Paravertebral Blockade of the Brachial Plexus in Dogs

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Local anesthetic techniques are often used perioperatively in combination with other analgesic drugs as an integral part of multimodal strategies to manage pain in small animals.1,2 Surgical trauma and inflammation produce sensitization of peripheral sensory fibers, and the subsequent barrage of nociceptive input produces sensitization of projection neurons in the dorsal horn of the spinal cord. Local anesthetics are the only class of analgesic drugs that can produce complete blockade of peripheral nociceptive input and prevent sensitization of central nociceptive pathways and the development of pathologic pain. Preoperative use of local anesthetic techniques reduces inhalant requirements and autonomic responses to noxious surgical stimuli. These reductions improve cardiopulmonary function during surgery and promote a rapid smooth recovery from anesthesia after surgery. Perioperative use of local anesthetic techniques also attenuates the neuroendocrine or stress response to surgical trauma and inflammation and reduces the incidence of postoperative complications dramatically.3

Neural blockade of the brachial plexus is used during the period around the time of surgery to manage pain in dogs undergoing surgical procedures of the forelimb. The block has traditionally been performed by injecting local anesthetic into the axillary space at the level of the shoulder.4,5 Although the axillary technique is relatively easy to perform, a large volume of local anesthetic is required, onset time is slow (20–30 minutes), structures proximal to the elbow are not anesthetized, and incomplete blockade of the brachial plexus is relatively common. Further, neural blockade of the elbow and antebrachium is easier to achieve by selectively blocking the radial,
ulnar, median, and musculocutaneous nerves above the humeral epicondyles. Given these drawbacks, the traditional axillary technique has limited clinical utility.

Paravertebral blockade of the brachial plexus was developed at the Atlantic Veterinary College and was first described by Lemke and Dawson in 2000. Recently, the anatomic landmarks, technical merits, and reliability of the paravertebral technique were confirmed independently in an anatomic study by Hofmeister and colleagues. A modified paravertebral technique, which was also developed at the Atlantic Veterinary College, is described for the first time in this article. Both paravertebral techniques have several advantages over the traditional axillary technique. Key anatomic landmarks are easier to identify, smaller amounts of local anesthetic are required, the entire forelimb (including the shoulder) is anesthetized, and complete blockade of the brachial plexus is easier to achieve. Unilateral blockade of the phrenic nerve and hemidiaphragmatic paresis are likely complications with both paravertebral techniques. Inadvertent intravascular injection and pneumothorax are potential complications with the paravertebral techniques and with the axillary technique. All three techniques are unreliable in obese or heavily muscled dogs, because anatomic landmarks are obscured. With both paravertebral techniques, a clear understanding of the anatomy of the brachial plexus and surrounding structures is required to use these techniques safely and effectively.

**CLINICAL ANATOMY**

The canine brachial plexus is formed by ventral branches of the sixth (C6), seventh (C7), and eighth (C8) cervical spinal nerves, and the first thoracic (T1) spinal nerve (Figs. 1 and 2). Contributions from the fifth cervical (C5) and the second thoracic (T2) spinal nerves are small (<1 mm) or absent. The phrenic nerve originates from ventral branches of C5, C6, and C7, and runs medial to the brachial plexus before entering the thoracic inlet ventral to the subclavian artery.

Several major vessels are close to the cervical spinal nerves that form the brachial plexus (Figs. 3 and 4). The vertebral artery runs medial to the ventral branches of C6, C7, and C8 as they emerge from their respective intervertebral foramina. The costocervical artery runs next to the ventral branch of T1 as it emerges from the intervertebral foramen and wraps around the medial surface of the first rib. The vertebral ganglion is located within the thoracic inlet near the origin of the vertebral artery and provides most, if not all, of the postganglionic sympathetic innervation to the heart.

Innervation to the shoulder and brachium is supplied by C6, C7, and C8, and innervation to the elbow and antebrachium is supplied by C7, C8, and T1. Consequently, neural blockade of the ventral branches of C6, C7, and C8 is sufficient for surgical procedures of the shoulder and brachium. The suprascapular nerve arises primarily from C6 and provides sensory innervation to the lateral aspect of the shoulder joint capsule and motor innervation to the supraspinatus and infraspinatus muscles. The subscapular nerve arises from C6 and C7 and provides motor innervation to the subscapular muscle. The musculocutaneous nerve arises primarily from C7 and provides sensory innervation to the cranio medial aspect of the antebrachium (medial cutaneous antebrachial nerve) and motor innervation to the coracobrachialis, biceps brachii, and brachialis muscles. The axillary nerve arises from C7 and C8, and provides sensory innervation to the caudal aspect of the shoulder joint capsule and the lateral aspect of the brachium (lateral cutaneous brachial nerve). The axillary nerve also provides motor innervation to the subscapularis, teres major, teres minor, and deltoideus muscles. The radial nerve arises from C7, C8, and T1 and provides sensory innervation to the lateral aspect of the elbow joint capsule and the cranialateral aspect of the
Fig. 1. Superficial dissection of the nerves of the canine brachial plexus (lateral view). Note the location of the large ventral wing of the transverse process of the sixth cervical vertebra, the head and costochondral junction of the first rib, and the axillary artery and vein. Ventral branches of the sixth and seventh cervical nerves can be blocked as they cross the cranial and caudal margins of the transverse process, respectively. Ventral branches of the eighth cervical nerve and the first thoracic nerve can be blocked as they cross the cranial and caudal margins of the head of the first rib, respectively. Alternately, ventral branches of the eighth cervical and first thoracic nerves can be blocked where they converge above the axillary artery along the cranial margin of the first rib. (From Done SH, Goody PC, Evans SA, et al. Color atlas of veterinary anatomy, the dog and cat. Vol 3. London: Elsevier; 1996. p. 3.14; with permission.)

Fig. 2. Detailed legend for the superficial dissection of the nerves of the canine brachial plexus (lateral view). (From Done SH, Goody PC, Evans SA, et al. Color atlas of veterinary anatomy, the dog and cat. Vol 3. London: Elsevier; 1996. p. 3.14; with permission.)
The radial nerve also provides motor innervation to extensors of the elbow (triceps and anconeus) and the carpus and digits (extensor carpi radialis, common and long digital extensors, and extensor carpi ulnaris) in addition to the supinator and abductor pollicis longus. The median nerve arises from C8 and T1 and provides sensory innervation to the medial aspect of the elbow joint capsule. The median nerve also provides motor innervation to flexors of the carpus and digits (flexor carpi radialis and superficial and deep digital flexors) and to the pronator teres and pronator quadratus. The ulnar nerve arises from C8 and T1 and provides sensory innervation to the caudal aspect of the elbow joint capsule and caudolateral aspect of the antebrachium (caudal cutaneous antebrachial nerve). The ulnar nerve also provides motor innervation to flexors of the carpus and digits (flexor carpi ulnaris and deep digital flexor).

Electrical stimulation of the ventral branches of C6, C7, C8, and T1 induces characteristic motor responses.7 Stimulation of the cranial branch of C6 causes contraction of the brachiocephalicus, supraspinatus, and infraspinatus in addition to outward rotation of the shoulder, and stimulation of the caudal branch causes inward rotation of the shoulder. Stimulation of the cranial branch of C7 causes contraction of the biceps and outward rotation of the brachium, stimulation of the middle branch causes contraction of the deltoideus and inward rotation of the brachium, and stimulation of the caudal branch causes contraction of the triceps and extension of the carpus. Stimulation of C8 causes contraction of the triceps and extension of the elbow, carpus, and digits, and stimulation of T1 causes flexion of the carpus and digits.
Electrical stimulation of more distal nerves of the brachial plexus also induces characteristic motor responses. Stimulation of the suprascapular nerve (C6) causes extension of the shoulder, and stimulation of the subscapular nerve (C6 and C7) causes inward rotation of the shoulder and abduction of the limb. Stimulation of the musculocutaneous nerve (C7) causes flexion of the shoulder, elbow, and carpus. Stimulation of the axillary nerve (C7 and C8) causes flexion of the shoulder, abduction of the elbow, and inward rotation of the carpus. Stimulation of the radial nerve (C7, C8, and T1) causes extension of the elbow, carpus, and digits in addition to splaying of the toes. Stimulation of the combined median-ulnar nerve trunk (C8 and T1) causes flexion of the elbow, carpus, and digits.

**PARAVERTEBRAL TECHNIQUE**

**Indications**

The paravertebral technique is used during the period around the time of surgery to provide analgesia and muscle relaxation for surgical procedures of the shoulder and brachium. The technique is relatively easy to perform provided that the anatomy of the brachial plexus is reviewed and that key anatomic landmarks are accurately identified. The technique is difficult to perform in obese dogs and in dogs with heavy cervical musculature, and it should not be performed if the transverse process of the sixth cervical vertebra and the head of the first rib cannot be identified.

**Clinical Technique**

The nerves of the brachial plexus can be successfully blocked in most patients by injecting 1-3 mL of 2% lidocaine or 0.5% bupivacaine using a 22-gauge (0.7-mm), 1-inch (25-mm), or 1.5-inch (38-mm) needle at each of the four sites (C6, C7, C8, C8, C8).
and T1). Particular attention should be paid to the location of the jugular groove, thoracic inlet, and major vessels that are close to the nerves of the brachial plexus. Syringes should be aspirated before each injection to avoid inadvertent intravascular administration. Doses of local anesthetics should be calculated carefully for small patients, and the total dose (based on lean body weight) should not exceed 8 mg/kg of 2% lidocaine or 2 mg/kg of 0.5% bupivacaine. For dogs weighing less than 10 kg, the maximum total dose is divided by four to obtain the dose for injection at each site.

After clipping and aseptic preparation of the site, the scapula is shifted caudally to expose the transverse process of the sixth cervical vertebra and the head of the first rib (see Figs. 1 and 2). An index finger is placed on the large ventral wing of the transverse process, and the cranial and caudal margins of the process are isolated. Ventral branches of C6 and C7 are relatively superficial at this site (<2–3 cm under the skin) and are just dorsal to the cranial and caudal margins of the transverse process, respectively. Placement of an index finger on this key anatomic landmark also covers the jugular groove and prevents inadvertent injection of local anesthetic near the jugular vein, carotid artery, and vagosympathetic trunk. The needle is inserted dorsal to the cranial and caudal margins of the process and is directed medially. Local anesthetic (1–3 mL or less for dogs weighing less than 10 kg) is injected along the nerve above the dorsolateral surface of the transverse process at each site. Ventral branches of C8 and T1 are located dorsal to the cranial and caudal margins of the head of the first rib, respectively (see Figs. 3 and 4). Next, with the scapula still shifted caudally, the first rib is palpated dorsal to the cranial and caudal margins of the scapula. An index finger is placed just ventral to the head of the rib, and the cranial and caudal margins are isolated. Placement of an index finger on this key anatomic landmark also covers the thoracic inlet and prevents inadvertent injection of local anesthetic near major vessels and the vertebral ganglion or within the pleural space. The needle is inserted dorsal to the cranial and caudal margins and is directed medially. Local anesthetic (1–3 mL or less for dogs weighing less than 10 kg) is injected dorsal to the head of the rib at each site. Care should be taken to avoid intravascular injection.

**Potential Complications**

The phrenic nerve originates from ventral branches of C5, C6, and C7, and runs medial to the brachial plexus (see Figs. 1 and 2). Blockade of the ventral branches of C6 and C7 or direct blockade of the phrenic nerve with local anesthetics can produce hemidiaphragmatic paresis. In human patients, a similar technique (interscalene block) consistently produces paralysis of the phrenic nerve and hemidiaphragmatic paresis, but adequate pulmonary function is maintained.11,12 Similarly, unilateral or bilateral blockade of the phrenic nerve does not seem to compromise pulmonary function in conscious or anesthetized dogs.13–16 Unilateral blockade of the brachial plexus should be avoided in patients that have compromised pulmonary function, however, and blockade of the brachial plexus should not be performed bilaterally. Accidental epidural or intrathecal administration is an unlikely but potential complication, and needles should be directed caudally to avoid insertion into intervertebral foramina. Inadvertent intravascular injection and direct nerve injury are also potential complications.

**MODIFIED PARAVERTEBRAL TECHNIQUE**

**Indications**

The modified paravertebral technique was also developed at the Atlantic Veterinary College and is used during the period around the time of surgery to provide analgesia and muscle relaxation for surgical procedures of the shoulder and brachium. The
modified technique is easier to perform than the standard technique because the ventral branches of C8 and T1 are blocked at their junction on the cranial border of the first rib rather than dorsal to the head of the rib. This technique is also difficult to perform in obese dogs and in dogs with heavy cervical musculature and should not be performed if the transverse process of the sixth cervical vertebra and the first rib cannot be identified.

Clinical Technique
After clipping and aseptic preparation of the site, the scapula is shifted caudally and the transverse process of the sixth cervical vertebra is identified (see Figs. 1 and 2). The index finger is placed on the transverse process, and the cranial and caudal margins of the process are identified. The ventral branches of C6 and C7 are blocked using the same approach as the standard technique. Next, with the scapula still shifted caudally, the axillary artery and the costochondral junction of the first rib are identified (see Figs. 3 and 4). The ventral branches of C8 and T1 converge 1 to 2 cm dorsal to the axillary artery and costochondral junction along the cranial margin of the first rib. Local anesthetic (1–3 mL or less in dogs weighing less than 10 kg) is injected along the cranial margin of the rib at one or two sites. Care should be taken to avoid intravascular injection and insertion of the needle into the thoracic inlet and pleural space.

Potential Complications
As with the standard technique, blockade of the phrenic nerve is a likely complication. Accidental epidural or intrathecal administration is an unlikely but potential complication, and needles should be directed caudally when blocking the ventral branches of C6 and C7 to avoid insertion into intervertebral foramina. Blockade of the ventral branches of C8 and T1 should be performed above the axillary artery along the cranial margin of the first rib. Needle placement within the thoracic inlet could result in pneumothorax, inadvertent intravascular injection, or blockade of the vertebral ganglion. Direct nerve injury is also a potential complication.

RADIAL, ULNAR, MEDIAN, AND MUSCULOCUTANEOUS NERVES TECHNIQUE

Indications
Complete neural blockade for surgical procedures of the elbow and antebrachium can be produced by blocking the radial, ulnar, median, and musculocutaneous (RUMM) nerves above the humeral epicondyles. This technique is easier to perform than the axillary and paravertebral techniques, and the potential for complications is lower. The radial nerve is blocked above the lateral epicondyle of the humerus between the lateral head of the triceps and brachialis. The ulnar, median, and musculocutaneous nerves are blocked above the medial epicondyle of the humerus next to the brachial artery. The musculocutaneous nerve lies cranial to the brachial artery, and the median and ulnar nerves lie caudal to the artery.

Clinical Technique
The RUMM nerves can be successfully blocked in most patients by injecting 1–2 mL of 2% lidocaine or 0.5% bupivacaine using a 22-gauge (0.7-mm) 1-inch (25-mm) needle at each of the three sites (radial, ulnar-median, and musculocutaneous). Particular attention should be paid to the location of the brachial artery and vein along the medial surface of the humeral shaft. Aseptic technique should be used, and syringes should be aspirated before each injection to avoid inadvertent intravascular administration. Doses of local anesthetics should be calculated carefully for small patients, and the
The total dose (based on lean body weight) should not exceed 8 mg/kg of 2% lidocaine or 2 mg/kg of 0.5% bupivacaine. For dogs weighing less than 10 kg, the maximum total dose is divided by three to obtain the dose for injection at each site.

The radial nerve can be palpated above the lateral epicondyle of the humerus between the brachialis and lateral head of the triceps. The needle is inserted proximal to the lateral epicondyle, and local anesthetic (1–2 mL) is injected along the nerve. The musculocutaneous nerve is cranial to the brachial artery, and the median and ulnar nerves are caudal to the artery. The needle is inserted proximal to the medial epicondyle over the brachial artery, and local anesthetic (1–2 mL) is injected along the cranial and caudal margins of the artery. Care should be taken to avoid intravascular injection.

**Potential Complications**

This technique is easier to perform than the standard and modified paravertebral techniques, and the potential for complications is lower. Inadvertent intravascular injection and direct nerve injury are potential complications.

**ELECTRICAL NERVE LOCATORS**

Successful neural blockade of the forelimb depends on precise localization of the ventral branches of C6, C7, C8, and T1 or more distal nerves of the brachial plexus. The location of superficial nerves can be determined by direct palpation, whereas deeper nerves require identification of distinct landmarks and an intimate knowledge of regional anatomy. Electrical nerve locators (ENLs) are used routinely to facilitate neural blockade of the brachial plexus in human patients.17–19 These devices can also be used to facilitate neural blockade of the brachial plexus in dogs using the standard or modified paravertebral technique, and they can also be used to localize and block more distal nerves of the brachial plexus (RUMM technique). Anatomic landmarks are often obscured in obese and heavily muscled dogs, and ENLs can be used in these patients to localize the nerves of the brachial plexus. Clinical use of ENLs facilitates correct needle placement and may shorten onset time, prolong duration of action, and reduce the risk for nerve injury. These devices are also excellent educational tools for professional students and for practicing veterinarians.

Most ENLs consist of a constant-current generator that is connected to an insulated needle and a remote electrode that is attached to the skin (Fig. 5). A 22-gauge (0.7-mm), 1.5-inch (38-mm) pinpoint-tip insulated needle is appropriate for neural blockade of the forelimb in most dogs (Fig. 6). When the insulated needle penetrates the skin, the circuit is closed and a constant current stimulus is delivered at a frequency of 1 or 2 Hz and for a duration of 0.1 to 0.2 milliseconds. Resistance varies with tissue impedance and the position of the remote electrode and ranges from 0.5 to 3.0 kΩ. Consequently, the current generator must vary the voltage according to Ohm’s law (I = V/R; I, current; V, voltage; R, resistance) to maintain a constant stimulus strength. Some models include a percutaneous electrode that allows transcutaneous stimulation and localization of nerves before needle placement (Fig. 7). The resistance between the percutaneous electrode and the remote electrode is approximately 25 kΩ, and a proportionally higher current (10 mA) and stimulus duration (0.5 ms) are required to depolarize adjacent nerve fibers.

The current required to depolarize motor nerve fibers varies with the distance of the needle tip from the fiber (r) according to Coulomb’s law \[E = K(Q/r^2); E, \text{threshold current required}; K, \text{constant}; Q, \text{minimal current}\]. As the needle tip approaches the nerve, less current is required to depolarize the nerve fibers and produce a motor response. Clinical use of ENLs can be divided into a search phase, an approach phase,
and an injection phase. During the search phase, an appropriate current (1–2 mA) is selected based on the expected depth of the nerve, the needle is inserted, and closure of the circuit is verified. The needle is advanced toward the nerve until the desired motor response is obtained. During the approach phase, the current is reduced (0.4–0.6 mA) and the needle is advanced slowly toward the nerve until the motor response is obtained again. Ideally, the motor response should be present at 0.4 mA but not at 0.2 mA. Persistence of the motor response at currents less than 0.2 mA and resistance to injection may indicate intraneural needle placement. With new pinpoint-tip insulated

Fig. 5. ENLs. These devices consist of a constant current generator (yellow box) with connections for an insulated needle (white connection) and a remote electrode (red). Some ENLs also include a percutaneous electrode (black pen) than allows transcutaneous stimulation and localization of nerves before needle placement. Pajunk MultiStim Sensor with Percutaneous Electrode Guidance.

and an injection phase. During the search phase, an appropriate current (1–2 mA) is selected based on the expected depth of the nerve, the needle is inserted, and closure of the circuit is verified. The needle is advanced toward the nerve until the desired motor response is obtained. During the approach phase, the current is reduced (0.4–0.6 mA) and the needle is advanced slowly toward the nerve until the motor response is obtained again. Ideally, the motor response should be present at 0.4 mA but not at 0.2 mA. Persistence of the motor response at currents less than 0.2 mA and resistance to injection may indicate intraneural needle placement. With new pinpoint-tip insulated

Fig. 6. Pinpoint-tip insulated needle (22-gauge, 40-mm, and 50-mm) for nerve location. Note the transparent nonconductive coating and the depth indicators (cm). Only the tip of the bevel is exposed and conducts current that allows more precise localization of nerves. Pajunk Uniplex Nanoline cannula with facet tip.
needles, the needle tip is close to the nerve (<5 mm) when a motor response is obtained at currents less than 0.5 mA. During the injection phase, the needle is immobilized and 1 to 3 mL of local anesthetic is deposited next to the nerve. As the solution is injected, the nerve is mechanically displaced and the motor response is lost. Characteristic motor responses of the ventral branches of C6, C7, C8, and T1 and the distal nerves of the canine brachial plexus were described in detail in early anatomic studies.7,8

SUMMARY

Local anesthetic techniques are usually the safest and most effective way to improve the quality of anesthesia and analgesia for dogs undergoing surgical procedures. Complete neural blockade of the canine brachial plexus is difficult to achieve using the traditional axillary technique. Paravertebral blockade of the ventral branches of C6, C7, C8, and T1 produces complete blockade of the brachial plexus. The paravertebral technique and the modified paravertebral technique are used during the period around the time of surgery to provide analgesia and muscle relaxation for surgical procedures of the shoulder and brachium. These techniques are relatively easy to perform provided that the anatomy of the brachial plexus is reviewed and that key anatomic landmarks (transverse process of the sixth cervical vertebra and first rib) are accurately identified. The RUMM nerve technique is used during the period around the time of surgery to provide analgesia and muscle relaxation for surgical procedures of the elbow and antebrachium. Proximal and distal nerves of the brachial plexus can be successfully blocked in most patients by injecting 2% lidocaine or 0.5% bupivacaine at a dose of 1 to 3 mL using a 22-gauge (0.7-mm), 1-inch (25-mm), or 1.5-inch (38-mm) needle at each site. Particular attention should be paid to the location of the jugular groove, thoracic inlet, and major vessels that are close to the nerves of the brachial plexus. Syringes should be aspirated before each injection to avoid intravascular administration, and doses of local anesthetics should be calculated carefully for small patients.

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