

CHAPTER 1

Introduction

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Handbook of Small Animal Regional Anesthesia and Analgesia Techniques, First Edition.
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Reasons to provide regional anesthesia

The use of regional anesthesia as a component of perioperative pain management has gained acceptance and popularity in small animal practice over the past few decades. Reasons for this include the fact that many of the regional blocks are straightforward to perform, requiring moderate technical skill given familiarity with patient anatomy; they can be conducted relatively safely given an understanding of local anesthetic drug pharmacology, complications and side effects; and they contribute to the two major tenets of treating pain: pre-emptive and multimodal analgesia.

Providing pre-emptive analgesia by performing regional anesthesia prior to surgery leads to a drastic reduction in intraoperative nociceptive (pain) stimulation. This results in a decrease in anesthetic maintenance drug as well as intra- and postoperative analgesic requirements, thereby decreasing the incidence of drug side effects during surgery, and improving postoperative patient comfort as well as duration of pain relief. Some techniques can be continued postoperatively to assist in managing pain after particularly painful surgeries once the patient has recovered from anesthesia, e.g. instilling local anesthetic into a chest tube after thoracotomy, or injecting local anesthetic into an epidural or spinal catheter after pelvic limb or abdominal surgery.

The experience of pain, a sensory process involving the nociceptive pathway, is complex, and involves several steps. Noxious stimuli involving mechanical, chemical or thermal injury to tissue are first transduced into electrical stimuli by peripheral nociceptors (pain receptors). These electrical impulses are then transmitted to the spinal cord, where they are modulated by neurons in the dorsal horn of the gray matter of the spinal cord. Here, impulse intensity can be increased (amplified) or decreased (suppressed). Finally, the nociceptive signals are projected via lateral nerve fibers to the brain where they are perceived.

Whereas most analgesic drugs either decrease the amount of excitatory neurotransmitters, or increase the level of inhibitory neurotransmitters released in the nociceptive pathway, drugs used to provide regional anesthesia block sodium channels in neurons. This completely prevents sensory neurons from transmitting noxious stimuli from the periphery to the brain and spinal cord, or from the spinal cord to the brain in the case of epidural or spinal analgesia, thus providing effective pain relief for the duration of the block. Using regional anesthetic techniques in conjunction with other analgesic drugs that act in different ways on the nociceptive fibers (e.g. with opioids, alpha-2 agonists, ketamine) results in multimodal analgesia, contributing to an overall decrease in excitatory neurotransmission within

the pain pathway both during and after surgery. This approach allows for the lowest effective dose of each drug to be used, which decreases side effects and enhances patient safety.

History of regional anesthesia/analgesia

The use of a local anesthetic drug was first demonstrated in 1884 when cocaine was used to desensitize the eye prior to surgery. Due to cocaine being habit forming and having a low safety margin, as well as the emergence of techniques allowing artificial synthesis of chemical compounds in the 1900s, non-toxic, non-addictive local anesthetics were sought, discovered, and manufactured. Initially, amino ester-type compounds were produced, until in 1943 lidocaine, an amino amide drug, was developed. Amide-type local anesthetic drugs are preferred for their longer duration of action, and several compounds in this group were discovered in the latter half of the 20th century, including mepivacaine, bupivacaine, and ropivacaine.

Principles of the major techniques

Topical application

Local anesthetic drops, e.g. proparacaine, can be directly applied to the eye for immediate relief of keratoconjunctival pain, although prolonged use delays corneal healing and is not recommended. Local anesthetic can also be directly applied to exposed tissue. Drug is directly deposited into the surgical field by dripping from a syringe, or soaking surgical sponges in local anesthetic and applying them to the tissue. Local anesthetic can also be instilled into the chest via a thoracostomy tube to desensitize the pleura following chest surgery, and into the abdominal cavity to treat pain following incision of the peritoneum. Local anesthetic cream is available as a mixture of lidocaine and prilocaine, which is used to desensitize skin for intravenous catheter placement. Lidocaine is also available as a transdermal patch.

Regional infiltration

Continuous regional analgesia is accomplished by placing fenestrated “soaker” catheters in areas that are not amenable to peripheral or regional analgesic techniques. The catheter is then attached to an infusion pump or an elastomeric bulb which delivers a set rate of local anesthetic over a specified period of time.

Intravenous regional analgesia

Analgesia can be provided to a distal limb by placing an esmarch bandage and injecting local anesthetic (lidocaine only) into a vein.

Intra-articular injection

Local anesthetics injected into joints have a long duration of action due to slow systemic uptake. There is *in vitro* evidence that local anesthetics may be detrimental to chondrocyte health, with preservative-free formulations being preferred. However, *in vivo*, this has not been shown to be definitively the case (Chu et al, 2008).

Peripheral nerve blockade

Individual or groups of sensory nerves supplying a specific region are located by palpation, electrophysiology, ultrasound or varying combinations of two or three of these techniques. Local anesthetic is then deposited adjacent to, but not into, the nerves. Nerves are typically blocked at sites proximal and distant to the site of surgery.

Epidural and spinal injection

Using specific epidural/spinal needles, local anesthetic is deposited either into the extradural space (epidural injection) or into the subarachnoid space (spinal or intrathecal injection). This provides longer lasting, more intense analgesia and muscle relaxation, while minimizing systemic side effects. Preservative-free formulations of drug are recommended for epidural or spinal injection whenever possible.

Local anesthetic drugs

Mechanism of action

Local anesthetics mainly act by blocking sodium (Na^+) channels, which prevents depolarization of the neuronal cell membrane, and thus generation of an electrical impulse does not occur in response to noxious stimuli. There is evidence to suggest that local anesthetics can also exert their activity by blocking calcium channels and inhibiting reuptake of the inhibitory neurotransmitter GABA, thus enhancing its effect.

Physicochemical properties

Local anesthetic drugs have an aromatic ring and an amine group separated by a hydrocarbon chain. The amine group can be ester or amide linked. Esters are typically shorter acting than amides as they can be hydrolyzed by plasma cholinesterases. Esters are therefore not reliant on the liver for clearance, whereas amides undergo hepatic metabolism. Speed of onset is inversely proportional to the drug's lipid solubility and pK_a , i.e. the pH at which the drug exists in equal amounts of charged and non-charged molecules. Duration of effect increases as lipid solubility increases, and decreases as the rate of systemic absorption increases. Drugs that cause vasodilation, like lidocaine, have a shorter duration of action.

Table 1.1 Clinical pharmacology of local anesthetic agents in cats and dogs

	Lidocaine	Mepivacaine	Bupivacaine	Ropivacaine
Onset (minutes)	5–10	5–10	20–30	20–30
Duration (hours)	1–3	1.5–3	3–8	3–8
Clinical dose (mg/kg)	0.5–2.0 dog 0.5–1.5 cat	Up to 3.0 dog Up to 1.5 cat	1.0–1.5 dog 1.0 cat	Up to 3.0 dog*
Toxic dose (mg/kg)	6.0 dog 3.0 cat	6.0 dog 3.0 cat	3.0 dog 2.0 cat	5.0 dog*

*Toxic dose not established in cats. Recommend not exceeding 2 mg/kg total dose.

Specific drugs

Amide-type local anesthetic drugs are preferred in current veterinary practice for their longer duration of action compared to ester-type drugs. See Table 1.1 for summary information.

Lidocaine

Lidocaine has a short onset due to its low pK_a of 7.9. Duration of action is short, lasting up to 2 h. This is due to its relatively low level of protein binding (70%), and the fact that it is a potent vasodilator. Lidocaine formulated with epinephrine has a longer duration of action due to the vasoconstriction epinephrine causes. Lidocaine is less toxic than other amide-type drugs if administered intravenously (IV), and can be administered IV to treat pain systemically, as well as to treat ventricular dysrhythmias.

Mepivacaine

Mepivacaine has a low pK_a of 7.6, and therefore a rapid onset of action. It is highly protein bound (95%), resulting in a duration of action of 6–8 h.

Bupivacaine

Bupivacaine has a pK_a of 8.1 and is highly protein bound (95%), resulting in a longer duration of action (6–8 h). The margin of safety is the lowest when compared to lidocaine, mepivacaine, and ropivacaine.

Ropivacaine

Ropivacaine has physicochemical properties similar to bupivacaine, and therefore has a similar onset and duration of action. Other local anesthetics are synthesized as racemic mixtures, whereas ropivacaine is a pure S-enantiomer, and has a wider margin of safety than bupivacaine.

Combination of drugs

Lidocaine and bupivacaine can be mixed in a 1:1 ratio to take advantage of lidocaine's shorter onset and bupivacaine's longer duration of action.

Additives to local anesthetics

Other drugs can be added to local anesthetics to enhance or extend blockade, or to decrease the pain experienced on injection.

Opioids

Opioids, particularly preservative-free morphine, are commonly administered with local anesthetics for epidural or spinal analgesia. This produces additive or synergistic multimodal analgesic effects, with analgesia lasting up to 24 h, far longer than with individual drug therapy. Complications of adding opioids include respiratory depression, particularly if high doses or volumes are used, urinary retention, vomiting (in conscious dogs), and pruritus. Myoclonus, hindlimb paresis, altered proprioception, and hyperesthesia are rare complications.

Alpha-2 adrenoceptor agonists

Agonism of pre- and postsynaptic alpha-2 receptors in the pain pathway results in analgesia. Xylazine (0.25 mg/kg) and medetomidine (15 µg/kg) have been used epidurally in dogs, with medetomidine providing analgesia for up to 8 h. Side effects included bradycardia and hypertension. Dexmedetomidine produces analgesia in a dose-dependent manner when given intrathecally and epidurally in dogs.

Ketamine

Ketamine most likely produces its analgesic effects when administered epidurally by blocking NMDA channels. Ketamine also blocks some sodium and potassium channels, thus decreasing propagation of nociceptive signals. Effective doses are 1–3 mg/kg. Side effects include increased heart rate, blood pressure, and myocardial work.

Epinephrine (adrenaline)

Epinephrine can be added to local anesthetic at a concentration of 5 µg/mL. Deposition of the combination results in local vasoconstriction, which leads to decreased systemic uptake and prolongation of blockade. This delayed uptake also results in fewer systemic side effects due to decreased plasma concentration of local anesthetic. Epinephrine should not be used when performing a Bier block or a ring block, as nerve ischemia may occur.

Sodium bicarbonate

Addition of sodium bicarbonate at 1 mEq per 10 mL of local anesthetic increases the amount of active (non-ionized) drug present, increasing diffusion across the cell membranes of neurons. This may lead to a shorter onset and longer duration of blockade. Pain experienced on injection of local anesthetic in the conscious patient is also decreased by addition of sodium bicarbonate. Sodium bicarbonate should not be added to bupivacaine or ropivacaine as precipitation will occur.

Hyaluronidase

Hyaluronidase improves permeability of tissue by depolymerizing hyaluronic acid, resulting in better spread of local anesthetic. It can be added at 3.75 IU per mL of local anesthetic to enhance the quality of blockade. Due to the enhanced permeability, duration may be decreased and toxicity increased due to increased systemic absorption. Adding hyaluronidase to ropivacaine does not enhance spread.

Equipment

Syringes

Due to the variety of sizes of dogs, a variety of sizes of syringes ranging from 1 mL to 20 mL should be available. Glass syringes, or specially made low-resistance plastic syringes, are useful when performing epidural techniques to check for loss of resistance. A specific type of syringe, called an Episure™ syringe, has been evaluated in people as an alternative to glass syringes when performing epidural anesthesia. This syringe features a compression spring, which supplies a constant pressure when attached to a needle. The operator can advance the needle using both hands, rather than one hand, allowing for steadier needle advancement and a visual sign that the epidural space has been entered (Riley & Carvalho, 2007).

Needles

Hypodermic needles ranging from 25 Ga to 20 Ga and 2–5 cm are used to perform many local nerve blocks.

Epidural/spinal needles are used when performing epidural or spinal analgesia. These needles have a sharp bevel and incorporate a stylet to avoid depositing tissue cores within the epidural or spinal space. These needles are available in a range of gauges (18, 20, and 22 Ga) and lengths (3.8, 6.3, and 9.0 cm).

A modified spinal needle, or Tuohy needle, is slightly curved at the tip, which facilitates advancement of the catheter when placing it in

the epidural space. This type of needle is usually marked in increments of 1 cm along its length to assist with determining how far to insert the catheter. Tuohy needles are typically of larger gauge (16 and 18 Ga) than standard epidural needles in order to place the catheter more easily, although this may hinder placement in small patients.

Epidural catheter kits

Sterilized kits for placing epidural catheters are available commercially. They typically include a Tuohy needle, a loss of resistance syringe, a radiopaque catheter with guidewire, a connector, and an antibacterial filter. Some kits also include a sterile pen, which is used to mark on the catheter the distance it should be advanced through the Tuohy needle.

Nerve locators

Nerve locators are used to improve accuracy of local anesthetic deposition, decrease local anesthetic dose required, and limit side effects.

Peripheral nerve stimulators

Peripheral nerve stimulators (PNS) are used in conjunction with Teflon-coated needles, which have a small conductive area at the tip, to locate nerves using an electrical current (Figure 1.1). The Teflon coating ensures that only the tip of the needle transmits the electrical current so that a high current density is achieved. The reader is advised to refer to the instruction leaflet enclosed with the peripheral nerve stimulator.

Briefly, the positive lead (anode) is attached to the skin by means of a sticky electrode (ECG pad) and the negative lead (cathode) is connected to the needle. Anatomical landmarks are palpated and the needle is inserted through the skin. The needle is advanced until it is in close proximity to the nerve. The operator then turns the nerve stimulator on, setting a current of 1.0–2.0 mA, pulse frequency 1–2 Hz and

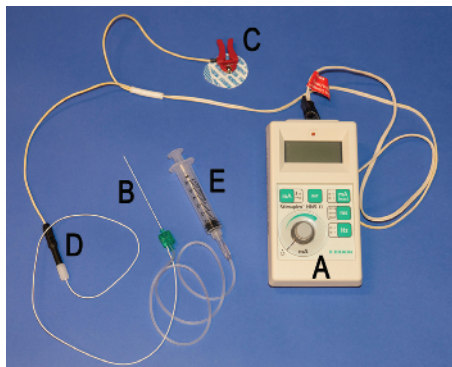


Figure 1.1 A, Peripheral nerve stimulator. B, Teflon-coated needle. C, Positive lead (anode) and sticky electrode (ECG pad). D, Negative lead (cathode). E, Syringe, injection port, and tubing. Reproduced with permission from The Ohio State University.

duration 0.1–0.3 msec. This generates an electrical field adjacent to the nerve, resulting in depolarization and muscle contraction, or twitches. The current required to elicit a twitch increases exponentially as the distance between the nerve and the needle increases. The current is reduced to the lowest possible setting required to elicit a twitch, and this is done whilst carefully redirecting the needle so that it is in close proximity to the nerve. The useful current is not a painful stimulus, and can be used in a sedated patient. Once the lowest possible current required to elicit a twitch has been determined, local anesthetic is injected through the needle via tubing. Injection of local anesthetic pushes the needle a little further away from the nerve, so twitches are usually diminished or lost immediately after injection.

Ultrasound

Ultrasound probes can be used to visualize nerves directly both prior to and during needle placement and anesthetic drug deposition, which allows for improved accuracy of blockade. This technique is often combined with a nerve stimulator to confirm nerve location, allowing drug deposition close to, but not into, the nerve.

Differential pressure transducer

The likelihood of injury to nerves during local anesthetic injection is increased when injections are performed under high pressure. The use of an in-line pressure transducer allows consistent force to be applied during injection.

Acoustic device

Identification of needle entry into, or puncture of, the epidural space can be difficult using the conventional loss of resistance technique. Acoustic amplification has been used to detect puncture more accurately. An in-line pressure transducer is attached to a pressure amplifier, which in turn is attached to a loudspeaker. The sound of the needle passing from low resistance surrounding tissues to the high resistance of the ligamentum flavum can be appreciated audibly (Lechner et al, 2002).

Complications and contraindications

In general safe practice, knowing when a local anesthetic technique is contraindicated is essential, as is an understanding of the complications of local anesthetic administration and how to treat them.

Complications can be broadly categorized as local or systemic problems.

Local

Skin

Local analgesic techniques should not be attempted where the skin overlying the site of injection is inflamed, infected, or clearly neoplastic as this may promote transmission and spread of infectious organisms or neoplastic cells into adjacent tissue.

Nerve

Direct trauma to nerves from the needle or high-pressure injection may result in loss of sensation, pain, discomfort and/or motor weakness that may be temporary, lasting days to years, or permanent. Damage to blood vessels close to nerves, particularly those with poor blood supply, may lead to ischemia. Finally, local anesthetic drugs or additives may be directly toxic to nervous tissue.

Systemic

Central nervous system

Excessive systemic uptake of local anesthetic can cause seizures. This occurs because inhibitory neurons are more sensitive to Na⁺ channel blockade, and if they are blocked then excitation results.

Cardiovascular

Local anesthetic techniques should be performed with caution or avoided in patients that are hypotensive or in shock, as inadvertent drug administration into a vein or unexpected rapid systemic drug absorption may lead to cardiovascular collapse.

Coagulopathy

Techniques in which hemorrhage is a possible complication, e.g. epidural block, should not be performed in patients where coagulopathy has been demonstrated or is suspected. Laceration of a blood vessel may lead to bleeding that will be hard to control. If uncontrolled hemorrhage occurs in a closed space, it may lead to pressure necrosis of adjacent tissues.

Species differences and considerations

As a species, cats are generally less amenable to being restrained for procedures unless they are heavily sedated or anesthetized, compared to dogs in which some techniques can be performed with light sedation. It can also be more challenging to accurately weigh cats, which may lead to inadvertent under- or overdosage. Regardless of species,

accurate dosing will lead to fewer complications. Inhalant anesthesia with isoflurane or sevoflurane decreases metabolism of lidocaine after 2 mg/kg intravenous administration in cats, even at relatively low inhalant doses, whereas this is not the case in dogs (Thomasy et al, 2005). Rapid inadvertent intravenous injection of lidocaine, while not ideal in any species, may be more problematic in cats.

Safe practice

Gaining confidence

Local anesthetic techniques vary in their level of difficulty to perform, effectiveness of block, and complexity of equipment required. Starting by using straightforward techniques that require little in the way of extra equipment, and have been reported to have high success rates, is recommended. Once comfortable with simple techniques, the practitioner can expand his or her repertoire. Attending continuing education seminars and courses on local anesthetic techniques, particularly when a wet lab is a component of the training, is recommended. We also believe that using this book will be an asset when it comes to performing techniques where the practitioner has little or no experience.

Making a plan

Regardless of technique, successfully performing local anesthetic blocks requires preparation of the appropriate equipment, and a thorough understanding of patient anatomy and local anesthetic drug pharmacology. It is also important that the clinician performing the local anesthetic block has an appreciation of the potential complications that might occur and is able to develop a plan to treat them (see Chapter 7). The person performing the block should also have in mind an alternative plan for providing analgesia should the block prove impossible to perform, or in cases where continuing with the block is contraindicated (e.g. severe drop in blood pressure during epidural administration, skin infection over injection site becomes apparent after clipping).

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