A Pilot Study Comparing the Accuracy of Two Approaches to the Inferior Alveolar Nerve Block in Canine Cadavers

E M Goudie-DeAngelis, DVM*

C J Snyder, DVM, DAVDC†

M R Raffe, DVM, MS, DACVAA, DACVECC‡

F H David, DEDV, DECVDI#

**Department of Anesthesiology, University of Minnesota College of Veterinary Medicine 1365 Gortner Avenue, Saint Paul, Minnesota, 55108 USA*

†Department of Dentistry University of Wisconsin-Madison School of Veterinary Medicine 2015 Linden Drive, Madison, Wisconsin, 53706 USA

‡Veterinary Anesthesia and Critical Care Associates, LLC 2770 Hodges Lane, Mounds View, Minnesota, 55112 USA

#Department of Radiology University of Minnesota College of Veterinary Medicine 1365 Gortner Avenue, Saint Paul, Minnesota, 55108 USA

§ E M Goudie-DeAngelis, egoudied@umn.edu

KEY WORDS: Dentistry, Anesthesia, Inferior Alveolar Nerve Block, CT, Local Anesthetic Technique
CT= Computed Tomography

ABSTRACT

Aims

The inferior alveolar nerve block provides sensory blockade of the body of the mandible and its associated structures. Two approaches, the intraoral and extraoral techniques, can be used. We hypothesized that the intraoral approach would result in a more accurate placement of solution at the inferior alveolar nerve.

Methods

Five canine cadavers (10-15 kg) were used. A random number generator was used to randomly assign the right-sided approach (intraoral or extraoral) for each head; the opposite approach was performed on the left. Blocks were performed using 22 g, 2.5 cm needles, 0.1 mL of 2% lidocaine and 0.3 mL of iodinated contrast medium. After blocks, computed tomography (CT) was performed on each head. Heads were positioned in the dorsoventral position for the CT scan. Computed tomographic images were evaluated for the percent of the mandibular foramen in contact with contrast, distance of contrast from the foramen, length of spread of contrast along the inferior alveolar nerve fascial plane, and degree of contrast between the mandibular lingual tissue planes. A Chi-square test was used to evaluate contrast between the mandibular lingual tissue. All other measurements were compared using the Wilcoxon-Mann-Whitney Test.

Results

Median contact with the inferior alveolar nerve ($p=0.025$) and percentage of mandibular foramen in contact with contrast pool

(p=0.009) was significantly greater for the intraoral approach.

Clinical Relevance

The intraoral approach to the inferior alveolar nerve block demonstrates greater accuracy of local block placement when compared with the extraoral approach. These findings suggesting the intraoral approach decreases risks associated with inaccurate placement and may improve clinical efficacy.

Conclusions

The intraoral technique showed superior precision with low volume injectate in cadaver dogs with normal anatomy, when compared with the extraoral approach.

INTRODUCTION

Preoperative use of regional and local anesthetic techniques address acute pain by preventing the propagation of nerve signals. Local anesthetics block the conduction of action potentials in the motor and sensory nerves through sodium channel blockade. Regional nerve blocks have demonstrated value in pain control in dental patients when used during dental procedures. (El-Anwar et al, 2015) The use of local anesthetics for the infraorbital nerve block in dogs has been shown to reduce the minimum alveolar concentration by 23% with exposure to a noxious stimulus. (Snyder and Snyder, 2013) The American Animal Hospital Association's standards for dentistry recommend the use of general anesthesia and intubation of patients undergoing dental procedures. (Wedel and Horlocker, 2009; Holmstrom, et al 2013) By using local and regional nerve block techniques the amount of inhaled anesthetic, and, therefore, the associated cardiorespiratory depressive effects, can be minimized. (Snyder and Snyder, 2013; Columb and MacLennan, 2014) Although used to provide regional anesthesia to the rostral aspect of the mandible, the middle mental nerve has been shown to have unpredictable results. (Krug and Losey, 2011;Nist, et al 1992)

In contrast to anatomic limitations of coverage by the middle mental nerve block, the inferior alveolar nerve block (sometimes referred to as the caudal mandibular nerve block) is commonly described to provide sensory blockade of the entire tooth bearing area of the mandible and associated soft tissues such as the gingiva, buccal and alveolar mucosa, and lip.

The mandibular nerve transmits both sensory and motor information with the sensory portion originating from the trigeminal nerve ganglion (cranial nerve V) and the motor region originating from the pons and medulla oblongata. The inferior alveolar nerve, a branch of the mandibular nerve, innervates the lower premolars and molars and rostral mandibular soft tissues. The caudal, middle, and rostral alveolar nerves branch from the inferior alveolar nerve during its course through the mandibular canal, innervating the ipsilateral mandibular teeth gingiva, lip, and soft tissues. The lingual nerve and inferior alveolar nerve branch off the mandibular nerve caudal to the mandibular foramen.

The mylohyoid nerve branches ventrally from the inferior alveolar nerve, but may also branch directly from the mandibular nerve (Evans and Kitchell, 1993). One human study evaluated the locations of the lingual and inferior alveolar nerves and found four patterns of variation based on the branching in relation to the mandibular notch (Okamoto, et al, 2000). The remainder of the inferior alveolar nerve continues rostral from the mandibular foramen to the mental foramen, where the mental nerve exits to provide sensory innervation to the mandibular lip and rostral most intermandibular region (Evans and Kitchell, 1993). The inferior alveolar nerve is responsible for sensory fibers innervating the skin and mucosa of the lower jaw, lower lip, and all of the mandibular dentition (Skarada and Tranquilli, 2004; Wedel and Horlocker, 2009). Considering the pattern of innervation, accurate infusion at the level of the inferior alveolar nerve has the potential to provide regional anesthesia to the entire ipsilateral mandibular dental arcade as well as anesthesia of the lip and mandibular skin. Two approches, the intraoral and extraoral techniques, have been described in veterinary medicine for the administration of local anesthetic to provide anesthesia to the inferior alveolar nerve (O'Morrow, 2010). To the authors' knowledge, these approaches have not been compared in veterinary species for the accuracy of injection at the desired site. Limitations sometimes exist impacting which block approach may be used based on existing disease (ie, invasive neoplasia and risk for iatrogenic tumor seeding) or challenges associated with patient size.

For example, in smaller patients, it may be difficult to palpate the mandibular foramen (Skarada and Tranquilli, 2004). Cats also demonstrate limitations in the extent and duration the oral cavity can be maximally opened due to the risk of compromised blood flow in the maxillary artery (Martin-Flores, et al, 2014). Both intraoral and extraoral techniques aim to deliver local anesthetic at the mandibular foramen, the entrance of the inferior alveolar nerve into the mandibular canal. Injection of local anesthetic drugs in the immediate vicinity of this site produces effective anesthesia to the ipsilateral mandible and associated teeth and soft tissues. Accurate placement of local anesthetic in this area is important to mitigate complications of the block including:

- Self-traumatization of the tongue on recovery due to desensitization of the lingual nerve
- Intra-arterial injection
- Failure to achieve complete sensory blockade of the nerve, and
- Nerve damage (prolonged paresthesia). (Pogrel, et al, 1995; Webber, et al, 2001; Skarada and Tranquilli, 2004; Gorell, 2013; Martin-Flores, et al, 2014)

To the authors' knowledge, no imaging studies comparing the accuracy of the intraoral and extraoral approaches to the inferior alveolar nerve block has been performed in dogs. Computed tomography (CT) has been used to evaluate the accuracy and diffusion of local infusion of contrast for several dental blocks in humans and veterinary species (Okamoto, et al, 2000; Henry, et al, 2014). The CT modality has been used to help guide nerve blocks in human medicine, regional anatomy is used to identify the fascial plane where the nerve is located and this is then used to guide placement of the local anesthetic (Lanzieri and Hilal, 1984). The purpose of this study was to evaluate if a difference exists in the accuracy of drug delivery of the intraoral and extraoral approaches to the inferior alveolar nerve block. Based on clinical experience and better visualization, we hypothesized that the intraoral approach would provide improved accuracy of injection compared with the extraoral approach.

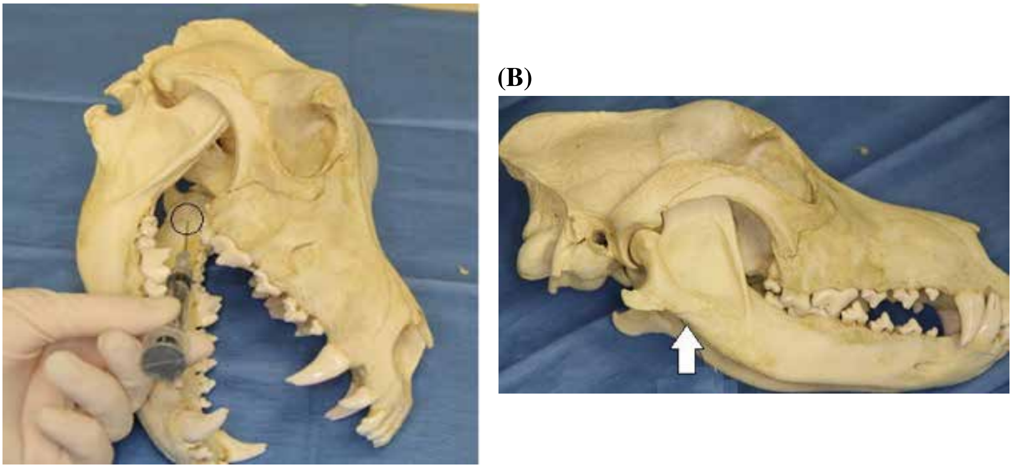
MATERIALS AND METHODS

A controlled, blinded, randomized study evaluating the diffusion of a lidocaine-contrast solution on CT scan images was performed. For this study, five mixed breed canine cadavers were used. Mean cadaver weight was 11.4 kg (10-15 kg). As dogs were previously euthanized and donated, Institutional Animal Care and Use Committee approval was not necessary. The dogs were unowned, and no owner consent approval was obtained. Brachycephalic, doliochepalic, and chondrodystrophic breeds were excluded from the study, as were dogs with any gross evidence of mandibular disease.

A total of 10 inferior alveolar nerve blocks were performed and imaged. Both the intraoral and extraoral approaches to the nerve were performed in each specimen. A computer-based random number generator program was used to assign which mandible of each specimen received the intraoral and extraoral techniques.[a] The initial block was performed on the right side; the approach was randomly assigned. Following the placement of the initial treatment, the head was placed with the treated side dependent for 3 minutes, the contralateral side was then blocked using the alternate technique (intraoral or extraoral), and then the head was positioned with the second treated side laterally recumbent for 3 minutes. For the

Figure 1. *(**A**)The intraoral approach to the inferior alveolar nerve block is demonstrated using a skull. The mandibular foramen is palpated while the needle bevel is passed along the lingual cortex of the mandibular ramus until the foramen is approximated. (In the demonstration, the operator's hand has been removed from palpating the mandibular foramen during simultaneous needle placement.) The extraoral end of the syringe barrel is then centered over the first premolar on the contralateral side of the oral cavity. The syringe is aspirated and the contrast is injected slowly over 30 seconds. (**B**)The extraoral approach to the inferior alveolar nerve block is demonstrated on a skull. An imaginary line is drawn from the lateral canthus of the eye to the center of the ventral notch of the mandible. The needle is inserted along the lingual cortex, against periosteum, of the ramus with the bevel facing towards the lingual cortical bone and advanced 1/3 the height of the mandibular body.*

(A) **(B)**



CT scan, the head was positioned in sternal recumbency. All blocks were performed by one trained observer (EMG) to ensure consistent technique.

TREATMENT TECHNIQUES

Extraoral Approach

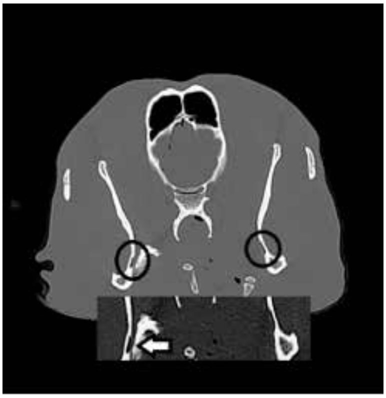
When performing the extraoral approach, the inferior alveolar nerve is infused with local anesthetic at its entry into the mandibular foramen using needle placement through skin at the caudoventral aspect of the mandible. The patient is positioned in lateral recumbency with the side to be blocked facing the operator (up-side). A line is drawn from the lateral canthus of the eye to the center of the ventral notch on the ipsilateral mandible. The ventral notch is located approximately 0.5-1.5 cm rostral from the angular process (Skarada and Tranquilli, 2004; Gorell, 2013; Campoy and Reed, 2002). The needle is inserted approximately 1/3 of the distance between the approximate height of the alveolar border and ventral cortex of the mandible, along the lingual surface of the ramus (Figures 1A and B). The syringe is aspirated for negative pressure and observed for the absence of blood. The injection is administered at a rate of 0.4 mL over 30 seconds (Gorell, 2013; Kanaa, et al, 2006; Rochette, 2005).

Intraoral Approach

The intraoral approach also positions the patient in lateral recumbency with the side to be anesthetized dependent. The mouth is opened and the mandibular foramen is palpated in the oral cavity. Following palpation, the needle is advanced through alveolar mucosa caudal to the last molar tooth along the medial aspect of the ramus and advanced parallel to lingual cortical bone (Figure 1B). When the point of the needle reaches the mandibular foramen, the syringe is aspirated to ensure an absence of blood and to note

*Figure 2. (A) CT image illustrating the positioning of specimens for evaluation and the inferior alveolar nerve. The mandibular foramina are illustrated by open circles. The distance between the mandibular foramen and contrast was measured in this plane. The enhancement at the bottom of the figure (arrow) shows the distance between the mandibular foramen and contrast pool that was measured. **(B)** CT image slice illustrating the positioning of specimens for the evaluation of the length of the contrast contacting the nerve. The fascial plane in which the inferior alveolar nerve traverses is indicated by the open rectangle. Enhancement of this region is illustrated to the right of the original image. The large arrow represents the area of facial plane not in contact with contrast while the smaller arrow represents the end of the contrast contact with the facial plane.*

(A)



(B)

negative pressure, and is followed by the injection as described above (Gorell, 2013; Kanaa, et al, 2006; Rochette, 2005).

STUDY TECHNIQUE

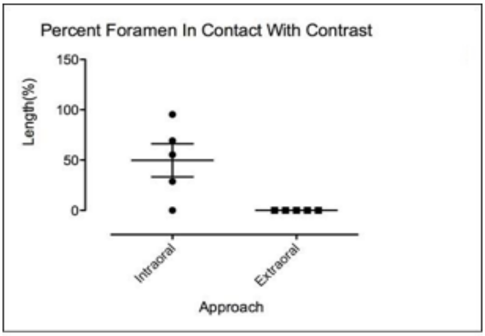
A solution consisting of 0.1 mL of 2% lidocaine and 0.3 mL of Optiray, an iodinated contrast medium composed of 3.6 mg Tromethamine and 0.2 mg Edetate calcium, was injected using a 2.5 cm 22 gauge needle attached to a 1 mL syringe.[b,f] Blocks were performed as previously described. In both approaches, the bevel of the needle was oriented toward the mandibular foramen and the lidocaine-contrast solution was infused over 30 seconds (Henry, et al, 2014; Kanaa, et al, 2006; Okamoto, et al, 2000). Immediately following each injection, the head was positioned with the blocked side down for 3 minutes to ensure any diffusion of injectate was consistent across specimens. The head was positioned in sternal recumbency for the CT.

Following placement of contrast media, CT scans were obtained using a 64 slice scanner in a transverse plane, using a 2 mm slice thickness, a 512 * 512 matrix, a 16 cm field of view, and 2 different image reconstructions (bone and soft tissue algorithm).[c] A board certified radiologist (FHD) evaluated each study, and performed measurements using a Picture Archive and Communication System.[d] The radiologist was blinded to the type of injection technique used.

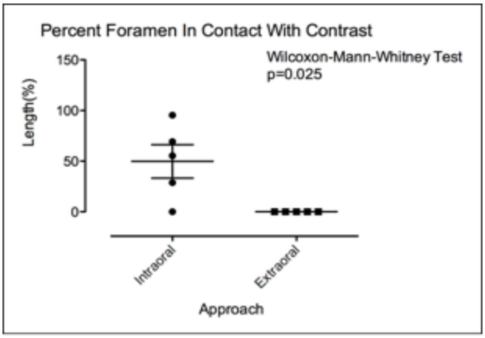
CT studies were analyzed in transverse, oblique, and dorsal planes. Based on previous studies, the CT images were evaluated to determine the proximity of the contrast to the mandibular foramen, the minimum distance between the edge of the mandibular foramen, and the closest edge of the contrast pool was measured in three planes (transverse plane, dorsal, and oblique reconstruction); (Lanzieri and Hilal, 1984; Okamoto, et al, 2000). The shortest distance in a single image represents the in-plane distance. Using the in-plane and the through-plane measurements, the straight-line distance between the mandibular foramen and the contrast pool was calculated according to

Figure 3. (A) A scatter plot illustrating the percentage of the mandibular foramen in contact with contrast. The median is represented for both blocks and standard deviations are present for the intraoral approach. Both groups were composed of five blocks. Data was analyzed using the Wilcoxon-Mann-Whitney test with significance set at p<0.05. All of the blocks approached with the extraoral technique had 0% contact between he mandibular foramen and the contrast pool (p=0.025). (B) A scatter plot illustrating the length of inferior alveolar nerve in contact with contrast for each approach. The median is represented. Both groups were composed of five blocks. Data was analyzed using the Wilcoxon-Mann-Whitney test with significance set at p<0.05. All of the blocks approached with the extraoral technique had 0 mm of nerve plane in contact with contrast. While all blocks approached with the intraoral technique had nerve plane in contact with contrast up to 21 mm. (p=0.009).

(A)



(B)



Pythagorean Theorem (Purcell-Jones, et al, 1989; Okamoto, et al, 2000). The percentage of mandibular foramen contacting contrast media was calculated (the minimal distance was 0 mm). The length of the mandibular foramen was measured on each axial image which was present, and the area of the foramen opening was calculated by multiplying the sum of the length on each slice by the slice thickness. On images demonstrating the foramen, the length of the foramen contacting contrast was determined by multiplying the sum of these lengths by the slice thickness. The percentage of area of the mandibular foramen in contact with the contrast was then calculated. (Figure 2A)

The fascial plane lateral to the medial pterygoid muscle, where the inferior alveolar nerve originates and spans before entering the mandibular foramen, was evaluated for contact with contrast. The length of the plane contacting contrast was used to determine length of nerve in contact with contrast. (Figure 2B)

In order to determine the magnitude of injection media spreading into undesired fascial planes, the contrast within the tissue plane located between the mandible and lingual periosteal tissue was subjectively quantified ("perimandibular contrast spread") by a single investigator (FHD). A subjective scoring system was used to describe the extent of perimandibular contrast spread. Zero was assigned if no contrast was observed between fascial layers; a score of 5 was assigned if all the contrast was believed to have leaked between the facial layers.

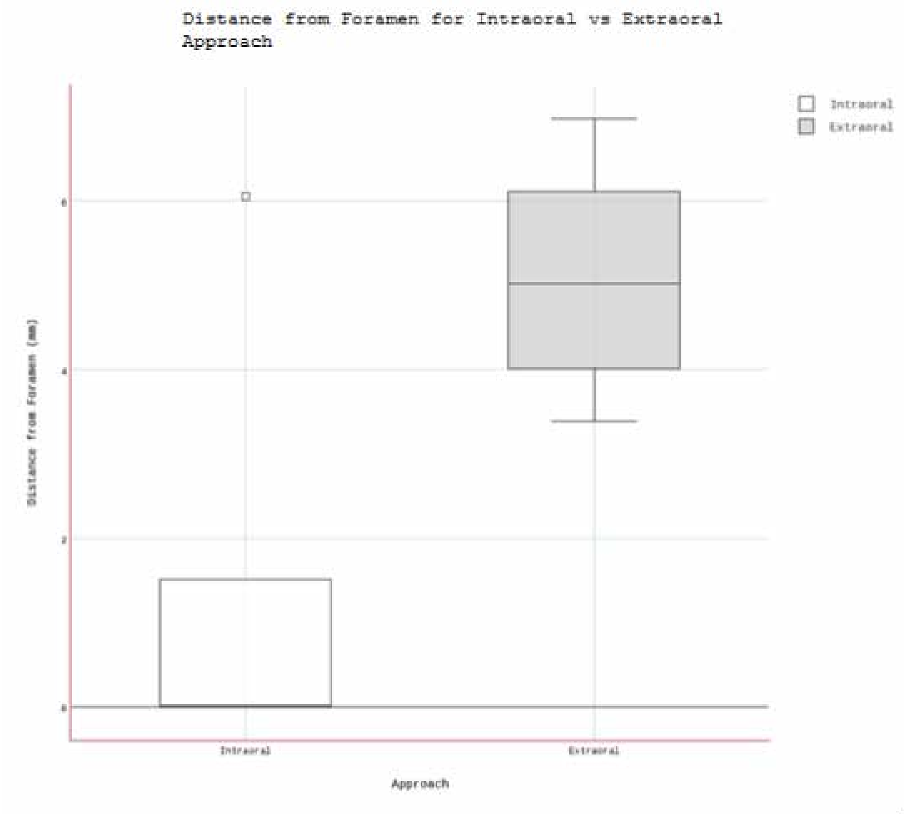
STATISTICAL ANALYSIS

Statistics were performed with the aid of a computer-based statistical program.[e] A Chi-square test was used to evaluate contrast between the mandibular lingual tissues. All other measurements were compared using the Wilcoxon-Mann-Whitney Test. Significance was set at $p < 0.05$. A Chi square test was used to test if perimandibular contrast spread was significantly different ($p<0.05$) between the approaches. Each block was evaluated as a separate data point.

RESULTS

The degree of contact between the mandibu-

Figure 4. *A box plot illustrating the spread of contrast between the tissue and mandible on the lingual side (perimandibular contrast spread) into the undesired tissue facial planes with each inferior alveolar nerve block approach. The spread is based on a scale from 0-5 with 0 representing no contrast present and 5 representing a large volume of contrast present within the perimandibular fascial plane. Both groups were composed of 5 blocks. Standard deviations from median are represented by solid lines through boxes. Data was analyzed using the chi-square test with significance set at p<0.05 (P=0.11).*



lar foramen and contrast pool was present in four out of five (4/5) dogs with the intraoral approach, as opposed to no contact in any of the dogs with the extraoral approach (0/5). Contact of the inferior alveolar nerve fascial plain with contrast was present in four out of five (4/5) dogs with the intraoral approach as opposed to no contact in any of the dogs with the extraoral approach (0/5). Median value for percentage of mandibular foramen contacting the contrast pool was 55.4% (range: 0%- 95%) and 0% (range: 0-0 %) for the intraoral and extraoral approaches, respectively. Only one of 5 (1/5) the intraoral approaches demonstrated > 0 mm distance between the mandibular foramen and the contrast pool.

All extraoral (5/5) approaches demonstrated > 0 mm distance between the mandibular foramen and the contrast pool; the median value for the minimum distance between the mandibular foramen and edge of contrast pool was 0mm (0 mm-6.05mm) and 5.02mm (3.39 mm-5.82 mm) for the intraoral and extraoral approaches, respectively. Likewise, in four out of five (4/5) dogs undergoing the intraoral approach, there was contrast present in contact with the inferior alveolar nerve fascial plane. None of the dogs in the extraoral approach group had contrast in contact with the inferior alveolar nerve fascial plane (0/5). Median length of inferior alveolar nerve fascial plane in contact with contrast was 7.91 mm (range: 0 mm- 21 mm) and 0 mm (range: 0-0 mm) for the intraoral and extraoral approaches, respectively (Table 1).

The percentage of foramen in contact with contrast medium and the length of nerve contacting contrast were compared between the approaches using the Wilcoxon-Mann-Whitney test. The percentage of foramen area contacting contrast was significantly different between the intraoral and extraoral approaches ($p=0.025$); (Figure 3 A). A significant difference existed between the intraoral and extraoral approaches for length of nerve in contact with contrast ($p=0.025$); (Figure 3B). A significant difference exists when comparing the presence of contrast in contact with the mandibular foramen ($p=0.009$) and for the contrast in contact with the inferior alveolar nerve fascial plane greater than 0 mm ($p=0.009$) between techniques. There was no difference ($p=0.16$) between the intraoral and extraoral approaches regarding the minimum distance from the foramen to the edge of the contrast pool. No difference ($p=0.11$) existed between the amounts of perimandibular contrast spread between the two approaches. In two of five specimens where the intraoral approach was used demonstrated no contrast present between the mandibular cortical bone and lingual tissue planes. This is contrary to the extraoral approach where all (5/5) blocks had the presence of perimandibular contrast spread (Figure 4).

DISCUSSION

There are two recognized approaches to the inferior alveolar nerve block in veterinary literature, the intraoral and extraoral approaches (Wedel and Horlocker, 2009; Gracis, 2013). Whichever technique is used for the inferior alveolar nerve block is practitioner-dependent based on personal preference and purpose for blockade. While the palpation of the mandibular foramen is often recommended for both approaches, it is recognized that there is risk of accidental needle-stick with the extraoral approach (Snyder, 2015b). This risk is likely greater during needle insertion with the extraoral approach versus the intraoral approach due to poor visualization.

Based on this study's findings, the intraoral approach to placement of the inferior alveolar nerve block is superior to the extraoral approach in achieving accurate placement of injected material at the mandibular foramen. Eighty percent of intraoral blocks resulted in >30% of the inferior alveolar nerve to be in contact with contrast. Likewise, in 80% of blocks using the intraoral approach, there were less than 1 mm of soft tissue between the mandibular foramen and the contrast pool. In the extraoral approach, 100% of the blocks had a ≥3 mm distance between the mandibular foramen and the contrast pool. No contact between the iodinated contrast and the inferior alveolar nerve plane was observed when utilizing the extraoral approach to perform the inferior alveolar nerve block.

Spread of local anesthetic away from the intended site can result in inadvertent sensory blockade of neighboring structures (eg, the lingual nerve). The volume of local anesthetic employed in this study is based on recommendations previously published in veterinary dental literature (Beckman, 2006). Injection of a smaller volume also allowed us to evaluate the differences between the approaches without extensive spread of the material from site of injection or distortion of the associated anatomy by a large volume. The extent of diffusion providing regional anesthesia remains unknown, but large volumes or inaccurate placement of local anesthetic increase the risk for inadvertent block of neighboring nerves such as the lingual nerve. In addition, larger volumes, especially under higher pressure, may cause tissue damage.

Despite the conservative volume choice, there was evidence of spread from the intended site of injection. This parameter was compared between the two approaches, and while there was no significant difference between the approaches, or between the extent of contrast spread into the perimandibular fascial planes, there was evidence that the extraoral approach resulted in spread of injected material away from the desired site of deposition. All extraoral approaches resulted in some intrafascial contrast (5/5), whereas two of five (2/5) intraoral approaches resulted in no undesired intrfascial contrast spread. A larger sample size may reveal a significant difference between techniques. The use of a multiple volume amounts or larger volumes may have yielded different results which may obscure the assessment of the accuracy in placement between the two techniques.

It is difficult to determine the exact cause for the lack of contrast contacting the nerve in the specimens using the extraoral approach. It is possible that the use of intraoral palpation of the mandibular foramen while inserting the needle using the extraoral approach may assist in a more accurate deposition of injected solution. However, it creates the risking of iatrogenic needle sticks to the operator. While not observed, the needle may have been bent or deflected during placement however in the author's clinical experience by following the previously described technique has resulted in clinical results indicative of successful placement. Future imaging studies evaluating the exact behavior of the local anesthetic administration needle when using the extraoral technique may provide additional information as to ways to improve the accuracy of local block placement.

Limitations of the study include:

- Physiologic changes to local tissues in cadaveric specimens
- A small sample size
- Variation in breed, size, and anatomy of the specimens

The randomized, blinded cross-over nature of this study helped to overcome these limitations by each specimen receiving both blocks, permitting the comparison of both the intraoral approaches and extraoral approaches for each head. In only one dog, both approaches resulted in a similar amount of contact along the inferior alveolar nerve and spread the same distance from the foramen. As this was the only dog that exhibited this result, it is likely the result of anatomic landmark variation. While no marked anatomic anomalies were noted in the specimens studied here, variation in anatomical structure of the canine mandible is recognized and has been previously identified via CT imaging (Snyder, 2015a).

Future directions include the use of live patients undergoing dental or surgical procedures. It is only necessary for three nodes of Ranvier to be exposed to local anesthetic to prevent nerve impulse transmission (Tasaki, 1953). As the intraoral approach had a significantly longer portion of the inferior alveolar nerve in contact with contrast, it would be expected that the intraoral approach would be more clinically effective. It is, however, an important next step to evaluate the clinical efficacy of these two approaches to evaluate if length of nerve contact corresponds with degree of clinical efficacy. A combined imaging and clinical evaluation using live dogs would allow the determination of what length and distance from foramen is necessary to appreciate a clinically effective sensory blockade.

Based on the results presented in this study, the intraoral technique showed superior precision with low volume injectate in cadaver dogs with normal anatomy, when compared with the extraoral approach. A difference in clinical efficacy between both techniques remains to be determined, however, small volumes with accurate placement help minimize the likelihood of inadvertent anesthesia to unintended structures such as the tongue.

FOOTNOTES

a: Microsoft Office Excel 2007; Microsoft Corp., WA

b: Mallinckrodt Pharmaceuticals, Dublin, Ireland

c: Toshiba Aquilion 64 CFX, CA

d: Carestream Kodak PACS, NY

e. GraphPad Prism, GraphPad Software,

Inc., 2015, La Jolla, CA

f. Vetone, MWI Veterinary Supply Company, Boise, Idaho

REFERENCES

1. Beckman, BW. Pathophysiology and management of surgical and chronic oral pain in dogs and cats. *Journal of Veterinary Dentistry* 23(1):50-60. (2006)
2. Campoy, L. Reed, M. Local Anesthetics in: Gaynor, JS, Muir, W. W. *Handbook of Veterinary Pain Management*. 3e pp.217. Mosby, St Louis, MO, USA. (2002)
3. Columb, MO, MacLennan, K. Local anesthetic agents. *Anesthesia and Intensive Care Medicine* 15(2): 83-87. (2014)
4. El-Anwar, MW, Hegab, A. Internal fixation of single mandibular fracture under mandibular nerve block. *Oral Maxillofacial Surgery*. Epub ahead of print. (2015)
5. Evans, HE, Kitchell, RL. Chapter 19: Cranial Nerves and Cutaneous Innervation of the Head in: Evans, HE, de Lahunta, A. *Miller's Anatomy of the Dog*, 4e. pp.716-721. Saunders, Philadelphia, PA, USA (1993)
6. Gracis, M. Chapter 10: The Oral Cavity in: Campoy, L, Reed, M. *Small Animal Regional Anesthesia and Analgesia* pp.119-130. Wiley-Blackwell,West Sussex, UK (2013)
7. Henry, T, Pusterla, N, Guedes, AG, Verstraete, FJ. Evaluation and clinical use of an intraoral inferior alveolar nerve block in the horse. *Equine Veterinary Journal* 46(6):706–710 (2014)
8. Holmstrom, SE, Bellows, J, Juriga, S, Knutson, K, Niemiec, BA, Perrone, J. 2013 AAHA Dental Care Guidelines for Dogs. *Journal of American Animal Hospital Association* 49:75–82. (2013)
9. Kanaa, MD, Meechan, JG, Corbett, IP, Whitworth, JM. Speed of injection influences efficacy of inferior alveolar nerve blocks: a double-blind randomized controlled trial in volunteers. *Journal of Endontics* 32(10):919-23. (2006)
10. Krug, W, Losey, J. Area of desensitization following mental nerve block in dogs. *Journal of Veterinary Dentistry* 28(3):146-50. (2011)
11. Lanzieri, CF, Hilal, SK. Computed tomography of the sacral plexus and sciatic nerve in the greater sciatic foramen. *American Journal of Roentgenology* 143(1):165-8. (1984)
12. Martin-Flores, M, Scrivani, PV, Loew, E, Gleed, CA, Ludders, JW. Maximal and submaximal mouth opening with mouth gags in cats: implications for maxillary artery blood flow. *The Veterinary Journal* 200(1):60-4. (2014)
13. Nist RA, Reader A, Beck M, Meyers WJ. An evaluation of the incisive nerve block and combination inferior alveolar and incisive nerve blocks in mandibular anesthesia. *Journal of Endontics* 18(9):455-9. (1992)
14. Okamoto, Y, Takasugi, Y, Moriya, K, Furuya, H. Inferior alveolar nerve block by injection into the pterygomandibular space anterior to the mandibular foramen: radiographic study of local anesthetic spread in the pterygomandibular space. *Anesthesia Progress* 47(4):130-133. (2000)
15. O'Morrow, C. Advanced dental local nerve block anesthesia. *Canadian Veterinary Journal* 51(12): 1411–1415. (2010)
16. Pogrel, M.A., Bryan, J., Regezi, J. Nerve damage associated with inferior alveolar nerve blocks. *Journal of the American Dental Association* 126(8): 1150-1155. (1995)
17. Purcell-Jones,G, Pither, CE, Justins, DM. Paravertebral somatic nerve block: a clinical, radiographic and computed tomographic study in chronic pain patients. *Anesthesia and Analgesia*. 68(1):32-39. (1989)
18. Rochette, J. Regional anesthesia and analgesia for oral and dental procedures. *Veterinary Clinics of North America Small Animal Practice* 35(4):1041-1058(2005)
19. Skarada, R, Tanquilli, W. Chapter 20: Local and regional anesthetic and analgesic techniques: dogs in: Tranquilli, W, Thurmon, J, Grimm, K. *Lumb and Jones' Veterinary Anesthesia and Analgesia* 4e. Blackwell Publishing, Oxford, UK pp.566. (2007)
20. Snyder CJ, Snyder, LBC. Effect of mepivicaine in the infraorbital nerve block on minimum alveolar concentration of isoflurane in clinically normal anesthetized dogs undergoing a modified form of dental dolorimetry. *Journal of the American Veterinary Medicine Association* 242:199-204. (2013)
21. Snyder, CJ, Soukup, JW, Drees, R, Tabone, TJ. Caudal Mandibular Bone Height and Buccal Cortical Bone Thickness Measured by Computed Tomography in Healthy Dogs. *Vet Surg*. 2016 Jan;45(1):21-9.
22. Snyder, CJ, Soukup J. Oral and Maxillofacial Disorders. In: *Canine and Feline Anaesthesia and Co-Existing Disease*. Snyder L, Johnson R, Wiley-Blackwell, pp 197. (2015b)
23. Tasaki, I. Nervous Transmission. Thomas, Springfield MA. (1953)
24. Webber, B., Orlansky, H., Lipton, C., Stevens, M. Complications of an intra-arterial injection from an inferior alveolar nerve block. *Journal of the American Dental Association* 132(12): 1702-1704. (2001)
25. Wedel, D, Horlocker, T. Chapter 52 Nerve Blocks. In: Miller, RD, Eriksson, LI, Fleisher, LA, Wiener-Kronish, JP, Cohen, NH, Young, WL. *Miller's Anesthesia* 7e pp.1662-1663. Churchill Livingstone London, UK. (2009)