Intensive Care, University of Veterinary Medicine, Vienna, Austria
[c]The University Veterinary Teaching Hospital, The School of Veterinary Science, The University of Sydney, 65 Parramatta Road, Camperdown, New South Wales 2050, Australia
[d]Departamento de Medicina y Cirugía Animal. Hospital Clínico Veterinario. Facultad de Veterinaria, Universidad CEU Cardenal Herrera, Valencia, Spain
[e]Department of Comparative, Diagnostic, and Population Medicine College of Veterinary Medicine University of Florida, Gainesville (FL), USA

Correspondence Pablo E Otero, Universidad de Buenos Aires, Facultad de Ciencias Veterinarias, Cátedra de Anestesiología y Algiología, Avenida Chorroarín 280 (C1427CWO), Buenos Aires, Argentina. E-mail: potero@fvet.uba.ar

Abstract

Objectives To evaluate the use of 0.7 mA as a fixed electrical current to indicate epidural needle placement and to confirm that 0.7 mA is greater than the upper limit of the minimal electrical threshold (MET) for sacrococcygeal epidural needle placement in dogs.

Study design Prospective clinical study.

Animals A group of 20 client-owned dogs.

Methods During general anaesthesia and with standard monitoring, the presence of the patellar reflex was confirmed in all dogs. An insulated needle was inserted through the sacrococcygeal intervertebral junction and absence of tail movement was confirmed when a fixed electrical current of 0.7 mA was applied. Then, the needle was further advanced towards the epidural space until the expected motor response was obtained – the 'nerve stimulation test' (NST). The NST was considered positive when a motor response of the muscles of the tail was elicited but not the perineal muscles, whereas it was considered negative when no movement of the tail was evoked. The electrical current was turned to 0 mA and then increased by 0.01 mA increments until tail movement was evoked, this was recorded as the MET. In the positive NST cases, 0.05 mL cm^{-1} occipitococcygeal length of 2% lidocaine or 0.25-0.5% bupivacaine was administered. Epidural blockade was confirmed by the loss of patellar reflex. Descriptive statistics were used to present data.

Results Sacrococcygeal epidural needle placement, corroborated by loss of the patellar reflex, was correctly predicted in 89.5% (95% confidence interval: 68.6%-97.1%) of the cases. The MET was 0.22 mA (0.11-0.36).

Conclusions and clinical relevance A current of 0.7 mA is approximately twice the upper limit of the MET for epidural placement. Therefore, this study demonstrates, with a success rate of 89.5%, the adequacy of using 0.7 mA as the fixed electrical current to detect sacrococcygeal epidural needle placement in dogs.

Keywords canine, extradural, local anaesthetic, minimal electrical threshold, muscle contraction, nerve location.

Introduction

The sacrococcygeal approach to the epidural space in dogs has seen increasing use in recent years and is nowadays considered a potentially safer alternative to the traditional lumbosacral epidural access (Gregori et al. 2014; Martinez-Taboada et al. 2019; Vesovski et al. 2019). This is because the spinal cord and dural sac are absent at the sacrococcygeal level and therefore the risk of spinal cord damage and inadvertent intrathecal injection are minimized (Fletcher 2013).

Electrical stimulation of the spinal nerves has been proposed as an objective method to detect the puncture of the ligamentum flavum during needle advancement in dogs (Garcia Pereira et al. 2010; Otero et al. 2014). This method relies on the different minimal electrical thresholds (METs) required to elicit a motor response when the needle is located within the epidural space *versus* outside the epidural space or intrathecal, as observed at the fifth-sixth and lumbosacral intervertebral spaces in dogs (Garcia-Pereira et al. 2010; Otero et al. 2014). In cats, a nerve stimulation test (NST) has been developed as a tool to confirm sacrococcygeal epidural needle placement using a fixed electrical current. The recommended magnitude of the current is between the upper limit of the MET used within the epidural space and the lower limit extradurally (Otero et al. 2015). Although the NST has been previously tested in dogs using a fixed electrical current of 0.7 mA (Martinez-Taboada et al. 2019), neither this value nor the MET for epidural needle placement have been evaluated yet.

The aims of this study were I) to evaluate the use of 0.7 mA as a fixed electrical current to perform an NST that would indicate epidural needle placement and II) to confirm that 0.7 mA is above the upper limit of MET for sacrococcygeal epidural needle placement in dogs.

Materials and methods

This study was approved by the Institutional Animal Care and Use Committee of the Faculty of Veterinary Science, University of Buenos Aires (Nº 2012/31). A sample size calculation indicated that 20 subjects would be sufficient to demonstrate reliability of the NST using 0.7 mA, assuming $\alpha = 0.05$, $\beta = 0.8$ and effect size = 0.66 (one-sample proportion test; pwr package 1.2-2; https://CRAN.R-project.org/package=pwr).

Dogs that were submitted to the veterinary teaching hospital to undergo surgical procedures caudal to the umbilicus and in which epidural anaesthesia was planned were included. Owner's written informed consent was obtained for all dogs enrolled in the study. Exclusion criteria included: dogs younger than 6 months of age, those with short tails, those with orthopaedic disease of the spine, neurological disease, coagulopathy, skin infection at the injection site, or any contraindication to the use of local anaesthetics. All dogs were physically examined and had haematology and serum biochemistry analysis performed.

Dogs were anaesthetized using different anaesthetic protocols, depending on the American Society of Anesthesiologists physical status, surgical procedure and attending anaesthetist's preference. Fluid therapy and drugs used for premedication and induction were based on the anaesthetist's appraisal. After orotracheal intubation (Rüschelit Safety Clear, Teleflex Medical, Ireland), general anaesthesia was maintained using isoflurane (Ineltano Vet; Richmond Vet Pharma, Argentina) in oxygen. Routine anaesthetic monitoring was performed during the procedure and consisted of lead II electrocardiography, respiratory rate, pulse oximetry, end-tidal carbon dioxide, noninvasive blood pressure, and oesophageal temperature using a multiparametric monitor (Goldway VET 420A; Goldway US, Inc., NY, USA)

The vaporizer dial was adjusted and therefore the plane of anaesthesia such that the patellar reflexes were maintained. After confirming the presence of the patellar reflexes in both pelvic limbs, the animals were placed in sternal recumbency, with the pelvic limbs drawn cranially. The region at the base of the tail was clipped and aseptically prepared. The sacrococcygeal junction was identified by palpation and marked using a skin-marking pen (Tondaus, Meditech Co, Guangdong, China). To perform the NST, a 21 gauge insulated needle (B Braun Medical Inc., PA, USA) with its extension line prefilled with the local anaesthetic solution, was used. Using the previously marked spot, the needle was introduced at a 45º angle to the spine, with its bevel pointing cranially. The needle was advanced through the intervertebral junction until its tip was believed to be dorsal to the ligamentum flavum. The nerve stimulator (Stimuplex, HNS12; B.Braun, Germany) was set to deliver a fixed electrical current of 0.7 mA, with a frequency of 2 Hz and a pulse duration of 0.1 ms. After confirming absence of tail movement, the needle was gently advanced towards the epidural space and as soon as tail movement was observed, needle advancement was stopped. Subsequently, the perineum was palpated to confirm absence of muscle twitches. The presence of tail movement with an absence of perineum twitching was considered as a positive NST (Otero et al. 2015). If tail movement was absent or present with perineum twitching, the needle was gently repositioned until the response a positive NST was evoked. Taking care not to dislodge the needle, the current was turned to 0 mA and then gradually increased by 0.01 mA increments to determine the minimal intensity to elicit tail movement, which was recorded as the MET. Then, provided no blood flow was observed or resistance to injection detected, 0.05 mL cm^{-1} occipitococcygeal length of lidocaine (2%; Lidocaine; Richmond Vet Pharma, Argentina) or bupivacaine (0.5% or 0.25%; Bupinex Vet; Richmond Vet Pharma, Argentina) were administered at a rate of 0.05 mL $second^{-1}$. At either 10 or 20 minutes after lidocaine or bupivacaine administration, respectively, the presence of the right and left patellar reflexes was evaluated. The loss of patellar reflexes was considered a positive endpoint for epidural injection (Martinez-Taboada et al. 2019).

In addition, the intensity of the tail movement during the application of a 0.7 mA current was subjectively graded as: null, weak, or strong. Injections were performed by trainees or anaesthetists experienced in epidural anaesthesia.

During the recovery period and 24 hours after anaesthesia, complications related to the injection were noted, as well as recovery of normal muscle function of the pelvic limbs.

Statistical analysis

Data were assessed for normality using the Shapiro-Wilk test and presented using descriptive statistics. Data are expressed as median (range). The number of cases in which loss of patellar reflexes was observed after injection over NST positive cases is expressed as the percentage of success (%). Statistical analysis was performed using R 4.0.1 (R Core Team 2020).

Results

Demographic data of the dogs are shown in Table 1. The median (range) age, weight and body condition score (using a nine-point scale; Laflamme 1997) of the dogs was 84 (8-144) months, 11.0 (5.0-38.0) kg and 5 (3-8), respectively.

A total of 14 punctures were performed by two anaesthetists experienced in epidural anaesthesia, while six were performed by four trainees. Out of the 20 punctures performed, blood flow was observed in one dog and it was removed from further analysis.

Using an electrical current of 0.7 mA, no motor response was observed when the needle was positioned dorsal to the ligamentum flavum in all of the cases. The NST was positive in all dogs but correctly predicted epidural injection in 17 out of 19 dogs, yielding a success rate of 89.5% [95% confidence interval (CI): 68.6%-97,1%]. In two dogs, minimal resistance to injection was detected, and although it was overcome by gentle repositioning of the needle, loss of patellar reflexes after injection was not observed. The success rate of the method was 85% for experienced operators and 100% for trainees. The intensity of tail movement for each puncture is presented in Table 1.

The MET of each dog is shown in Table 1. The median (range) value of MET was 0.22 (0.11-0.36) mA, which was derived from the MET of those dogs in which epidural injection was confirmed by loss of patellar reflexes.

No cardiovascular or ventilatory alterations were detected in any of the dogs throughout the procedure until 20 minutes after injection. No complications related to injection were detected and normal muscle function had returned in all dogs before discharge.

Discussion

This study showed that in dogs, a fixed electrical current of 0.7 mA could be used to detect puncture of the ligamentum flavum at the level of the sacrococcygeal space, with a success rate of 89.5%. Given that 0.7 mA is approximately twice the upper limit of MET for epidural placement, it is an appropriate value to perform the NST in the sacrococcygeal space in dogs.

Electrical nerve stimulation has been documented as a tool to confirm epidural needle placement in dogs, with a greater sensitivity and specificity than traditional methods such as the 'pop sensation', the hanging drop technique or the loss of resistance technique (Garcia-Pereira et al. 2010; Otero et al. 2014; Martinez-Taboada et al. 2019). The success rate of 89.5% we obtained in this study is comparable to the 87.1% success rate obtained using the same approach in dogs by Martinez-Taboada et al. (2019).

The resistance to injection observed in two dogs of our study could be explained by either a tissue plug or partial occlusion of the needle's eye with the ligamentum flavum (Tsui et al. 2004). The volume of the injectate was assumed to be sufficient to anaesthetize the spinal nerves that mediate the patellar reflex. However it remains to be determined whether its presence after injection was the result of test failure, an inadequate distribution of the injectate or lack of efficacy. Therefore, it is important to consider the NST as a complementary tool to indicate when needle advancement should be stopped. Its use in addition to the lack of resistance test would be the authors' recommendation when performing epidural anaesthesia in dogs. It is noteworthy that under the specific settings of this study, the lower 95% confidence limit was 68.6% and therefore, further studies with a larger sample size are warranted.

The MET that indicated epidural needle placement in this study was 0.22 (0.11-0.36) mA. Considering that 1.2 ± 0.13 mA is the minimal MET value when the needle is outside the epidural space (Garcia-Pereira et al. 2010), 0.7 mA is an adequate intermediate value to perform the NST in dogs. This is also in agreement with the reported MET when the needle is placed dorsal to the ligamentum flavum in the sacrococcygeal space in cats (1.76 ± 0.34 mA; Otero et al. 2015).

The strength of muscular contraction during peripheral nerve block is said to be directly related to the current intensity, but inversely related to the distance between the needle and the target nerve and to the current duration (März 1990; Hadzic et al. 2004). In our study, different grades of motor response were observed at the same intensity and duration of impulse. The variations in motor response may be explained by anatomical differences in the positioning of the caudal spinal roots, the lack of muscle mass in the needle's pathway, the specific tissue impedance or the presence of epidural fat tissue. However, tail movement was indicative of the position of the epidural needle's tip, independently of the strength of the motor response, in 89.5% of the cases. To the authors' knowledge, this has not been studied in neuraxial anaesthesia and we believe it is useful information that warrants further investigation.

The success rate for this method was higher for trainees than for operators experienced in neuraxial anaesthesia. Although many variables could have contributed to this result such as the selection of cases for trainees or the individual dog's characteristics, it appears that this could be a simple and accessible technique in inexperienced hands.

This study has some limitations. Firstly, the loss of patellar reflex was considered the positive endpoint for epidural injection and more objective methods such as imaging studies were not used. Although loss of the patellar reflex is not the gold standard for assessing epidural needle placement, this method has been previously reported (Martinez-Taboada et al. 2019). It appeared to be suitable for our setting in which local anaesthetics were administered via the epidural route. Secondly, this was a clinical study that was not designed to detect false positive cases, that is, observation of tail movement without the needle being located within the epidural space. In two dogs the injection did not result in loss of the patellar reflex, but it remains to be determined whether this was a failure of the test or an inadequate distribution of injectate.

In conclusion, this study demonstrates, the adequacy of 0.7 mA as the fixed electrical current to detect sacrococcygeal epidural needle placement in dogs, with a success rate of 89.5%.

References

Fletcher TF (2013) Spinal cord and meninges. In: Miller's Anatomy of the Dog. Evans and De Lahunta (Eds). Elsevier, USA. pp. 589-610.

Garcia-Pereira FL, Hauptman J, Shih AC, et al. (2010) Evaluation of electric neurostimulation to confirm correct placement of lumbosacral epidural injections in dogs. Am J Vet Res 71, 157–160.

Gregori T, Viscasillas J, Benigni L (2014) Ultrasonographic anatomy of the sacrococcygeal region and ultrasound-guided epidural injection at the sacrococcygeal space in dogs. Vet Rec 175, 68–71.

Hadzic A, Vloka JD, Claudio RE, et al (2004) Electrical nerve localization: effects of cutaneous electrode placement and duration of the stimulus on motor response. Anesth 100, 1526–1530.

Laflamme D (1997) Development and validation of a body condition score system for dogs: a clinical tool. Canine Practice 22, 10-15.

Martinez-Taboada F, Otero PE, Laredo F, Belda E (2019) Identification of the sacrococcygeal epidural space using the nerve stimulation test or the running-drip method in dogs. Vet Anaesth Analg, https://doi.org/10.1016/j.vaa.2019.09.008

März P (1990) Kann bei der elektrischen Nervenstimulation aus der Intensität der Muskelkontraktion auf den Abstand zum Nerven geschlossen werden? Mögliche Einflüsse und Fehlerquellen [In electric nerve stimulation can the distance from the nerves be inferred from the intensity of muscle contraction? Possible parameters and sources of error]. Reg Anaesth 13, 179–185.

Otero PE, Verdier N, Ceballos MR, et al. (2014) The use of electrical stimulation to guide epidural and intrathecal needle advancement at the L5-L6 intervertebral space in dogs. Vet Anaesth Analg 41, 543–547.

Otero PE, Verdier N, Zaccagnini AS, et al. (2015) The use of a nerve stimulation test to confirm sacrococcygeal epidural needle placement in cats. Vet Anaesth Analg 42, 115–118.

Tsui BCH, Wagner A, Cave D, Seal R (2004) Threshold current for an insulated epidural needle in pediatric patients. Anesth Analg 99, 694–696.

Vesovski S, Makara M, Martinez-Taboada F (2019) Computer tomographic comparison of cranial spread of contrast in lumbosacral and sacrococcygeal epidural injections in dog cadavers. Vet Anaesth Analg 46, 510–515.