Administration of local anesthetics decreases nociceptive input into the CNS during invasive procedures and thereby decreases the facilitation of nociceptive pathways that can worsen the experience of pain in the postoperative period. Regional nerve blocks are used extensively in veterinary medicine in awake and anesthetized animals. In awake or chemically restrained animals, this treatment is essential to provide humane conditions for the procedure. In anesthetized animals, a regional nerve block can minimize sensory input and decrease the requirements for general anesthetic agents. Since most general anesthetics, particularly inhalants, cause a significant dose-dependent cardiopulmonary depression, a technique that allows the animal to be kept at a lighter plane of anesthesia is likely to decrease these negative effects.

An infraorbital nerve block was described in dogs as early as 1928, and further descriptions have been incorporated in most major veterinary anesthesia textbooks, but there is very little information on the effectiveness of the block. The infraorbital nerve that courses through the infraorbital canal supplies sensory neurons to the superior premolar teeth from the middle superior alveolar branches and to the incisor and MC teeth on the ipsilateral side from the rostral superior alveolar branches. However, the caudal premolar and molar teeth are supplied by the caudal superior alveolar branches that originate from the infraorbital nerve before it enters the infraorbital canal. The gingiva on the aboral side of the maxillary teeth is supplied by the same nerves. Thus a local anesthetic introduced into the infraorbital canal would not be expected to block sensation to the caudal premolar and molar teeth unless it spreads caudally along the nerve to block the caudal superior alveolar branch. Such caudal spread into and beyond the end of the

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OBJECTIVE
To determine the onset, duration, and extent of regional nerve blocks performed by administration of lidocaine or lidocaine-bupivacaine into the infraorbital canal in dogs.

ANIMALS
6 healthy hound-type dogs.

PROCEDURES
Under general anesthesia, stimulating needles were inserted into the gingiva dorsolateral to both maxillary canine (MC) teeth and the maxillary fourth premolar (MPM4) and second molar (MM2) teeth on the treatment side. A reflex-evoked muscle potential (REMP) was recorded from the digastricus muscle after noxious electrical stimulation at each site. After baseline measurements, 1 mL of 2% lidocaine solution or a 2% lidocaine-0.5% bupivacaine mixture (0.5 mL each) was injected into the infraorbital canal (at approx two-thirds of the canal length measured rostrocaudally). The REMPs were recorded for up to 7 hours. The REMP data for the contralateral (untreated control) canine tooth were used to normalize results for all stimulation sites.

RESULTS
With both treatments, nerve block for MC teeth on the treated side was achieved by 5 (n = 5 dogs) or 10 (1) minutes after injection, but nerve block for ipsilateral MPM4 and MM2 teeth was successful for only 3 dogs and 1 dog, respectively. Mean duration of nerve blocks for MC teeth was 120 and 277 minutes following injection of lidocaine and lidocaine-bupivacaine, respectively.

CONCLUSIONS AND CLINICAL RELEVANCE
Local anesthesia, as performed in this study, successfully blocked innervation of MC teeth, but results for MPM4 and MM2 teeth were inconsistent. This specific technique should not be used during tooth extractions caudal to the MC teeth. (Am J Vet Res 2016;77:682–687)
canal was identified when radiographic contrast medium was deposited into the infraorbital canal of canine cadavers. A variety of methods have been used to test for presence of an effective dental nerve block in dogs. Electrical stimulation has been used in other investigations, in which the anode was coated with electrode gel to provide good contact and attached to each tooth, and the cathode was inserted into the gingival mucosa. This technique may have stimulated both the pulpal and gingival nociceptors. The REMP method is used to quantify the response to a noxious stimulus applied to the teeth and gingiva. It is objective and provides a reliable definition of a sensory block because it can be used to detect the presence of a complete block as well as gradations of recovery. A cold thermal stimulus, achieved by application of a cotton ball sprayed with refrigerant, has been used to assess a mental nerve block in dogs. The responses of heart rate and blood pressure, and change in the minimum alveolar concentration of an inhalation anesthetic agent have also been used as outcome measures to assess local nerve blocks affecting the oral cavity in dogs.

Lidocaine and bupivacaine are commonly used in veterinary practice as local anesthetics with shorter and longer durations of action, respectively. Mixtures of lidocaine and bupivacaine have been used to speed the onset of anesthetic action, compared with that achieved by bupivacaine alone, while increasing the duration of action, compared with that attained by lidocaine alone. In some circumstances, the mixture may even be more effective than lidocaine alone.

The objective of the study reported here was to determine the onset, duration, and spread of local anesthesia following an infraorbital nerve block as assessed by REMPs following an injection of lidocaine or a lidocaine-bupivacaine mixture in anesthetized dogs.

Materials and Methods

Dogs
Six adult sexually intact female mesaticephalic hound dogs with a mean ± SD weight of 21.3 ± 1.4 kg were used in the study. Each dog was deemed to be healthy on the basis of results of a physical examination as well as CBC and serum biochemical analysis variables within reference ranges for the institution’s laboratory. The stage of the estrus cycle was not assessed during experiments. Food was withheld for 12 hours before the study, although water was available ad libitum until the dogs were transported to the laboratory for the test procedure. The study was approved by the Institutional Animal Care and Use Committee of the University of California-Davis.

Study design
The original design of the study was to compare the effects of lidocaine versus bupivacaine for regional infraorbital nerve blockade, and the treatments were assigned in random order with the first side treated by local anesthetic administration (left or right) also assigned randomly. Unfortunately, because of inconsistencies in the data recording, the results from the bupivacaine part of the study were not usable, and the duration of effect of nerve blocks for which data were recorded was > 10 hours. Thus it was decided that a further, separate experiment should be performed to assess the local anesthetic effects of a mixture of lidocaine and bupivacaine, with the expectation that the duration of the local nerve block would be shorter than that observed following bupivacaine treatment alone. This meant that the order of treatments was not randomized. At least 2 weeks were allowed between experiments; the same dogs were used, and the side to be injected was again randomized.

Procedures
A 20-gauge, 4.8-cm venous catheter was placed percutaneously into a cephalic vein. Anesthesia was induced with propofol delivered IV by slow infusion (approx 1 mg/kg/min) until endotracheal intubation could be achieved. Anesthesia was then maintained with isoflurane in oxygen delivered via a partial rebreathing circle system. The dogs were placed in randomly assigned left or right lateral recumbency on a warm water heating pad, and body temperature was maintained by use of a warm air circulating blanket. An esophageal thermometer was introduced and advanced so that the tip was positioned over the heart; body temperature was monitored throughout the procedures and maintained between 36.8° and 38.3°C. The end-tidal partial pressure of carbon dioxide and expired concentration of isoflurane were monitored by means of a Raman gas spectrometer. Intermittent positive-pressure ventilation was used to maintain end-tidal partial pressure of carbon dioxide at 31 ± 3 mm Hg. The isoflurane concentration was adjusted to maintain a plane of anesthesia with a lack of movement in response to gingival stimulation. This resulted in an end-tidal isoflurane concentration of 1.9 ± 0.1%. Pulse rate and systolic arterial blood pressure were monitored with a Doppler monitor with the probe applied to the metacarpal region and a blood pressure cuff measured to have a width of 40% of the circumference of the antebrachium. Lactated Ringer solution was administered IV at a rate of 5 mL/kg/h.

For each site, 2 shielded, stimulating unipolar needle electrodes were inserted approximately 5 mm apart into the gingiva on the aboral side of the MC, MPM4, and MM2 teeth on the side to be injected (with the dog in lateral recumbency) and over the MC tooth on the contralateral side. The needles were inserted as close to the dental gingival border as possible. The contralateral MC tooth served as a control to normalize the values determined from the burned side. The end-tidal partial pressure of carbon dioxide and expired concentration of isoflurane were monitored by means of a Raman gas spectrometer. Intermittent positive-pressure ventilation was used to maintain end-tidal partial pressure of carbon dioxide at 31 ± 3 mm Hg. The isoflurane concentration was adjusted to maintain a plane of anesthesia with a lack of movement in response to gingival stimulation. This resulted in an end-tidal isoflurane concentration of 1.9 ± 0.1%. Pulse rate and systolic arterial blood pressure were monitored with a Doppler monitor with the probe applied to the metacarpal region and a blood pressure cuff measured to have a width of 40% of the circumference of the antebrachium. Lactated Ringer solution was administered IV at a rate of 5 mL/kg/h.

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electrical stimulus was applied to each pair of gingival electrodes, and the current was increased and then decreased until there was a maximal amplitude of the first REMP wave with minimal stimulus artifact. The current intensity varied between 30 and 80 mA; a 0.5-millisecond pulse width was used at a frequency of 1 Hz for 20 seconds. Three baseline values for each site were then recorded at 10-minute intervals, with each cycle taking 2 to 3 minutes to complete. One of the 2 anesthetic solutions (1 mL of 2% lidocaine, or 0.5 mL of 2% lidocaine mixed with 0.5 mL of 0.5% bupivacaine) was then injected into the infraorbital canal. The 27-gauge, 3.2-cm needle was advanced into the canal from the mucosal surface and into the infraorbital foramen until the tip of the needle was positioned at approximately two-thirds of the length of the canal, as judged by the distance from the insertion point to a sagittal line drawn from the medial canthus of the eye (ie, the estimated caudal end of the canal). The syringe was then attached and aspirated to ensure that the tip of the needle was not in a blood vessel, and the solution was injected. The needle was withdrawn; no pressure was applied over the site. Further REMP recordings were made at 5, 10, 15, 30, 45, and 60 minutes (with the time of injection considered time 0) and then every 20 minutes for 7 hours or until the areas under the REMP waves from the control and treated MC teeth were subjectively similar. At the end of each experiment, carprofen (2 mg/kg) was administered IV before the dogs were recovered from anesthesia.

**Statistical analysis**

For analysis, the normalized area under the first REMP wave was used as the main measurement. Latency (time from stimulus to start of the wave), duration (time from beginning to return to same voltage), and amplitude (height of the wave) were also examined (Figure 1). A calculation was then made to normalize all the values according to the control recordings, according to the following equation:

\[
\text{Normalized value} \times 100 = \frac{C}{TC} \times \frac{TT}{TRC} \times 100
\]

where C is the mean of 3 baseline values for the contralateral (untreated control) MC tooth; TC is the subsequent value for the untreated control tooth at time T; TT is the value recorded for the tested tooth on the treated side at time T; and TRC is the baseline value for the treated tooth.

Any normalized REMP value < 15% was taken as evidence of substantial desensitization (ie, a successful nerve block). The value of 15% was selected post hoc on the basis of visual inspection of the data. The duration of the blockade was measured from the time of the first point < 15% to the time of the first point > 15%. The duration of the blockade for the treated MC tooth was compared between the 2 local anesthetic treatments by means of a 1-tailed Wilcoxon signed rank test; values of \( P < 0.05 \) were accepted as significant. Results for other teeth were not tested statistically because of the small numbers of successful blocks. Latencies, durations, and amplitudes of the waves during recovery were also not tested statistically because of the variable numbers of data points.

**Results**

Infraorbital administration of lidocaine solution resulted in successful local nerve block (ie, normalized REMP < 15%) for gingiva over the MC tooth in 5 of 6 dogs within 5 minutes after injection and in the remaining dog within 10 minutes after injection. Blockade for the MPM4 tooth was achieved for 3 dogs (by the 5-minute time point in 2 and by the 10-minute time point in 1), but was not achieved for the remaining 3 dogs. Blockade for the MM2 tooth was successful at the 5-minute time point in 1 dog. Mean ± SD duration of the nerve block for the MC tooth was 120 ± 54 minutes (range, 80 to 220 minutes; \( n = 6 \)), and that for the MPM4 tooth was 168 ± 107 minutes (range, 45 to 240 minutes; \( n = 3 \)). For the 1 dog that had a successful block of the MM2 tooth, duration was 15 minutes.

After infraorbital administration of the lidocaine-bupivacaine solution, nerve block for gingiva of the MC tooth was successful in 5 of 6 dogs within 5 minutes and in the remaining dog within 10 minutes. Blockade for the MPM4 tooth was successful by the 5-minute time point in 1 dog and by the 10-minute time point in 2 dogs. Nerve block for the MM2 was successful at the 5-minute time point in 1 dog. Mean ± SD duration of the nerve block for MC teeth was 277 ± 43 minutes (range, 220 to 340 minutes; \( n = 6 \)), and this was significantly \( (P = 0.016) \) longer than the duration when lidocaine was used alone. The duration of nerve block for MPM4 teeth with lidocaine-bupivacaine treatment was 253 ± 83 minutes (range, 160 to 320 minutes; \( n = 3 \)). In the 1 dog that had a successful nerve block for MM2 block, the duration was 45 minutes.

The mean normalized values of the normalized REMP wave areas for the MC teeth had recovered to

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**Figure 1**—Illustration depicting a typical baseline REMP wave after a repeated stimulus (20 stimuli for which the mean REMP was calculated) and variables measured in a study to evaluate the onset, duration, and spread of local anesthesia following an intraorbital nerve block with 2% lidocaine solution (1 mL) or a lidocaine-bupivacaine mixture (0.5 mL of 2% lidocaine mixed with 0.5 mL of 0.5% bupivacaine) in healthy anesthetized dogs. The start of the stimulus occurred at the y-axis. The beginning and end of the REMP, represented by the thick lines delimiting duration, were determined by computer.
Figure 2—Mean of the normalized percentage area of the REMP for the calculated area under the first REMP waves following gingival stimulation over the MC (triangles), MPM4 (squares), and MM2 (circles) teeth in healthy anesthetized dogs (n = 6 unless otherwise indicated) that received 1 mL of 2% lidocaine solution administered by injection into the ipsilateral infraorbital canal. Baseline measurements were normalized to 100% posttreatment REMPw were measured beginning 5 minutes after injection (with the time of injection considered time 0). A value of 0% represents a complete nerve block (no response), and a value of 100% indicates an REMP equal to that of the contralateral (untreated control) MC tooth. Values > 100% resulted when the area of an REMP wave for an unblocked tooth was greater than its baseline value. Vertical bars represent the SD.

almost 100% by 300 minutes after injection with lidocaine (Figure 2) but had only recovered to about 25% by 340 minutes after injection with lidocaine-bupivacaine (Figure 3). For the 3 dogs that had successful nerve blocks for MPM4 teeth, these REMP values had returned to 100% by 200 minutes after lidocaine administration and were still at approximately 60% at 340 minutes after lidocaine-bupivacaine treatment. There was an effect of the local nerve blocks on mean REMP values for MM2 teeth, but only 1 dog had any values < 15% with each treatment.

The latency and duration of the REMP waves could not be measured if the amplitude was 0, so the mean latencies were only reported for times when there were no 0 values for amplitude and there were ≥ 5 dogs with recorded values at that time (ie, once values were no longer being recorded for 2 dogs, values for the remaining dogs were not reported). After lidocaine injection, there were no calculable REMP wave latencies for MC teeth according to these criteria, but mean ± SD normalized latencies of REMP waves for MPM4 and MM2 teeth were 97 ± 8% and 91 ± 6%, respectively. After injection of lidocaine-bupivacaine, the mean ± SD normalized latencies for these periods were 110 ± 10%,112 ± 3%, and 100 ± 3% for MC, MPM4, and MM2 teeth, respectively. After lidocaine treatment, the mean ± SD normalized latencies of REMP waves for MPM4 and MM2 teeth were 101 ± 16%, and 103 ± 13% for MC, MPM4, and MM2 teeth, respectively. After lidocaine-bupivacaine treatment, these values were 82 ± 10%, 89 ± 6%, and 104 ± 6%, respectively. The mean ± SD normalized amplitudes after lidocaine treatment were not calculable, 115 ± 51%, and 103 ± 27% for MC, MPM4, and MM2 teeth, respectively; whereas those after lidocaine-bupivacaine treatment were 29 ± 7%, 59 ± 12%, and 119 ± 20%, respectively. The dogs were observed for 24 hours after each experiment, and none had signs of postoperative pain (eg, depression, inappetence, face rubbing, or excessive lip licking).

Discussion

Both local anesthetic treatments in the present study resulted in successful nerve block for the MC teeth on the treated side; this was identified ≤ 5 minutes after injection for most (5/6) dogs. Deposition of lidocaine, which has a relatively rapid onset of action, in close proximity to the nerve supplying the region of interest was expected to result in a rapid block. Likewise, it was expected that the longer duration of action of bupivacaine would confer a longer duration of nerve block after lidocaine-bupivacaine treatment compared with lidocaine alone. In a clinical situation, the shorter-duration nerve block obtained with lidocaine may be useful if dental extractions are not expected to take much time and postoperative analgesia is to be managed with other drugs; the lidocaine-bupivacaine combination as used in the present study provided local anesthesia (evidenced by normalized REMP wave duration) lasting > 3.5 hours, which would likely be adequate for many rostral maxillary tooth extractions and may extend into the postoperative period.

The technique used for assessing the onset and duration of nerve blocks in this study was stimulation of the gingiva while simultaneously recording the REMP. The recordings obtained were from a repeated stimulus (20 repetitions) for which the mean REMP was calculated by the computer; thus, these results were not comparable to those of Whalen,11 where a
It also became apparent that the reflex was bilateral, and therefore the stimulus could be applied on the same side as or the opposite side to the injection in the infraorbital canal. This allowed the changes over time on the unblocked side to be used to normalize the values obtained from the injected side. Only the gingiva over the MC tooth was used as a control because of the difficulty in keeping the needles in place on the recumbent side for MPM4 and MM2 teeth. Overlapping right-to-left innervation is possible, but this has not been described in dogs. The choice of < 15% of the normalized control value as an indication of nerve block was based on examination of the data. It was evident that, below this cutoff, there were small increases and decreases over time, but above it, the normalized values tended to increase sequentially, representing regression of the nerve block. The innervation of the aboral gingiva is the same as for the adjacent teeth, although there may be some differences in the types of neurons supplying the tooth pulp versus the gingiva. In a study comparing pulpal and gingival neurons in rats, there were fewer small pulpal neurons, and they were much less likely to bind isolectin B4 (a plant lectin that binds to small primary sensory neurons) than were the gingival neurons. These differences are unlikely to alter the response to acute stimulation.

In the present study, stimulation of the gingiva at the opposite MC tooth was included as a control value. In preliminary studies, it was noticed that the amplitude of the REMP did not stay constant but typically decreased over time. It was not clear whether this was related to the effect of the local anesthetic, the isoflurane, or a fatigue of the reflex, although increasing anesthetic depth blunted the reflex. The latencies of the REMP did not appear to change with time, and the durations of the waves were also close to the baseline values throughout, so the major contributor to the change in area was the change in amplitude.

The nerve block described in this study was performed by depositing the local anesthetic at approximately two-thirds the length of the infraorbital canal with some expectation that the drug would move caudally from the site of injection. However, this caudal spread appeared to be inconsistent and did not substantially affect the caudal superior alveolar branches, as evidenced by failure to result in successful nerve blocks for the MPM4 and MM2 teeth in ≥ 3 of 6 dogs. From other studies, it would appear that the depth of local anesthetic injection is important. Depositing lidocaine approximately 0.5 cm into the infraorbital canal did little to blunt the response to rhinoscopy in 8 mixed-breed dogs under general anesthesia. Mepivacaine, deposited approximately 0.5 cm into the infraorbital canal, was tested by evaluating changes in isoflurane minimum alveolar concentration in response to an electrical stimulus applied to an MC tooth in Beagles. Although a 23% reduction in minimum alveolar concentration was measured, mean heart rates and arterial blood pressures increased with gingival stimulation, suggesting that the block was not completely effective, at least in some dogs. In another study, chloroprocaine was instilled through a catheter inserted into the infraorbital canal, and REMPs were measured to examine the efficacy of the nerve block in halothane-anesthetized dogs of unspecified breeding. With this method, it was possible to abolish or diminish REMPs following stimulation of dental pulp of the MC, MPM4, and first molar teeth. However, responses to stimulation of MM2 teeth were not tested. Although the dogs in that study were of similar size to dogs of the present study and the volume of injectate was also 1 mL, the depth of insertion of the catheter was not fully described. Investigators of a more recent study evaluated 2 different injection techniques in canine cadavers. One of the methods included insertion of a catheter that was advanced to the level of the lateral canthus of the eye, placing the end of the catheter beyond the caudal end of the infraorbital canal. The authors examined nerve staining following injection of 0.5 mL of methylene blue and decided that ≥ 6 mm of the maxillary nerve had to be stained to represent a positive effect. In that study of 37 cadavers, 24 (65%) had ≥ 6 mm of the nerve stained, 10 (27%) had some staining, and 3 (8%) had none. Results of the present and previous studies indicate that it is important to deposit the local anesthetic at least at the caudal end of the infraorbital canal, if not further. The use of a catheter, rather than a needle, as in 2 of the previous studies may allow the drug to be deposited near the nerve with minimal risk of trauma and less likelihood of injection into the medial pterygoid muscle. In all the described studies, it is possible that simply increasing the volume of drug injected may have enhanced caudal spread and increased the likelihood of successfully blocking nerves for the more caudal teeth.

There are at least 4 other techniques described for blocking the maxillary nerve and obtaining better desensitization of the caudal teeth because this would block the caudal superior alveolar branches of the infraorbital nerve. The method originally described in 1928 used a percutaneous approach from under the zygomatic arch directing the needle rostrally toward the caudal end of the infraorbital canal (pterygopalatine fossa). This approach was investigated in the aforementioned cadaver study, and only 8 of 37 dogs had ≥ 6 mm of the maxillary nerve stained. However, the individuals that performed the injections were inexperienced with the technique, which may have accounted for the high failure rate. Two other lateral approaches have been described; in one, a needle is advanced perpendicularly through the skin at (or slightly rostral to) the high point of the ventral border of the zygomatic arch, and in the other, the needle is advanced caudally past the cranial border of the coronoid process toward the origin of the maxillary nerve at the rostral alar foramen. Lastly, an intraoral approach has been described, with the needle being directed dorsally from behind the MM2 tooth and medial to the zygomatic arch. To the author's knowledge, none of these last 3 approaches have been studied objectively.

Although a control treatment (eg, injection of an equal volume of saline [0.9% NaCl] solution instead of
local anesthetic) would have allowed for control of the influence of chemical, temperature, or volume-related effects associated with treatments in the present study; this was not included because a previous study of dogs showed no effect of saline solution injection alone on the REMP associated with dental stimulation in anesthetized dogs. However, the first recording in that study was at 10 minutes after injection, whereas in a study of human patients that had REMPs recorded at 1-minute intervals following injection of local anesthetic to achieve a regional (obtur- ator) nerve block or injection of the same site with saline solution, a 50% decrease in the REMP amplitude was noted at 2 minutes, returning to the baseline value by 5 minutes after injection, for patients that received the saline treatment. The first recording in the present study was at 5 minutes, and it was considered likely that any effect from injection of saline solution would have passed. However, having the first measurement at 5 minutes also limited the ability to detect an earlier onset of local nerve block in this study. A further limitation was that the lidocaine experiments were completed before the lidocaine-bupivacaine experiments; thus, there could have been a temporal effect on the data. The means of the REMP areas for the 2 treatments were < 10% different for the control MC teeth at baseline, suggesting that overall conditions before the injections were similar. Only 1 dog was injected on opposite sides for the 2 treatments, despite randomization of the side of injection; consequently, results following administration of the lidocaine-bupivacaine treatment in the other 5 dogs could have been influenced by tissue damage. However, it was noted that the increase in duration of nerve blocks after the latter treatment, compared with results for the lidocaine treatment, was similar among all dogs.

In the present study, although deposition of lidocaine or a lidocaine-bupivacaine mixture at approximately two-thirds of the length of the infraorbital canal (as measured caudally from the needle insertion point) provided a complete nerve block for gingiva of the ipsilateral MC tooth, the fact that blockade of innervation to the MPM4 and MM2 teeth on the treated side was not reliable suggested this method would not be useful for invasive dental procedures in a clinical setting. A volume of 1 mL of either solution was used in this study of dogs that weighed approximately 20 kg (ie, 0.05 mL/kg), and the effects of solution volume on the effectiveness, latency, and duration of this type of nerve block need to be examined further.

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Footnotes

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