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Locoregional anaesthesia and analgesia in small animals: a review of basic principles and techniques

Paikallispuudutuksen perusteet pieneläimillä

SUMMARY

Locoregional anaesthesia and analgesia are an important part of pain management in small animals. The use of local anaesthetics is cost effective and techniques are easy to learn. Locoregional blockade prevents neuronal transmission from a certain area of the body, including conduction of nociceptive information, to the central nervous system, and is reversible. The local anaesthetics work by blocking sodium ion channels on neuronal cell membrane and thus blocking impulse transmission via nerve fibres to central nervous system. Thus, local anaesthetics may alleviate pain more effectively than other anaesthetic method. The agents most commonly used in small animal practice are lidocaine and bupivacaine. A particular hazard of local anaesthetics is the potential toxicity due to overdose or accidental intravenous injection, bupivacaine being the most toxic agent in use. The toxicity of local anaesthetics is important to consider particularly when these agents are used in small animals, and thus greater attention to dosing and preventing intravascular injections are required. Common techniques used in small animals are blockade for dental and ophthalmic procedures and procedures on the extremities. Commonly performed blocks include the blockade of infraorbital, retrobulbar, inferior alveolar, epidural, sciatic and femoral nerves, and radial, ulnar, median and musculocutaneous nerves. Basic principles and techniques are relatively easy and help increase patient comfort. A good understanding of the mechanisms of action, safety and techniques maximizes rgw success of locoregional anaesthesia.

YHTEENVETO

Paikallispuudutus on tärkeä osa nykypäivän kivunhoitoa pieneläimillä. Paikallispuudutteiden käytöllä on hyvä hinta-hyötysuhde ja tekniikat on suhteellisen helppo oppia. Paikallispuudutus ehkäisee hermoimpulssin, mukaan lukien kipuinformaation, kulun tietystä kehon osasta keskushermostoon, ja sen vaikutus on palautuva. Paikallispuudutteet vaikuttavat hermosolun solukalvon natriumkanaviin pysäyttäen hermoimpulssin kulun hermosoluja pitkin kohti keskushermostoa. Näin paikallispuudutteet saattavat poistaa kivun paremmin kuin muut kivunhoitomenetelmät. Pieneläinpraktiikassa yleisimmin käytetyt paikallispuudutteet ovat lidokaiini ja bupivakaiini. Erityinen haitta paikallispuudutusten käytössä on mahdollinen akuutti myrkyllisyys yliannostuksen tai vahingossa suonensisäisesti annostellun pistoksen yhteydessä. Bupivakaiini on käytössä olevista puudutteista myrkyllisin. Myrkyllisyys on otettava huomioon erityisesti hoidettaessa pienikokoisia eläimiä, joilla yliannostuksen vaara on suuri. Paikallispuudutusta käytetään pieneläimillä usein muun muassa hammas- ja silmätoimenpiteissä ja toimenpiteissä raajojen alueella. Yleisimmin käytettyjä hermopuudutuksia ovat infraorbitaali-, retrobulbaari-, alveolaari-, epiduraali-, iskias-, ja femoraalis-, sekä radiaalis-, ulnaaris-, mediaani- ja muskulokutaaninen hermopuudutus. Paikallispuudutuksen perustekniikat on suhteellisen helppo omaksua ja ne auttavat potilaiden kivunhallinnassa. Vaikutusmekanismien, turvallisuuden, ja tekniikoiden tuntemus maksimoi puudutusten onnistumisen.

INTRODUCTION

Providing pain relief for patients is increasingly important in veterinary medicine. Locoregional anaesthesia and analgesia are an important part of pain management in small animals before, during and after surgery.

Local anaesthetic (LA) agents are used to induce neural blockade and thereby locoregional anaesthesia and analgesia. The blockade prevents neuronal transmission from a certain area of

the body, including conduction of nociceptive information, to the central nervous system, and is reversible. Thus, LA may alleviate pain more effectively than any other anaesthetic method.[1] Local anaesthetic agents may be used alone or in conjunction with sedation for minor surgical procedures, or to supplement general anaesthesia as part of the balanced anaesthesia and multimodal analgesia.[2,3] Studies in people and animals suggest that the use of regional anaesthesia avoids central sensitization and chronic pain, and reduces the amount of systemic analgesic and anaesthetic required during the perioperative period.[1, 4-7] In addition, recovery from anaesthesia is faster when locoregional techniques are used compared with the systemic administration of opioid analgesics that may cause additional sedation and delay the emergence phase.[8]

We review the basic principles of locoregional anaesthesia and analgesia in small animals and highlight some commonly used locoregional techniques.

LOCAL ANAESTHETICS AGENTS

LAs act by blocking neuronal impulse transmission via nerve fibres to central nervous system, by blocking sodium ion (Na+) channels on neuronal cell membrane.[9] Local anaesthetics are weak bases and exist predominantly in the ionised form at physiological pH, as their pKa exceeds 7.4. The unionised lipid-soluble form passes through the phospholipid membrane where, in the axoplasm, it is protonated. In ionised form it binds to the internal surface of a Na+ channel, preventing it from leaving the inactive state. The degree of blockade in vitro is proportional to the rate of stimulation due to the attraction of local anaesthetic to 'open' Na+ channels. Alternatively, 'membrane expansion' may offer an additional mechanism of action: the unionised drug dissolves into the phospholipid membrane and may cause swelling of the Na+ channel or adjacent lipoprotein matrix, resulting in its inactivation.[10] Some other sites of action may be involved including potassium and calcium ion channels.[9] All types of nerve fibres are affected, including myelinated intermediate diameter nociceptive fibres Ad (responsible of sharp pain) and un-myelinated small C fibres (responsible of dull, aching pain), but also large myelinated motor motor fibres Aa, Ab, Ab and small myelinated autonomic B fibres are affected. Small un-myelinated C fibres may be more resistant to LA blockade and appear to be blocked after larger sensory Ad and motor Aa, Ab, Ag fibres.[11] On the other hand, small un-myelinated fibres require less LA to produce a blockade, as the length of fibre needed in order to prevent nerve impulse from propagating is shorter than in myelinated nerves where the impulse can jump 2–3 Ranvier nodes. Thus larger volume (e.g. length) of LA is required to prevent impulse in 3 consecutive Ranvier nodes. Thus it is possible to create a selective sensory blockade, as clinically Ad and C fibres appear to be blocked faster than larger motor fibres.[12]

Local anaesthetic agents commonly used in veterinary medicine are divided into two subclasses based on the linkage between the aromatic lipophilic group and the hydrophilic amine group: amino-esters (for example procaine, tetracaine) and amino-amides (lidocaine and bupivacaine). Amides have an '*i*' in the prefix (l*i*docaine, bup*i*va-caine), are rarely implicated to cause allergic reactions and are metabolized via hepatic biotransformation. Esters are common allergens, especially procaine, as they produce para-aaminobenzoic acid (PABA), when they are hydrolysed by plasmatic cholinesterase enzyme.[9]

Today, most commonly used local anaesthetic agents in small animal medicine are lidocaine and bupivacaine. Their individual structures confer different physicochemical and clinical characteristics to these agents. As LAs are weak bases, they exist in two forms ionised (BH+) and unionised (B). The pKa of LAs determines the pH at which both forms exist in equal amounts. As the pH of tissues differs from the pKa of specific drugs, more of the drug exists in either the ionised or unionised form. This is expressed by the Henderson-Hasselbalch equation: pKa – pH = log [BH+] / [B], where [B] is the concentration of unionised and [BH+] the concentration of ionised drug. Bupivacaine, with a higher pKa of 8.1, has a greater fraction present in the ionised form at physiologic pH, which is unable to penetrate the phospholipid membrane. The result is a slower onset of action than that of lidocaine, which has a lower pKa of 7.7, allowing a higher fraction of molecules to be present in the unionised form

MAIN POINTS:

- Locoregional blockade reversibly prevents neuronal transmission, including conduction of nociceptive information, from a certain area of the body to the central nervous system.
- Local anaesthetics may alleviate pain more effectively than any other anaesthetic method.
- Local anaesthetic toxicity is a particular risk for small patients, requiring attention to dosing and preventing intravascular injections.
- Principles and techniques of local anaesthesia are relatively easy.

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FIGURE 1 KUVA

Dorsal approach of a retrobulbar block visualised on a canine skeleton. The needle tip is placed dorsally and the needle advanced ventro-medially. See text for details. Picture courtesy of Dr. Patrick Burns.

Retrobulbaaripuudutus dorsaalisella lähestymistavalla esitettynä koiran pääkallon avulla. Neulan kärki sijoitetaan dorsaalisesti ja puudutettavaa hermoa lähestytään ventromediaalisesti. Katso tarkempi selitys tekstissä. Kuva: eläinlääkäri Patrick Burns.

and thus a faster onset of action, as more is available to cross the phospholipid membrane.[11, 12] Higher concentration gradient will also increase the efficacy of the neuronal blockade, decrease the onset of action and prolong the duration of action. Injection of LA close to the nerve decreases drastically the action and decreases the dose requirements. The degree of vascularisation is inversely proportional to the duration of block and also to the risk of toxicity by systemic absorption. Adrenaline is sometimes used to prolong the duration of action by producing local vasoconstriction, thus limiting the systemic absorption and elimination of the LA. However, these additives should be avoided in peripheral blocks to avoid necrosis of peripheral tissues. Other additives such as alkalinising agents (for instance sodium bicarbonate) are used to increase the amount of LA existing in the unionised, lipid-soluble form available to diffuse across lipid cell membranes thus speeding the onset of action of LA agents.[9]

LOCAL ANAESTHETIC TOXICITY

A particular hazard of LAs is the potential to produce toxicity due to overdose or accidental intravenous (IV) injection of LA agent. Central nervous system toxicity effects generally precede cardiac effects; however, many neurotoxic signs may go unnoticed especially in sedated or anaesthetised animals. These effects include tingling of the lips, dizziness, visual disorders, muscle twitches, seizures and loss of consciousness, coma, and cardiorespiratory arrest. Sodium channel blockers are considered as Class-1B anti-arrhythmics (for instance lidocaine) as they also affect the myocardial Na^+ channels. Consequently, they decrease electric excitability and contractility and decrease conduction via sinoatrial and atrioventricular nodes. Overdose or accidental IV injection of LA agent may cause severe cardiac effects leading up to cardiac arrest. Doses required to produce toxicity are specific to the animal species and the LA agent. To avoid toxicity, it is necessary to aspirate before each injection to verify that the needle is not in a blood vessel. Bupivacaine has a lower margin of safety compared to lidocaine, and thus the recommended maximal doses in dogs are lidocaine at 6–8 mg/kg and bupivacaine at 4 mg/kg.[11] Maximum doses are smaller for cats: lidocaine at 6 mg/kg and bupivacaine at 2 mg/kg.[11] Despite the reasonable safety profile of bupivacaine, it is suggested that it be replaced by levobupivacaine and ropivacaine, as their cardiac and central nervous system safety profile is superior and they may produce less unwanted motor blockade.[9] However, cost and available agents and formulations may prevent this replacement in veterinary practice.

Lipid rescue by IV infusion of lipid emulsion has been advocated to the treatment of LA toxicity in humans and in animals. It has been demonstrated to be successful in dogs after cardiac toxicity caused by bupivacaine.[13] Lipid rescue and the existing theories behind the mode of action has been reviewed recently in veterinary literature.[14] The prevailing theory behind administration of lipid emulsion is by creating lipid sink within plasma. This lipid phase sets up a gradient that pulls the offending lipid-soluble drug into the lipid partition in the blood, away from the heart and brain. Dosing recommendations are lacking the support of clinical research. However recommended dosing can be found in the literature.[14] An initial bolus of 1.5 ml/kg of 20% lipid emulsion followed by a constant rate infusion ranging

FIGURE 2 KUVA

A) Infraorbital block visualised on a canine skull.
B) Infraorbital block visualised on a dog cadaver.
See text for details. Picture courtesy of Dr. Robert Menzies.

A) Infraorbitaalipuudutus esitettynä koiran pääkallon avulla.
B) Infraorbitaalipuudutus esitettynä lopetetulla koiralla.
Tarkempi selitys tekstissä. Kuva: Robert Menzies.

from 0.25–0.5 ml/kg/min (not to exceed 10 ml/kg) over 30 minutes.

Other potential complications from LA injection include injection site infection, bleeding and direct nerve damage following intraneural injection. In addition, there is a potential for direct cell toxicity (neuro-, myo- and chondrotoxicity).

APPROACHES FOR PERIPHERAL NERVE BLOCKADE

By definition, local anaesthesia implies temporary loss of sensation on a definite part of the body without loss of consciousness. Regional anaesthesia implies loss of sensation in a part of the body by interruption of sensitive innervations conducting the nervous influx into that region of the body. Infiltration anaesthesia means that the surgical site is desensitised by injecting LA around it. Peripheral nerve block (PNB) means that LA is injected close to a nerve, the conduction of which one wishes to block.

The blind technique to perform peripheral nerve blocks only requires the use of the anatomical landmarks that can be used to lead the tip of the needle close to the neural tissues. It is a simple method, in which the skills of the veterinarian and the volume and concentration of the anaesthetic solution influence the outcome of the block. It is mostly used to perform PNB of pure sensory nerves (for instance the cranial nerves of the head).

To improve the success of the blind technique electrolocation of the nerves may be used. Peripheral nerves are generally mixed nerves composed of sensory, motor and autonomic fibres. When an electrical current with an appropriate intensity (mA) and duration (ms) reaches a nerve, it will induce axon membrane depolarization, and if the nerve contains motor fibres, it will induce the contractions of the effector muscle. Since the needle is placed close to the nerves, smaller volume of LA can be used per injection site than with blind techniques. This produces a better success rate as the precision of the injection is augmented and the risk of side effects is diminished. As the delivery of the electrical current may be unpleasant, electrolocation techniques are performed in sedated or anaesthetized animals.[15] More about electrolocation can be found elsewhere.[16-18]

Ultrasound guidance can also be used to obtain a real-time image of the position of a nerve trunk, the advancement of the needle for injection and of the LA distribution around the target nerve. Ultrasound provides an objective tool for determining how close nerve trunk the LA is administered. Its use decreases the risk of an intraneural injection and an accidental vascular puncture.[15] More on ultrasound-guided blockade can be found elsewhere.[19, 20]

SPECIFIC LOCOREGIONAL TECHNIQUES

Head

Sensory nerve blocks of the head are often used for ocular surgeries and dental procedures. Several blocks are described in literature-

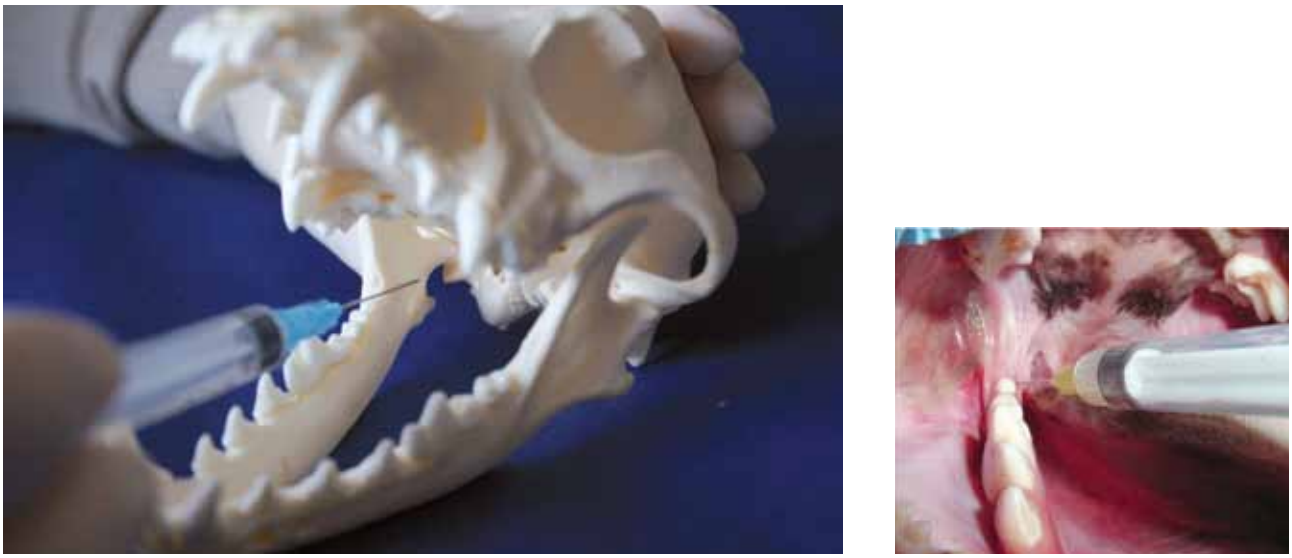

FIGURE 3 KUVA

A) Inferior alveolar block (intraoral approach) visualised on a canine skull.
B) Inferior alveolar block (intraoral approach) visualised on a canine cadaver.
See text for details. Picture courtesy of Dr. Robert Menzies.

A) Alaleuan alveolaari-puudutus suun sisäinen lähestymistapa esitettynä koiran pääkallon avulla.
B) Alaleuan alveolaari-puudutus suun sisäinen lähestymistapa esitettynä lopetetulla koiralla.
Tarkempi selitys tekstissä. Kuva: Robert Menzies.

each of them can be performed by several different approaches. Here we present retrobulbar block (dorsal approach), infraorbital block (intraoral approach) and inferior alveolar or mandibular block (intraoral approach). As the nerves are essentially sensory in composition, a blind approach technique based on anatomical landmarks is generally employed.

Retrobulbar block (figure 1) will desensitise the cranial nerves II–V and VII behind the eye globe. Since the technique carries the risk of optic nerve or eyeball puncture, it is usually reserved for enucleation. The dorsal approach is potentially less dangerous than more caudally directed approaches for retrobulbar block, as there is less risk of getting the local anaesthetic inside the optic foramen posterior to the eye and through the meninges, which would have dramatic consequences. In the dorsal approach, the block is performed by palpating the depression just behind the orbital ligament and advancing the needle ventromedially. Once the needle tip pushes on the conus ocularis, the globe will turn slightly dorsally. Once the needle tip punctures the conus, the globe will return ventrally. The movement of the globe will help to identify proper anatomical positioning. As with all local blocks, aspirating for blood before injection is mandatory to avoid intravascular injection. An appropriate volume (approximately 0.5 ml/10 kg of LA) is injected slowly without resistance to avoid direct nerve damage. There is a potential risk to induce oculocardiac reflex while performing this block, but however, once the block is effective it will decrease the risk of this reflex from ocular manipulation during the surgical procedure of the eye.

The infraorbital block (figure 2) will desensitise the infraorbital nerve, which is part of the maxillary branch of the trigeminal nerve (V). This will desensitise maxillary tissues rostral to the injection site on that hemi-maxilla. This nerve is blocked by first palpating the infraorbital foramen below the eye, in dogs approximately at the level of the third premolar tooth, then the lip is pushed up and the needle tip inserted through the buccal mucosa into the foramen and advanced caudally. Depending on the level of blockade required, the needle may be advanced further into the foramen more caudally.

The inferior alveolar block (figure 3) will desensitise the mandibular branch of the trigeminal nerve (V). It will desensitise mandibular tissues rostral to the injection site on that hemi-mandibula. This nerve is blocked via intraoral approach by opening the mouth and first palpating the mandibular foramen through the buccal mucosa, then inserting the needle at the opening of this foramen. If the foramen cannot be palpated,

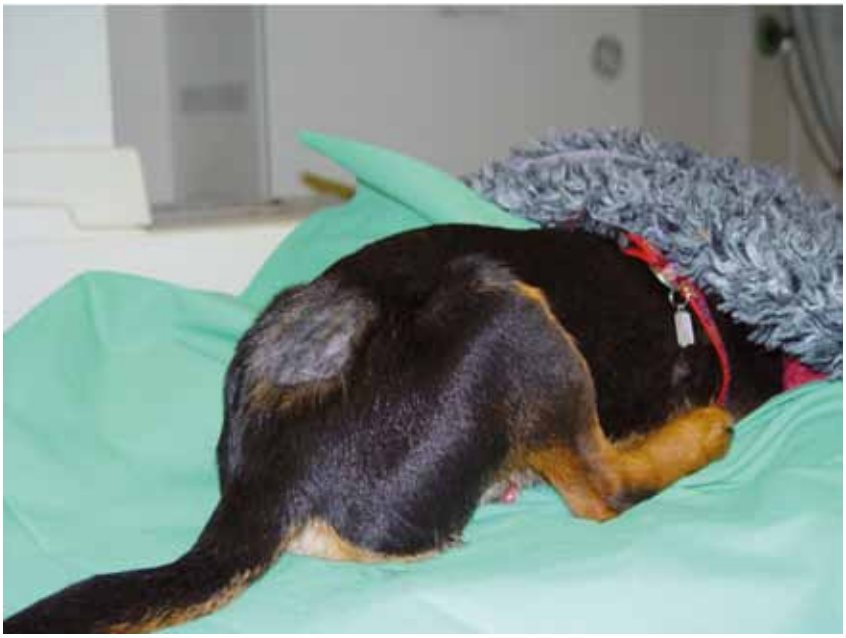

FIGURE 4A KUVA

Epidural regional anaesthesia sternal positioning in a dog. See text for details. Picture courtesy of Dr. Paula Larenza Menzies.

Epiduraalipuudutus sternaali-asennossa koiralla. Tarkempi selitys tekstissä. Kuva: eläinlääkäri Paula Larenza Menzies.

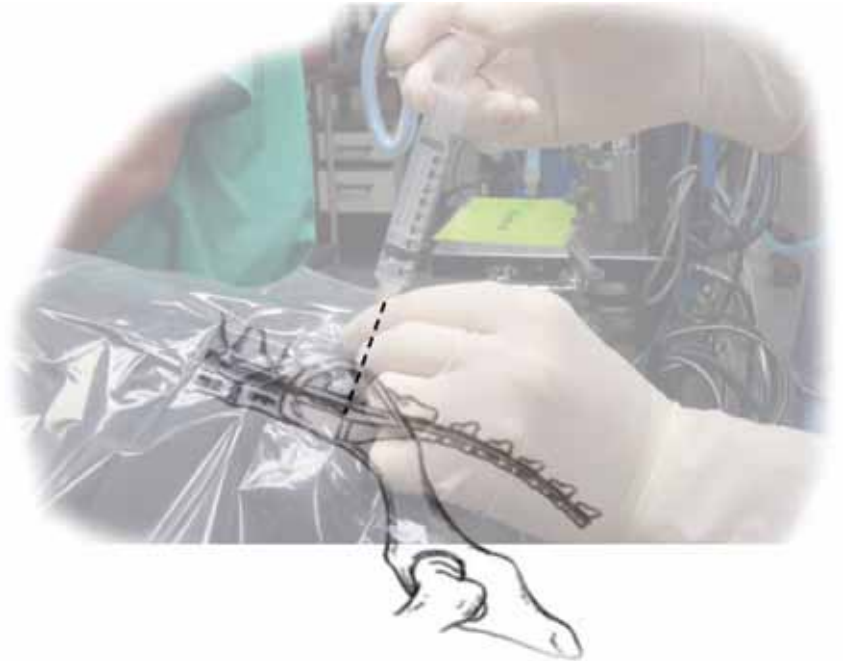

FIGURE 4B KUVA

Anatomical landmarks to perform an epidural injection in dogs. See text for details. Picture courtesy of Dr. Paula Larenza Menzies.

Epiduraalipuudutus koiralla. Tarkempi selitys tekstissä. Kuva: Paula Larenza Menzies.

an anatomical landmark may be used for guidance. The foramen is on the medial aspect of the mandible, approximately 2/3 and 1/2 distances between the last molar tooth and the angular process of the mandible in dogs and cats, respectively. The needle is inserted from the medial aspect of the mandible, keeping the needle tip close to the bone, up to the measured distance. The doses should be based on the calculated maximum total volume for all performed blocks combined to avoid systemic toxicity, but usually 0.25 ml/10 kg volumes are adequate for performing these blocks.

Thoracic limb

The blockade of the radial, ulnar, median and musculocutaneous nerves (*RUMM* block) is relatively easy to perform with blind approach.[11] This block may be used for surgery performed distal to the elbow joint. The radial nerve is blocked from the lateral aspect of the limb. It can sometimes be palpated proximal to the lateral humeral epicondyle, between the lateral head of triceps and brachialis muscles. The needle is directed proximally between these muscles.

From the medial aspect, the needle is inserted close to the medial humeral epicondyle and advanced proximally between the biceps brachialis and the medial head of the triceps to block the ulnar, median, and musculocutaneous nerves. Since the brachial artery and vein are close to these nerves, care should be taken to avoid intravascular injection.[11]

Hind limb

Epidural anaesthesia and analgesia are often used to manage pain associated with procedures and injuries of the hind limb. Lumbosacral epidural administration of LA produces a segmental blockade of the lumbar and sacral nerve roots.

How far cranially the epidural LA will spread, depends on the volume of the injection. The injected volume must be calculated using the lean body weight of each patient. A small volume (0.1 ml/kg) is usually appropriate for caudal and hind limb procedures while larger volumes (0.2 ml/kg, but maximum of 6 mL total volume)[16] will extent the blockade up to the umbilical area. Morphine is often added to the LA to produce long lasting post-operative neuraxial analgesia. Contraindications for performing epidural anaesthesia include skin infection at the site of needle insertion, septicaemia, uncorrected hypovolaemia and hypotension, and known coagulopathies.[11] Pelvic fractures and anatomical malformations may also prevent the use of epidural anaesthesia. Potential side effects of epidural are hypotension due to sympathetic blockade induced vasodilation, and bradycardia that may occur already during epidural injection if this is performed too rapidly.

Positioning of the patient in sternal recumbency with hind limbs extended forward will help in identification and opening of the lumbosacral (LS) space (figure 4a). This space is just caudal to the wings of ilia, which are palpated first. The last lumbar processus spinosus (L7) are palpated cranially and sacrum caudally to the L-S space. After aseptic preparation of the site, an appropriate size spinal needle is placed in the centre of the depression perpendicular to the plane of the pelvis and advanced slowly towards the epidural space (figure 4b). A strict sterile technique must be used. The stylet of the spinal needle is removed and sterile saline hanging drop may be used to verify correct needle placement. An increase of resistance is felt, followed by an abrupt loss of resistance (a pop), when the epidural space is reached. The hanging drop may be sucked inside the space.

FIGURE 5A KUVA

Sciatic nerve block in a dog. See text for details. Picture courtesy of Dr. Diego A. Portela.

Iskiashermopuudutus koiralla. Tarkempi selitys tekstissä. Kuva: eläinlääkäri Diego A. Portela.

The correct placement can be verified also by the absence of resistance to injection of sterile saline. After aspirating to ensure non-vascular injection, preservative-free LA agent may then be injected slowly into the epidural space. The addition of 1–2 ml of air into the LA syringe will aid in recognising a collapse of this air bubble in the syringe. This indicates increased resistance to injection and that the needle tip may have moved away from the epidural space.[11]

As an alternative to the epidural

FIGURE 5B KUVA

Femoral nerve block in a dog. See text for details. Picture courtesy of Dr. Diego A. Portela.

Femoraalis-hermopuudutus koiralla. Tarkempi selitys tekstissä. Kuva: Diego A. Portela.

block, both the sciatic nerve and the femoral nerve can be blocked for surgeries involving the tissues distal to the knee joint. [16] The sciatic nerve can be blocked utilizing a blind-technique which involves introducing the needle in the depression formed by the sciatic tuberosity and the greater trochanter of the femur and injecting 0.3–0.5 ml/kg of local anesthetic (figure 5a).[18] If electrolocation is used, contraction of the biceps femoris muscle is observed during advancement of the needle. Two muscular responses may be elicited based on which component of the sciatic nerve is being stimulated: a) flexion of the tarsus joint and/or digital extension (peroneal nerve component); or b) the extension of the tarsus joint and/or the digital flexion (tibial nerve component). The block of the sciatic nerve at this level determines the anesthesia of the caudolateral portion of the thigh, including the caudal part of the articular capsule and intra-articular structures of the knee, tibia, tarsus, metatarsus and digits (except the first digit and the dorsal part of the second digit). The femoral nerve can be easily blocked in the inguinal region. [17] The needle should be introduced at the level of the medial and proximal aspect of the thigh (figure 5b). Pulsations of the femoral artery can be used as a landmark to perform the block. The insulated needle, connected to the nerve stimulator, can be introduced cranially to the artery until twitches from the femoral head of the quadriceps muscle are elicited (extension of the knee joint). A volume of 0.1 to 0.2 ml/kg of LA should be administered after checking the extravascular position of the needle by negative blood aspiration test and the lack of quadriceps muscular response at 0.2 mA. The block desensitizes the region innervated by the femoral nerve distal to the distal third of the femur.

A multitude of other techniques are found in the literature.[11, 12] Training to perform loco-regional anaesthetic techniques will greatly improve the success rate of the blocks and thus promote the comfort of patients.

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