Evaluation of electric neurostimulation to confirm correct placement of lumbosacral epidural injections in dogs

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Objective—To determine the minimal electric threshold (MET) of neurostimulation in and out of the lumbosacral epidural space necessary to cause muscle contraction of the hind limb or tail, determine an MET cutoff value that indicates epidural needle placement, and compare predictability of epidural needle placement attained by use of neurostimulation versus the standard technique that uses loss of resistance in dogs.

Animals—96 healthy Beagles.

Procedures—Dogs received nonionic contrast medium (90 mg/kg) either in or out of the epidural space. Correct placement of the needle was evaluated by use of neurostimulation and loss of resistance of injection and confirmed by use of epidurography.

Results—With the neurostimulator test, MET was significantly lower in dogs with needle placement in the epidural space (mean ± SEM, 0.30 ± 0.07 mA) than those with needle placement out of the epidural space (1.2 ± 0.13 mA). When an electric current cutoff of ≤ 0.28 mA for the neurostimulator test was used to suggest correct needle placement in the lumbosacral epidural space, sensitivity and specificity were 74% and 93%, respectively. The loss of resistance test had sensitivity of 63% and specificity of 90%. The combination of both tests yielded a sensitivity of 89% and specificity of 83%.

Conclusions and Clinical Relevance—Neurostimulation is a useful tool to suggest correct lumbosacral epidural needle placement in dogs. (*Am J Vet Res* 2010;71:157–160)

Epidural anesthesia is an important technique to obtain analgesia of the caudal portion of the abdomen, lumbosacral area, and hind limbs of veterinary patients. The technique is often used in anesthetized patients to reduce the dose requirement of anesthetic agents. Epidural anesthesia is also used to safely reduce postoperative pain without the potentially adverse effects often seen with systemically administered agents.[1] In dogs, the lumbosacral space is the most commonly used and easiest site for epidural injections.[2]

Placement of a needle or catheter into the epidural space is challenging and requires operator experience.[2,3] In veterinary medicine, correct needle placement is suggested by a sudden decrease in resistance to injection of saline (0.9% NaCl) solution or air (loss of resistance technique) and is aided by the observation that fluid placed on the needle hub suddenly disappears as the needle enters the epidural space (hanging drop technique).[1] However, proper epidural placement of a needle or catheter is never definitively confirmed unless additional techniques such as contrast medium injection and radiography are used. In dogs, successful epidural placement of a needle is reported to be variable and dependent on experience of the operator.[4,5] Variability may be a result of the operator's inability to recognize loss of resistance to injection or because of loss of resistance occurring in a location other than the epidural space, such as in loose connective tissue around the epidural space or in cavitary formations of degenerated interspinous ligaments.[2,4,6]

Abbreviation

MET Minimal electric threshold

In human medicine, electric nerve stimulation has been reported as a means to confirm proper placement of a needle in the epidural space.[7–12] For example, when the needle is in the epidural space, a small electric stimulus will elicit contraction of the muscles innervated by the stimulated nerves of the spinal cord. If the needle is outside of the epidural space, a much greater stimulus is required to induce the same muscle contraction.[13] Because this technique does not require patient cooperation, it is applicable to veterinary medicine. The technique could assist in epidural injection at higher levels

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of the spinal cord (lumbar or thoracic), decreasing the risk of spinal cord injury and inadvertent intravascular or subarachnoid injections.[9] This could also be important for lumbosacral epidural injection in a percentage of dogs in which the dural sac extends caudally to the level of the seventh lumbar vertebra.[14]

The purpose of the study reported here was to determine the MET of neurostimulation in and out of the lumbosacral epidural space necessary to cause muscle contraction of the hind limb or tail, determine an MET cutoff value that indicates epidural needle placement, and compare predictability of epidural needle placement attained by use of a neurostimulator versus the standard technique that uses loss of resistance in dogs. We hypothesized that the use of the neurostimulator would increase sensitivity and specificity, compared with the standard method of loss of resistance, in suggesting correct lumbosacral epidural needle placement.

Materials and Methods

This study was approved by the Institutional Animal Care and Use Committee of Michigan State University. Ninety-six healthy Beagles being used in a nonsurvival surgical laboratory for a third-year class of veterinary students at Michigan State University were used in this study. Dogs were premedicated with acepromazine (0.05 mg/kg, IM) and morphine (0.5 mg/kg, IM) and anesthetized with thiopental (10 mg/kg, IV). Following endotracheal intubation, anesthesia was maintained with isoflurane in oxygen. Pulse rate and quality, respiratory rate, and anesthetic depth were monitored throughout anesthesia. Subsequently, dogs underwent abdominal exploratory surgery and a combination of splenectomy, gastropexy, enterotomy, and/or enteroanastomosis. After the laboratory was completed, and for the purpose of the study reported here, dogs were randomly allocated into 2 groups of equal number. One group received contrast medium (iohexol)[a] injection (90 mg/kg) in the lumbosacral area just outside of the epidural space (before the needle punctured the interacuate ligament of the lumbosacral intervertebral space [group 1_{out}]), and the other group (group 2_{in}) received the same amount of contrast medium in the lumbosacral epidural space.

Group 1_{out}—Dogs were positioned in sternal recumbency, and the lumbosacral area was clipped and aseptically prepared for an epidural injection. After palpation of landmarks to find the lumbosacral vertebral joint, as described,[1] an electrically insulated, 3.25-inch, 22-gauge spinal needle[c] was inserted by the anesthetist (FGP) through the skin over that area and immediately connected to a neurostimulator.[d] The neurostimulator cathode was connected to the insulated spinal needle, and anode placement was standardized by connecting it to the skin over the semitendinosus muscle on the left hind limb. After the needle was believed to be in close proximity to, but outside, the epidural space at the level of L7-S1, a low-resistance syringe[b] was connected (by use of anatomic landmarks and the anesthesiologist's [FGP] sense of touch) to the injection port of the spinal needle to monitor loss of resistance to injection. Loss of resistance (yes/no) was subjectively assessed (SEL) and recorded. Then a stimulus with a frequency of 1 Hz, pulse width of 0.1 milliseconds, and current of 5 mA was applied to the needle as described.[13,15] Then nerve stimulation was started, and when hind limb muscle twitching was present, electric current was decreased by 0.3 mA until no muscle twitching could be seen. Then the current was increased by 0.3 mA to reestablish muscle response; this value was recorded as the MET. After the MET was found, the anode lead was moved from the left to the right hind limb over the semitendinosus muscle to ensure that the muscle contraction was being caused by stimulus of the lumbosacral epidural plexus, not from a peripheral nerve or direct muscular stimulation over the left semitendinosus muscle. When the muscle contraction is caused by epidural stimulation, the change in the anode position should not change the muscle group contracting, the degree of contraction, or the electric current needed to cause such a response. If no change in muscle contraction was detected, the MET was recorded. At this time, contrast medium was injected through the spinal needle, and a lateral radiograph was obtained to confirm needle position. If the needle was found to be within the epidural space, the dog was then considered to be in group 2_{in} for certain analyses.

In this group, it was expected that muscle twitching would be achieved without a positive response to the loss of resistance test. By use of the nerve stimulator settings as described, muscle twitching should not have been observed until the needle was in close proximity (< 2 cm) to the epidural space.

Group 2_{in}—This group underwent the same procedure as in group 1_{out} except that the electrically stimulated spinal needle was believed to have been placed into the epidural space. If the needle was found to be within the epidural space, the dog was then considered to be in group 1_{out} for certain analyses.

Statistical analysis—Age, sex, and MET were analyzed between groups by use of a 2-sample, 2-tail Student *t* test.[e] Significance was set at $P \leq 0.05$. An electric current cutoff value (≤ 0.28 mA) that best predicted muscle twitching when the needle was correctly placed in the epidural space was chosen. This cutoff was used to calculate the specificity and sensitivity of the neurostimulation test. Specificity and sensitivity of loss of resistance and neurostimulation techniques were compared.

Results

A dog of group 2_{in} had contrast medium out of the lumbosacral epidural space during radiographic evaluation and was categorized as group 1_{out}. In group 1_{out}, 8 dogs had contrast medium inside the epidural space via radiographic evaluation and were allocated to group 2_{in}. One dog in group 2_{in} was removed from the study because of overexposed radiographs and inability to evaluate the lumbosacral region; therefore, group 2_{in} had 54 dogs and group 1_{out} had 41 dogs for statistical analysis.

There were no differences in age or sex between group 2_{in} and group 1_{out}. By use of the neurostimulation

test, the MET needed to cause muscle twitching of the hind limbs, tail, or both was significantly ($P < 0.001$) lower in group 2_{in} (mean ± SEM, 0.3 ± 0.07 mA) than in group 1_{out} (1.2 ± 0.13 mA).

In group 2_{in}, use of the neurostimulation test resulted in correct prediction of the success of 40 epidural injections (sensitivity, 74%), whereas use of loss of resistance resulted in correct prediction of the success of 34 epidural injections (sensitivity, 63%). In group 1_{out}, use of the neurostimulation test resulted in correct prediction of 38 injections out of the epidural space (specificity, 93%), and use of loss of resistance resulted in correct prediction of 37 injections (specificity, 90%). When the 2 tests were combined, sensitivity of 89% and specificity of 83% were attained.

Discussion

Epidural anesthesia is underused in veterinary medicine. Perhaps lack of experience with the technique and uncertainty of correct epidural needle placement are the cause of its limited use by most veterinarians. For several years, electric stimulation of the spinal cord has been used in humans to treat chronic pain and to guide the placement of needles or catheters at different levels of the epidural space.[7,8,16,17]

The purpose of the study reported here was to determine and compare the MET needed to cause hind limb muscular contraction after stimulation of the epidural lumbosacral plexus of dogs through an insulated needle placed in or out of the epidural space. In this study, neither the neurostimulation nor loss of resistance test was used to estimate correct epidural needle placement. Instead, correct placement of the needle was obtained by use of landmarks and an experienced anesthesiologist's sense of touch. The loss of resistance and the neurostimulator techniques were then evaluated with regard to prediction of needle location in or out of the epidural space, which was confirmed via contrast radiography. The sensitivity and specificity of the combination of neurostimulation and loss of resistance tests to predict accurate placement of the needle were 89% and 83%, respectively. A study in which the loss of resistance and neurostimulation techniques are combined to actually locate the epidural space may find better sensitivity for loss of resistance and for the test combination than did the present study.

In 1 study,[6] using a loss of resistance test to suggest the correct needle placement in the lumbosacral epidural space, the authors achieved 100% correct placement with corresponding loss of resistance in all of the dogs. In pigs, results of neurostimulation suggested that the needle had entered the epidural space before loss of resistance was achieved.[13] The author assumed that this discrepancy indicated that the tip of the needle had barely entered the epidural space and the needle lumen was still covered by the ligamentum flavum.[13] If the spinal needle had been advanced further ventrally in our study, perhaps loss of resistance would have been found more often.

As expected, changing the position of the anode to the opposite limb did not change the current needed to cause the same degree of muscular contraction. This indicated that muscular contraction was being caused by stimulation of the epidural plexus and not by peripheral nerve stimulation, which would cause muscular contraction to diminish or cease completely with the same current applied on the opposite limb.

Interestingly, the minimal electric current applied with a needle in the epidural space needed to cause muscular response of dogs in our study was much lower than that found in pigs.[13,15] In those studies, 3.6 ± 0.6 mA (mean ± SD) was required to cause muscle twitching in response to electric stimulation applied in the epidural space at several levels of the spinal cord (C7, T14-15, L6-7, and S4). In the present study, the MET was 0.3 ± 0.07 (mean ± SEM), one-tenth that found in pigs. We postulate that this disparity could be attributable to anatomic differences between the species and the level of needle insertion in relationship to the spinal cord. Spinal cord length varies considerably among species. In dogs, the spinal cord terminates at the level of the sixth or seventh lumbar vertebra,[18] whereas in pigs it can extend to the second or third sacral vertebra.[19] At the level of the cauda equina, the dura mater tapers and becomes a fibrous filament that covers the caudal nerves into the sacral area.[18,19] The thickness of the dura mater at the lumbosacral level in dogs is probably less than that in pigs because the spinal cord and the other meninges in dogs terminate at a higher level. Therefore, it is reasonable to conclude that the MET required in the lumbosacral area to stimulate a muscular response would be lower in dogs. A study on the influence of dura mater thickness on the MET is still lacking, to the authors' knowledge. In human clinical studies, injections at lower levels of the vertebral column in the epidural space resulted in a lower current needed to cause muscle twitching, compared with injections at the level of the thoracic vertebrae.[20,21] The conclusion was that injections at the sacral level of the vertebral column yielded lower METs because of the needle's closer proximity to the stimulated nerves.

An electric stimulus with duration of 0.1 milliseconds was used in the study reported here. Durations < 0.15 milliseconds cause selective stimulation of motor fibers (Aα fibers) without causing signs of pain or sympathetic response.[22] In our study, the cathode was connected to the insulated needle and the anode to the skin over the semitendinosus muscle because inverting the position of these leads would cause an increase in current required to cause a motor response.[22]

A correlation between age and MET was not found in the present study; however, because of the young age of the study group (mean ± SEM, 2.7 ± 0.2 years), this possibility cannot be ruled out. In the human literature, it seems that MET is not influenced by age.[8,23]

In our study, neurostimulation testing resulted in few false-positive results (7%), but a larger percentage of false-negative results (26%) was detected. These results were similar to those of a study[23] in humans that used neurostimulation for confirmation of epidural catheter location and revealed a sensitivity of 80% and a specificity of 100%.

A possible problem with the present study was that air volume used to check for loss of resistance was not standardized. The variable amount of air injected in the epidural space could have modified the distance

between the needle tip and the nerve plexus before MET was measured. Therefore, the current needed to cause a motor response could have been greater in dogs in which a large amount of air was injected. That could explain the high rate of false-negative results found by use of neurostimulation in this study. Tsui et al[15] found that use of saline solution instead of air in pigs to check for loss of resistance was advantageous to avoid any possible hindrance to electric conduction.

a. Omnipaque-300, GE Healthcare Inc, Princeton, NJ.
b. Epilor low resistance syringe, BD Medical Systems, Franklin Lakes, NJ.
c. Nanoline 22-gauge, 3.25-inch insulated spinal needle, Dyna Medical, London, ON, Canada.
d. Stimuplex, B. Braun Medical, Bethlehem, Penn.
e. NCSS 2001, NCSS, Kaysville, Utah.

References

1. Skarda RT, Tranquilli WJ. Local and regional anesthetic and analgesic techniques: dogs. In: Tranquilli WJ, Thurmon JC, Grimm KA, eds. *Lumb and Jones' veterinary anesthesia and analgesia*. 4th ed. Oxford, England: Blackwell Publishing, 2007;561–593.
2. Brook G. Spinal (epidural) anaesthesia in domestic animals. *Vet Rec* 1935;15:659–667.
3. Heath RB. The practicality of lumbosacral epidural analgesia. *Semin Vet Med Surg (Small Anim)* 1986;1:245–248.
4. Sharrock NE. Recordings of an anatomical explanation for false positive loss of resistance during lumbar extradural analgesia. *Br J Anaesth* 1979;51:253–258.
5. Jones RS. Epidural analgesia in the dog and cat. *Vet J* 2001;161:123–131.
6. Iff I, Moens Y, Schatzmann U. Use of pressure waves to confirm the correct placement of epidural needles in dogs. *Vet Rec* 2007;161:22–25.
7. Urban BJ, Nashold BS Jr. Combined epidural and peripheral nerve stimulation for relief of pain. Description of technique and preliminary results. *J Neurosurg* 1982;57:365–369.
8. Tsui BCH, Gupta S, Finucane B. Confirmation of epidural catheter placement using nerve stimulation. *Can J Anaesth* 1998;45:640–644.
9. Tsui BCH, Gupta S, Finucane B. Detection of subarachnoid and intravascular epidural catheter placement. *Can J Anaesth* 1999a;46:675–678.
10. Tsui BCH, Gupta S, Finucane B. Determination of epidural catheter placement using nerve stimulation in obstetric patients. *Reg Anesth Pain Med* 1999b;24:17–23.
11. Tsui BCH. Innovative approaches to neuraxial blockade in children: the introduction of epidural nerve root stimulation and ultrasound guidance for epidural catheter placement. *Pain Res Manag* 2006;11:173–180.
12. Prusinkiewicz C, Lang S, Tsui BCH. Lateral cervical epidural catheter placement using nerve stimulation for continuous unilateral upper extremity analgesia following a failed continuous peripheral nerve block. *Acta Anaesthesiol Scand* 2005;49:579–582.
13. Tsui BCH, Emery D, Uwiera RRE, et al. The use of electrical stimulation to monitor epidural needle advancement in a porcine model. *Anesth Analg* 2005;100:1611–1613.
14. Fletcher TF. Spinal cord and meninges. In: Evans HE, Christensen GC, eds. *Miller's anatomy of the dog*. 2nd ed. Philadelphia: WB Saunders Co, 1979;947–962.
15. Tsui BCH, Wagner A, Finucane B. The threshold current in the intrathecal space to elicit motor response is lower and does not overlap that in the epidural space: a porcine model. *Can J Anaesth* 2004;51:690–695.
16. Kumar K, Nath R, Wyant GM. Treatment of chronic pain by epidural spinal cord stimulation: a 10-year experience. *J Neurosurg* 1991;75:402–407.
17. North RB. Spinal cord stimulation for chronic intractable pain. In: Devinsky O, Beric A, Dogali M, eds. *Electrical and magnetic stimulation of the brain and spinal cord*. New York: Raven Press, 1993;289–301.
18. Fletcher TF, Kitchell RL. Anatomical studies on the spinal cord segments of the dog. *Am J Vet Res* 1966;27:1759–1767.
19. Dellman HD, McClure RC. Porcine nervous system. In: Getty R, ed. *Sisson and Grossman's the anatomy of the domestic animals*. 5th ed. Philadelphia: WB Saunders Co, 1975;1360–1408.
20. Tsui BCH, Tarkkila P, Gupta S, et al. Confirmation of caudal needle using nerve stimulation. *Anesthesiology* 1999c;91:374–378.
21. Tsui BCH, Wagner A, Cave D, et al. Threshold current for an insulated epidural needle in pediatric patients. *Anesth Analg* 2004;99:694–696.
22. Campoy L. Fundamental of regional anesthesia using nerve stimulation in the dog. In: Gleed RD, Ludders JW, eds. *Recent advances in veterinary anesthesia and analgesia: companion animals*. Ithaca, NY: International Veterinary Information Service, 2008. Available at: www.ivis.org/advances/toc_advances.asp. Accessed Apr 8, 2008.
23. Medicis E, Tetrault JP, Martin R, et al. A prospective comparative study of two indirect methods for confirming the localization of an epidural catheter for postoperative analgesia. *Anesth Analg* 2005;101:1830–1833.