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Development of Enhanced Recovery After Surgery (ERAS) protocols in veterinary medicine through a one-health approach: the role of anesthesia and locoregional techniques

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ABSTRACT
Enhanced Recovery After Surgery (ERAS) is a new and emerging concept in human medicine that involves rethinking the preoperative, intraoperative, and postoperative periods. The ultimate, overarching aim is to improve patient outcome following surgery and, thus, return to a normal daily routine as soon as possible. The development and implementation of locoregional anesthetic techniques in humans is one of the key elements driving these protocols. In veterinary medicine, we are no exception: the rapidly growing interest, development, and refinement of these techniques in our veterinary species is changing the way we think of anesthesia and analgesia. The potential real benefits are yet to be determined, as this concept is implemented into our veterinary hospitals in general, and our surgical patients in particular, in a more systematic and routine way. In this article, we will introduce the reader to the concept of ERAS protocols and the role of regional anesthesia in some common surgical procedures.

A new emerging concept in human medicine is starting to spark interest within our veterinary specialty hospitals. Enhanced Recovery After Surgery (ERAS), also known as a fast-track or enhanced-recovery pathway, is a new approach that involves rethinking the preoperative, intraoperative, and postoperative periods. The ultimate, overarching aim is to improve patient outcome following surgery and thus, return to normal daily routine as soon as possible. In the human arena, the ERAS Society, has shown that hospital stay and complications can be reduced for a number of different surgical procedures such as total hip or total knee replacement as examples.[1]

Recent development and routine implementation of locoregional anesthetic techniques in the human field is allowing the rethinking of surgery, perioperative pain management, anesthesia, hospital flow, operating room throughput, and overall patient care. The superior perioperative pain management that locoregional anesthesia has to offer has become one of the key elements contributing to the implementation of ERAS. The potential real benefits are yet to be determined, as this concept is adopted in our veterinary hospitals in a more systematic and routine way. Some of these benefits may include the migration of complex surgical procedures requiring extensive use of opioid based analgesia into ambulatory, day procedures, decreased opioid consumption, or simply shorter hospital stays in which patients may be discharged to the care of their owners on oral medications and with a reasonable vital function. This, in turn, may lead to an overall decrease in cost.

Procedure, patient, and client considerations in veterinary medicine

Careful surgical procedure, patient, and client selection consideration are important elements of this equation. Many orthopedic surgical procedures as well as some soft tissue have the potential to be the subject of ERAS. To increase efficiency and decrease the number of unanticipated procedure cancellations with subsequent rescheduling and disruption of flow, it is important to develop a plan that is able to flag patients with comorbidities and perhaps optimize their condition prior to the day of the procedure. Patients with poorly stabilized comorbidities may not be suitable for ERAS protocols; however, there are many medical conditions that can be optimized and improved from the time of the first visit to the time at which the surgical procedure is scheduled. Diet changes, optimized cardiovascular medication, diabetes control, or respiratory disease may be some of the examples that fall into this category.

The importance of clarity and setting up realistic expectations regarding communication with the client cannot be emphasized enough. The initial conversation following establishing a diagnosis and the need for a surgical resolution should include topics such as the anesthesia, identification of potential complications, possible postoperative residual deficits from any anticipated locoregional techniques, as well as the recovery period. These topics are important and will probably decrease the number of unnecessary hospital calls and client stress. It is during this conversation that needs to be emphasized that "home readiness" is not equivalent to "street fit" when talking about discharge criteria.

Anesthesia and ERAS

In preparation for general anesthesia, fasting time should be optimized with the goal of minimizing stomach content volume and optimize gastric content pH, thus decreasing the incidence and severity of potential esophagitis from silent regurgitations or the severity and risk of aspiration pneumonitis. Savvas et al[2,3] suggested that, in the dog, a light meal 3 hours prior to premedication would decrease stomach content pH the least. In our institution, a 6-hour fasting time is still recommended. We prescribe antiemetics and medication such as proton pump inhibitors (eg, omeprazole) to be administered prior to admission the day of the procedure. Allowing patients access to water until the time of premedication will ensure optimal patient hydration and avoid unnecessary delays or intraoperative hydration status corrections. Among the drugs commonly used in anesthesia, short-acting drugs with minimal residual effects are preferred (eg, propofol and sevoflurane).[4] Locoregional anesthesia in conjunction with a light plane of hypnosis is becoming the preferred method of providing general anesthesia in small animals, allowing for a significant decrease in opioid requirements or even opioid-free anesthesia.[5,6] Undesirable opioid associated side effects in our small animal species may include sedation,[7] ventilatory depression,[8,9] emergence dysphoria,[10] nausea and/or inappetence.[11]

The recovery process should include opioid-sparing drugs, such as nonsteroidal anti-inflammatory drugs, acetaminophen (paracetamol), and gabapentinoids (eg, gabapentin and pregabalin), unless there are known contraindications to their administration. Antiemetics such as maropitant as well as proton pump inhibitors such as omeprazole or pantoprazole may also be prescribed to minimize the effects of fasting and thus encourage early return to eating. Opioids may be used sparingly as "rescue" medication on an as-needed basis rather than on a scheduled basis.

The role of locoregional anesthesia in ERAS protocols

Locoregional analgesia in the dog (peripheral nerve blocks and neuraxial anesthesia) is associated with early mobilization and return to normal behavior, potentially, leading to decreased hospital stays and early discharge.[6] Opioid-sparing analgesic techniques may also be indicated in obese patients with high body condition scores. Opioid ventilatory depression can be aggravated and enhanced by obesity and may lead to potential severe respiratory depression and subsequent hypercapnia and hypoxia during the recovery period potentially delaying discharge.

Advancements in ultrasound technology have represented a breakthrough in the field of regional anesthesia with development of new techniques and refinement of existing ones.[12–15] Ultrasound-guided peripheral nerve blocks are unique since the target nerve or structure can be visualized and the needle trajectory can be tracked and controlled in real time, thus reducing the risk of trauma to sensitive surrounding anatomy, including the nerves, vessels, and other anatomic structures such as pleura.[16] Traditional locoregional techniques such as epidural anesthesia are being revisited in small animals and substituted for more selective locoregional techniques in many surgical procedures.[17] The incidence of associated observed side effects with neuraxial techniques such as intraoperative hypotension, postoperative residual motor paralysis, or urinary retention is significantly decreased in the dog,[18] making peripheral nerve blocks preferred. More recently, ultrasound-guided fascial plane blocks (injection of local anesthetic within a selected fascial plane to target nerves that run through that plane) are gaining popularity,[19–23] and a number of injection techniques are being described and successfully adapted from human anesthesia to be used in the dog.[24–27]

Currently, there are no standards in veterinary anesthesia regarding ERAS protocols and locoregional anesthesia for individual surgical procedures; however, there is enough published literature and clinical information to make some informed recommendations. The use of long-acting local anesthetics such as bupivacaine or ropivacaine with the possible addition of coadjuvants such as dexmedetomidine is recommended since their prolonged analgesic effect will be carried over into the early postoperative period.[18] However, this more conventional approach does not appear to provide more than 24 hours in the dog.[18] Recently, the use of bupivacaine liposome suspensions is receiving some attention. This formulation is claimed to offer up to 72 hours in duration of action,[28] which makes it especially interesting in this setting. So far, it has been successfully used in dogs undergoing tibial plateau leveling osteotomy (TPLO) as part of a nonspecific periarticular soft tissue infiltration.[29,30] Their use has also been reported in the cat as part of soft tissue infiltrations.[31] Additionally, its use has been described in the dog and as part of a peripheral nerve block[32] as well as part of fascial plane blocks in other surgical procedures such as laparatomies among others.

Pelvic limb surgery

Saphenous nerve block—Its use has been described in surgical procedures such TPLO, tibial tuberosity advancement, extracapsular lateral suture stabilization, and meniscectomies, among other orthopedic procedures involving the canine stifle (all in combination with a sciatic nerve block).[6,7] The main benefit of this block is that it does not cause motor paralysis of the quadriceps group; therefore, it is preferred to epidural anesthesia and even a femoral nerve block since it allows for the patient to remain ambulatory. When combined with a sciatic nerve block, complete anesthesia of almost the entire stifle joint can be achieved. In this instance, sciatic deficits will be observed in the blocked limb[32] and was first described by Costa-Farre et al[33] in 2011. The technique **(Figure 1)** is well described previously.[34]

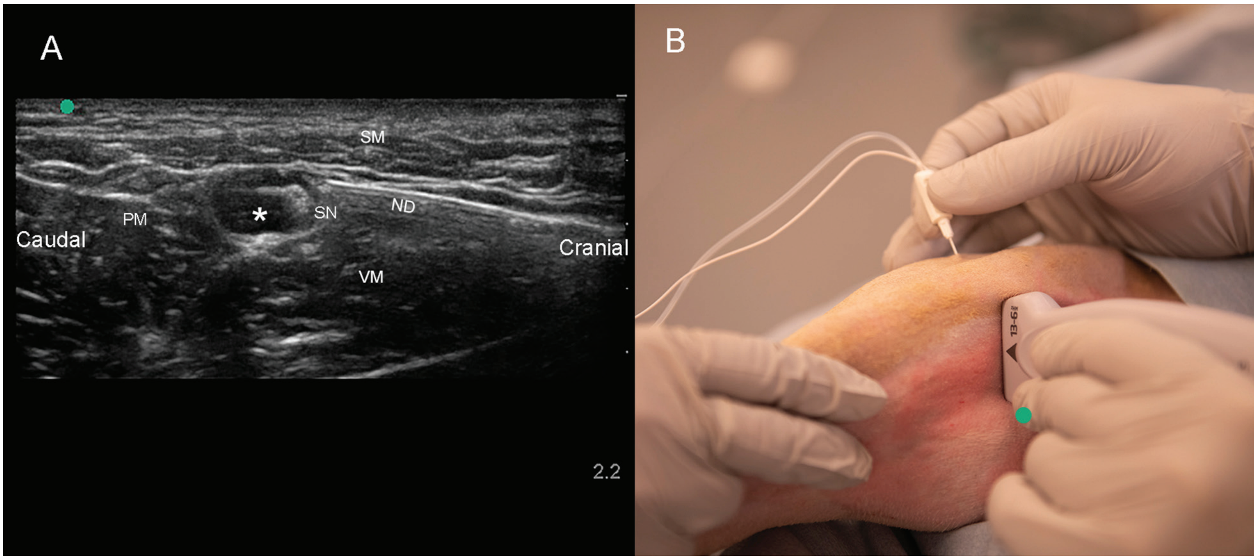

Figure 1—A—Relevant ultrasound anatomy pertinent to the saphenous nerve block. The marker (green circle) is oriented caudally. The saphenous nerve cannot be always observed and it is located within the neurovascular sheath, which contains the femoral artery, femoral vein and the nerve. The goal is to advance the needle into the sheath and inject following verification of a negative aspiration test. Appropriate location of the injection will be verified by observing the transient compression of the artery caused by the injectate. B—Ultrasound-guided right saphenous nerve block being performed on a Beagle dog. The dog is positioned in lateral recumbency with the leg to be blocked abducted approximately 90° and the corresponding knee in extension. A high-frequency, linear array ultrasound transducer should be positioned at the level of the medial aspect of the midthigh in an approximate transverse orientation related to the direction of the ipsilateral femur and with the marker (green circle) oriented caudally (towards the table). The needle puncture site is located caudal to the edge of the sartorius muscle and should be advanced in plane. *Femoral artery. ND = Needle. PM = Pectineus muscle. SM = Sartorius muscle. SN = Saphenous nerve. VM = Vastus medialis muscle.

Kalamatas et al[7] reported successful use of this block in combination with a sciatic nerve block in dogs undergoing unilateral TPLO surgery. These authors reported no need for rescue analgesia in any of the dogs for the first 24 hours postoperatively. Ferrero et al[35] reported an analgesia that was similar in quality to epidural anesthesia but with significantly less side effects such as intraoperative hypotension or postoperative urinary retention. These reported qualities may indicate initial suitability for implementation in ERAS protocols.

Of special interest is the publication by Boesch et al[36] in which the authors reported the use of radiofrequency ablation for the treatment of uncontrolled pain associated with severe stifle osteoarthritis.

Sciatic nerve block—A sciatic nerve block, in conjunction with a saphenous nerve block, may be used in surgical procedures involving the stifle, tibia, foot, and ankle. It is important to note that this block will cause sciatic nerve deficits such as knuckling and a pseudohypermetric gait due to the inability to flex the ankle (hock). This deficit may last for up to 24 hours depending on the local anesthetic and the volume used.[32] Communication with the surgeon and client is important to preempt confusion. A soft bandage or padding to protect the dorsal aspect of the foot and minimizing walking on abrasive surfaces should be strongly advised to avoid causing ulcerations of the dorsal aspect of the paw.

The ultrasound-guided caudal approach was first described by Campoy et al[15] **(Figure 2)**. More recently, 3 manuscripts have been published describing and evaluating its clinical use.[5,34,37] Alternatively, an intraoperative infiltration of the posterior capsule or an ultrasound-guided preoperative infiltration in between the popliteal artery and joint capsule has been proposed in human anesthesia targeting the genicular nerves and sensory only terminal branches.[38–40] A letter to the editor reporting successful implementation of this technique in the dog was published in 2020.[41]

Abdominal Surgery

For major abdominal surgery, epidural anesthesia may still be the recommended and most often used technique. However, new fascial infiltration techniques such as the transverse abdominis plane (TAP) block can be of special interest. Perhaps still too premature to recommend one versus the other, but fascial plane blocks are becoming increasingly popular as part of a multimodal approach. The advantage versus epidural anesthesia is the absence of side effects such as postoperative motor impairment of the pelvic limbs from the local anesthetic or the possible urinary retention from the administration of opioids (morphine, perhaps the most prevalent).[35,42] One exception can be the use of neuraxial (epidural) anesthesia in cesarean sections in which low-dose ("walking") epidural anesthesia is still the preferred technique.[43,44] For abdominal procedures, 2 techniques are of special interest and

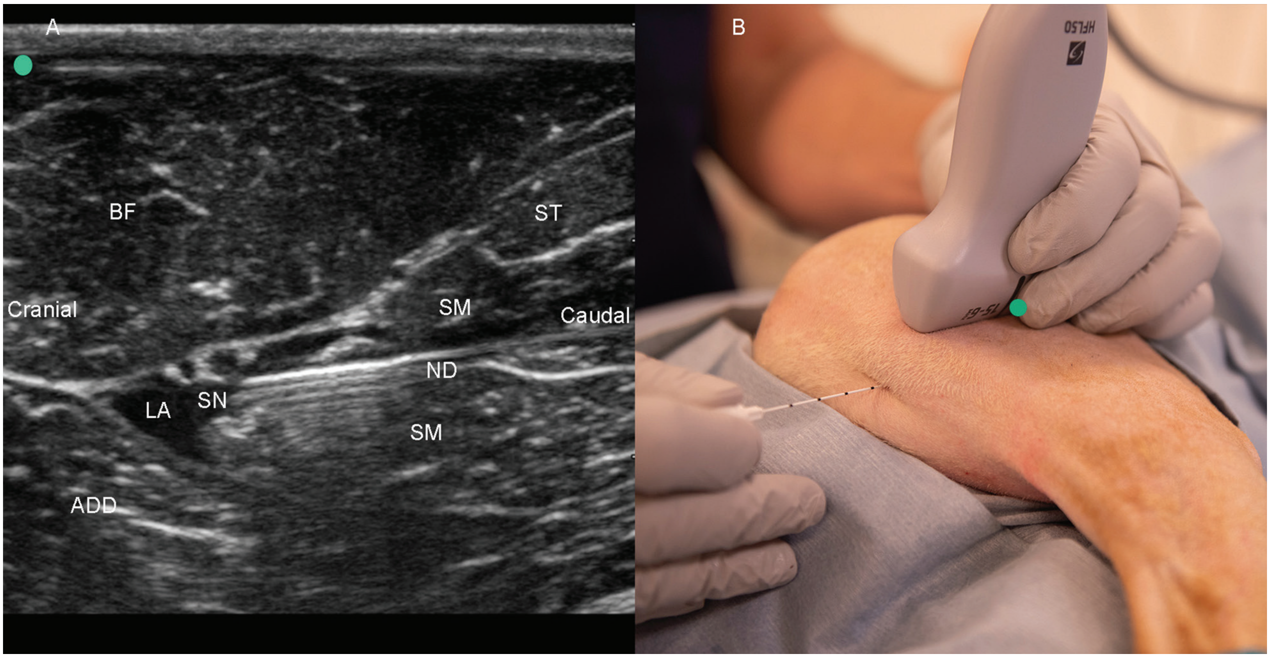

Figure 2—A—Relevant ultrasound anatomy pertinent to the sciatic nerve block. The marker (green circle) is oriented cranially. The sciatic nerve can be observed as a double discoid structure with a hyperechoic halo and a hypoechoic center. The goal is to advance the needle to the medial aspect of the sciatic nerve. Local anesthetic will appear hypoechoic and can be observed surrounding the nerve. B—Ultrasound-guided right sciatic nerve block being carried out on a Beagle dog. The dog is positioned in lateral recumbency with the leg to be blocked in a natural position. A high-frequency, linear array ultrasound transducer should be positioned at the level of the lateral aspect of the midthigh over the biceps femoris muscle in an approximate transverse orientation related to the direction of the ipsilateral femur and with the marker (green circle) oriented cranially. The needle puncture site is located in the caudal aspect of the thigh and should be advanced in plane. ADD = Adductor muscle. LA = Local anesthetic. SM = Semimembranosus muscle. SN = Sciatic nerve. ST = Semitendinosus muscle. ***See*** Figure 1 for remainder of key.

worth mentioning: the TAP block and the quadratus lumborum (QL) block.

TAP block—This fascial plane infiltration targets the relevant ventral spinal branches traveling in between the transverse abdominis and internal oblique muscles of an area in the dog that extends from dermatomes T9 to L3 **(Figure 3)**.[45] The abdominal wall and, possibly, the skin (depending on whether or not the local anesthetic extends as far as the lateral cutaneous branches), but not the internal abdominal organs will be desensitized. However, some studies in humans claim that this block also provides visceral as well as somatic analgesia.[46,47] The lateral cutaneous nerves, at this level, branch off fairly proximal and leave the transverse abdominis plane going through the internal and external oblique muscles to supply the skin. The TAP block is perhaps the best described and studied fascial plane infiltration in the dog to date and slight variations in the execution of this technique have been published.[27,34,48–50] This block may be of particular interest in procedures involving the abdomen and abdominal wall, such as splenectomies, liver surgery as well as mass removals, herniorrhaphies, or laceration repairs among others. Its clinical use in dogs undergoing ovariohysterectomy has been recently reported.[51] In this study, the authors claimed lower postoperative pain scores, less need for rescue analgesia and lower overall opioid consumption compared with a parenteral opioid-based group.

Pain management with epidural anesthesia may be of better quality since it provides anesthesia not only to the abdominal wall but also to the internal abdominal organs. However, a TAP block is fast to execute, it does not require extra clipping, and it appears to provide adequate postoperative analgesia for abdominal procedures. In addition, this infiltration will not interfere postoperatively with ambulation or urinary control as it may be the case with epidural anesthesia,[35,42] thus making it perhaps better suited for ERAS protocols. Further clinical studies comparing these 2 techniques are needed before we can make specific recommendations.

QL block—Initially described by Garbin et al[52] in the dog and by Argus et al[53] in the cat.[53] It targets the ventral branches of the thoracolumbar spinal nerves (approx T13 and L3) as they travel between the QL and the psoas muscle (it can vary a little depending on the approach; **Supplementary Figure S1**). The infiltration site is proximal to where the lateral cutaneous branches leave off the nerves and, in many cases, the local anesthetic spreads toward the sympathetic trunk approximately between T10 and L4. Therefore, it is claimed to provide not only somatic but also visceral analgesia to the abdomen. This relatively newly described fascial infiltration

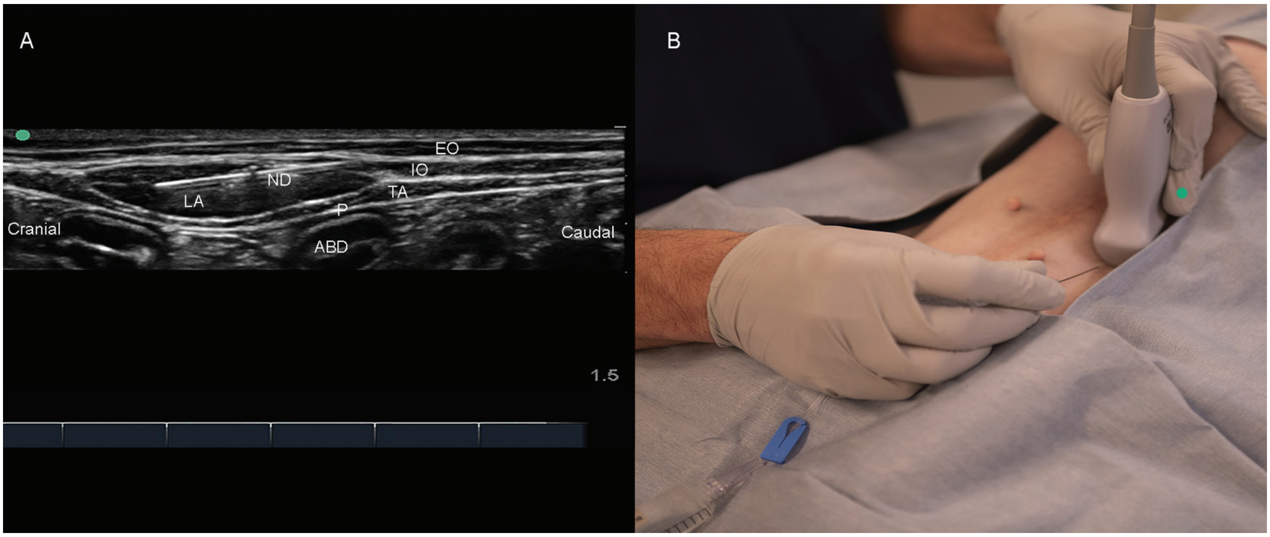

Figure 3—A—Relevant ultrasound anatomy pertinent to the transverse abdominis plane (TAP) block. The marker (green circle) is oriented cranially. The transverse abdominis muscle can be observed in contact with peritoneum. The goal is to advance the needle towards the plane between the transverse abdominis muscle and the internal oblique. The ventral branches of the relevant spinal nerves run within this intermuscular fascial plane. In order to verify the correct positioning of the needle a small amount of local anesthetic can be injected. Local anesthetic will appear hypoechoic and can be observed cumulating within this fascial plane. The needle should be advanced in a cephalad direction as the injectate is being administered. B—Ultrasound-guided TAP block being carried out on a Beagle dog. The dog is positioned in dorsal recumbency. A high-frequency, linear array ultrasound transducer should be positioned on the abdominal wall, in a longitudinal orientation related to the body axis and with the marker (green circle) oriented cranially. The needle should be advanced in plane. ABD = Abductor muscle. EO = External oblique muscle. IO = Internal oblique muscle. P = Peritoneum. TA = Transverse abdominis plane. ***See*** Figure 2 for remainder of key.

does not spread beyond L3, and it does not appear to cause any epidural migration, making it interesting for ERAS protocols in procedures involving the abdomen because it does not appear to cause motor deficits of the pelvic limbs or urinary retention. It can be used in procedures such as ovariohysterectomies[54] or cholecystectomies. Additionally, it can be used to produce analgesia in cases such as pancreatitis or gallstones.

Thoracic wall surgery

Major thoracic surgery may be beyond the scope of ERAS protocols; however, there may be various surgical procedures involving the thoracic wall that may be considered. It is worth noting that thoracic wall pain may lead to postoperative respiratory complications and thus make these techniques good complements or even alternatives to a pure opioid-based analgesic protocol.

Serratus plane block—Developed to supplement anesthesia for thoracic procedures such as sternotomies (bilateral block), intercostal thoracotomies,[55,56] thoracic wall defects or masses, skin flaps, broken ribs, rib resections, etc. Proposed as a simpler approach to thoracic paravertebral blocks or even epidural anesthesia. Two different infiltrations have been described: the deep infiltration was first described by Drozdzynska et al.[57] A few years later, Freitag published the superficial infiltration.[26] This fascial plane infiltration targets the relevant ventral spinal branches traveling in between the serratus ventralis muscle and the external intercostal muscle for the deep infiltration and the serratus ventralis and latissimus dorsi muscle for the superficial infiltration at the level of T4 or T5 **(Supplementary Figure S2)**. So far, both techniques appear to be effective at providing analgesia to the thoracic wall with no complications reported.

Intercostal nerve block—The use of intercostal nerve blocks has been described for quite some time.[9] Reported to be an effective tool in the management of postoperative analgesia following intercostal thoracotomies. Intercostal nerve blocks have been reported to improve postoperative respiratory parameters compared with parenteral opioids in dogs undergoing thoracotomy.[58,59] The intercostal nerve travels on the surface of the parietal pleura and therefore the precision of any blind approach has a low success rate. Additionally, the lateral cutaneous branch is often missed and therefore the skin often times is not desensitized with this technique. Recently, intercostal nerve blocks are recently gaining new popularity in the light of ultrasound-guided techniques **(Figure 4)**. Thomson et al[60] reported a significantly increased success rate, irrespectively of the level of expertise in regional anesthesia, between a blind versus an ultrasound-guided technique.

Thoracic limb

Radial, ulnar, musculocutaneous, and medial block—The use of a radial, ulnar, musculocutaneous,

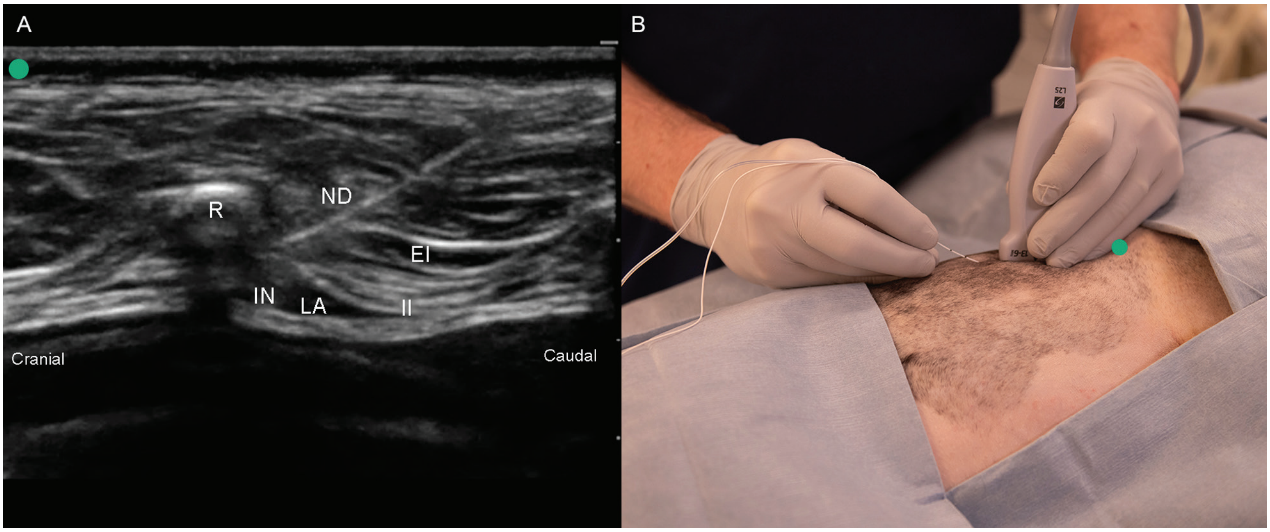

Figure 4—A—Relevant ultrasound anatomy pertinent to the intercostal nerve block. The marker (green circle) is oriented cranially. The intercostal nerve can be observed in the caudomedial aspect of the rib. The goal is to advance the needle deep to the external intercostal and internal intercostal muscles. A "click" may be felt when entering the space. B—Ultrasound-guided intercostal nerve block being carried out on a Beagle dog. The dog is positioned in lateral recumbency. A high frequency, linear array ultrasound transducer should be positioned over the ribs, in a transverse orientation in relation to the ribs with the marker (green circle) oriented cranially. The needle should be advanced in plane. EI = External intercostal muscle. II = Internal intercostal muscle. IN = Intercostal nerve. R = Rib. ***See*** Figures 2 and 3 for remainder of key.

and medial block was first described by Trumpatori et al.[61] This was a landmark-based technique. Complete nerve block of the 4 nerves was obtained in only 1 out of the 16 injected. The first ultrasound-guided clinical use was described in a report by Portela et al,[62] in which the authors successfully used it in a surgical resolution of a carpal luxation. Its execution is well described by Portela et al.[63] This block targets the radial nerve as it crosses over toward the lateral aspect of the midhumerus, and the musculocutaneous, medial, and ulnar nerves located in the medial aspect of the midhumerus **(Figure 5)**. A slight variation in the execution was published by Otero et al[64] in which blockade of all the nerves was executed from the lateral aspect. This is an effective block in patients undergoing radius and ulna surgery and carpal surgery such as carpal arthrodesis. Deficits will be observed at the level of the carpus; however, shoulder and elbow motor function will be generally well maintained. Patients will be unable to extend or flex the carpus for 8 to 12 hours, although shoulder and, in most cases, the elbow motor function will be preserved. In some cases, and depending at what level this block is executed, motor function of the elbow will be lost; however, as shoulder function will be maintained, patients will be able to maintain sternal recumbency.

Spinal surgery

Erector spinae block—Erector spinae (ESP) block is one of the newest and latest fascial plane infiltrations to be implemented in veterinary species. First described by Ferreira et al,[25] it aims to deposit the local anesthetic in between the multifidus and longissimus muscles or between multifidus, longissimus, and iliocostalis muscles, depending on the approach, in direct contact with lamina where the dorsal branch of the relevant spinal nerves run. No injectate migration to the ventral branches or sympathetic trunk has been observed in any of the cadaveric studies published to date.[24] However, epidural space migration in 2 out of 17 cadavers was reported by Medina-Serra et al.[65] The infiltration at this level will selectively and segmentally distribute along the dorsal branches (medial and lateral) of the spinal nerves[66] and thus block the paraspinal muscles, laminae and facets.[67] making it especially interesting for spinal surgery. So far, the ESP block is showing promising clinical results when used as part of a multimodal approach in thoracolumbar hemilaminectomies.[68] The dog reported by Zannin et al did not need any rescue analgesia during the first 12 hours postoperatively. Portela et al[69] published a retrospective cohort study looking at 114 records of dogs undergoing hemilaminectomy, 42 dogs with ESP block, and 72 with opioid-based analgesia. Preoperative block was associated with lower intra- and postoperative opioid administration, a reduced incidence of complications such as postoperative vomiting or regurgitation requiring treatment, and a shorter time to return to voluntary feeding. Two cases of sinus arrest have been reported. In both cases, a previous hemilaminectomy had been performed and therefore epidural or even spinal local anesthetic migration had a high probability of being the cause. Both dogs recovered uneventfully. Additionally, a letter to the editor has been published recently regarding the use of an ESP block as an analgesic technique in a case of acute pancreatitis.[70]

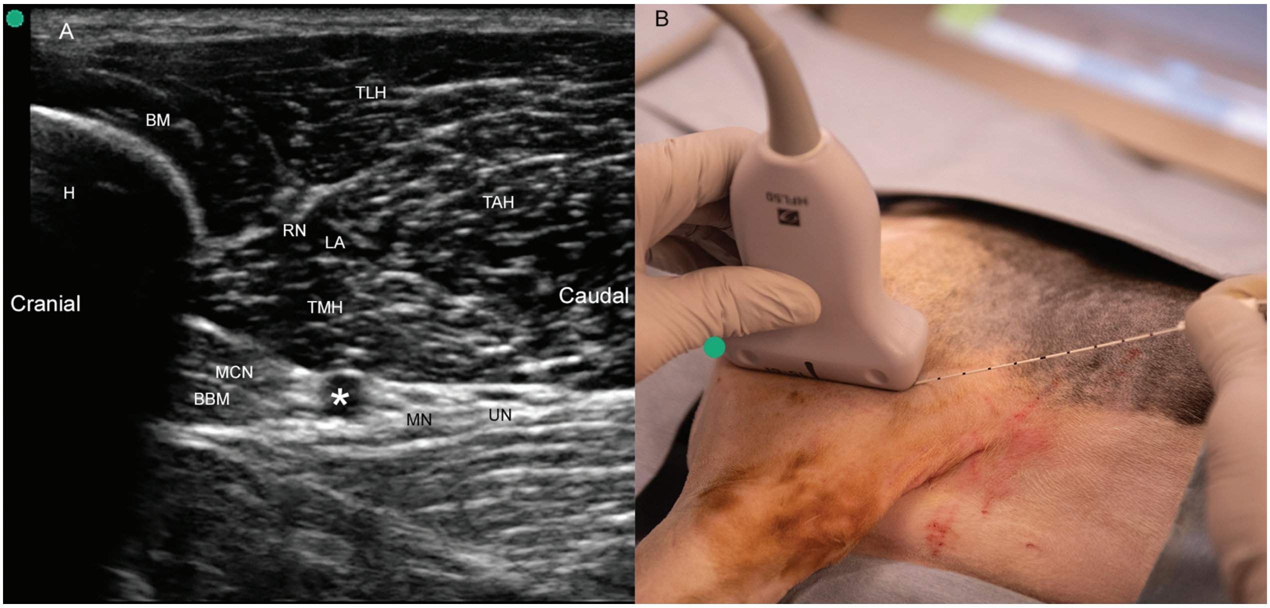

Figure 5—A—Relevant ultrasound anatomy pertinent to the radial, ulnar, musculocutaneous, and median nerve block. The marker (green circle) is oriented cranially. The radial nerve can be observed in between the brachialis, lateral, accessory, and medial heads of the triceps. The goal is to first advance the needle into the medial aspect of the radial nerve and administer the first aliquot of local anesthetic. Secondly, the needle should be redirected and advanced towards the brachial neurovascular sheath where the brachial vessels, musculocutaneous, median, and ulnar nerves can be found. Following verification of a negative aspiration test, a second aliquot of local anesthetic should be administered in this location. Expansion of the neurovascular sheath should be observed during the injection. B—Ultrasound-guided radial, ulnar, musculocutaneous, and median nerve block being carried out on a Beagle dog. The dog is positioned in lateral recumbency with the limb to be blocked positioned uppermost. A high-frequency, linear array ultrasound transducer should be positioned on the lateral aspect of the brachial area, over the triceps muscle, in a transverse orientation related to the ipsilateral humerus and with the marker (green circle) oriented cranially. The needle should be advanced in plane. *Brachial artery. BM = Biceps femoris muscle. H = Humerus. MCN = Musculocutaneous nerve. MN = Median nerve. RN = Radial nerve. TAH = Triceps muscle accessory head. TLH = Triceps muscle lateral head. TMH = Triceps muscle medial head. UN = Ulnar nerve. ***See*** Figure 2 for remainder of key.

Closing thoughts

As in today, one of the main barriers to implement locoregional anesthetic techniques into routine practice and ERAS protocols, not only in veterinary but also in human medicine, is the lack of training and expertise among clinicians in general and anesthesiologists in particular. This, we believe, is changing rapidly with the current expansion of e-learning, training bootcamps, and the efforts of some professional associations such as the New York School of Regional Anesthesia in the human field and the American College of Veterinary Anesthesia and Analgesia and the European College of Veterinary Anesthesia and Analgesia in the veterinary arena. Collaborations between human health-care providers (anesthesiologists) and veterinary anesthesiologists help our profession stay at the forefront.[71] Exponential growth in the training of new generations of residents and other clinicians interested in this subject is needed to achieve a critical mass able to finally implement these techniques in our hospitals and clinics. Certainly, a lot is changing in our veterinary world, but a lot more needs to be done. It is just a matter of time.

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