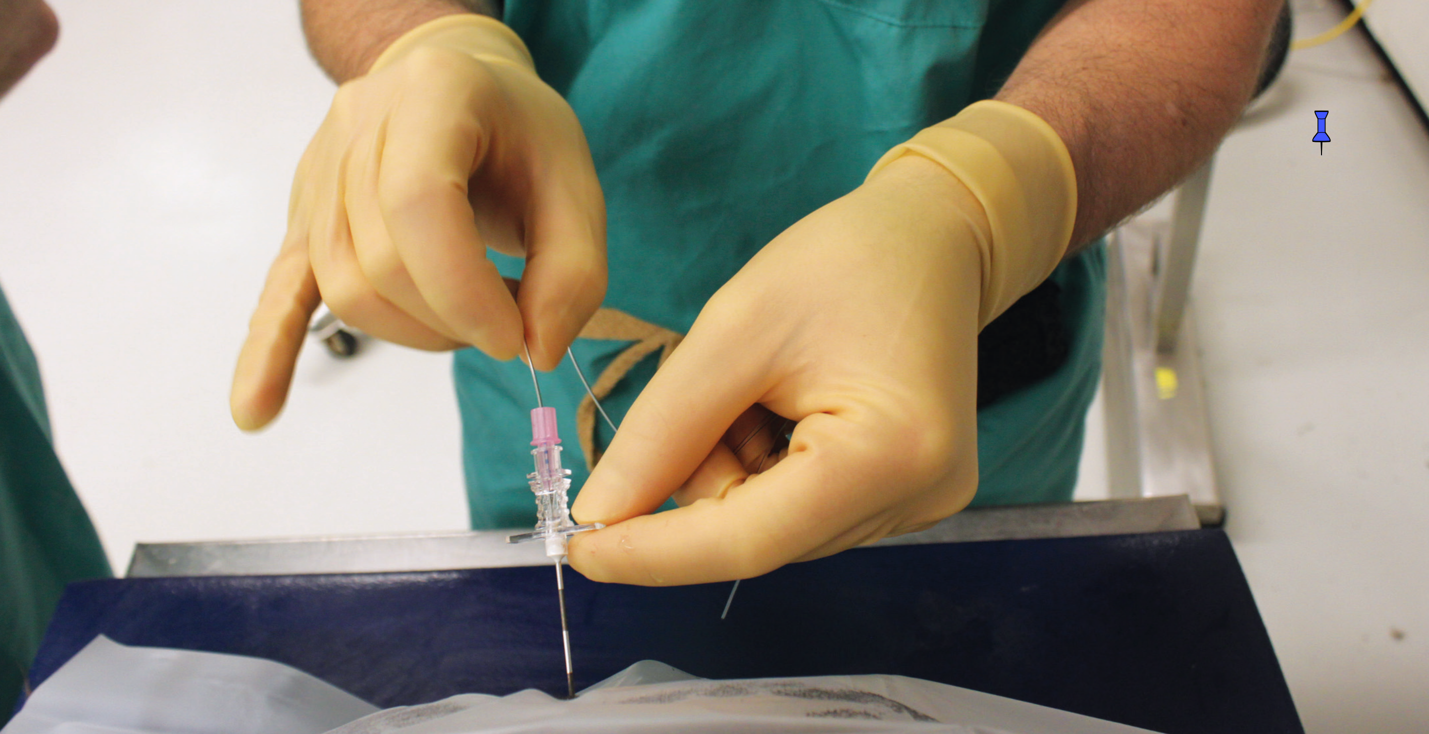
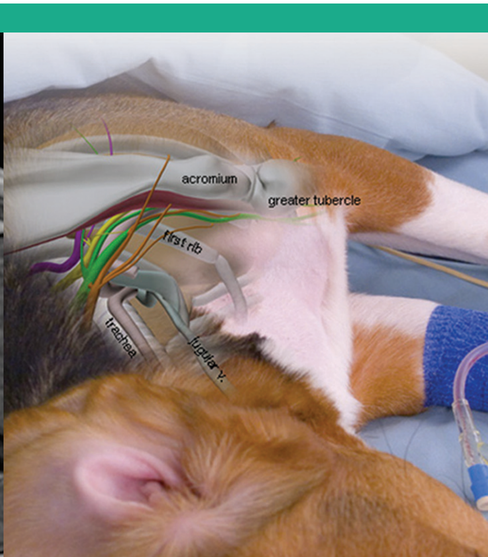


Small Animal Regional Anesthesia and Analgesia

Edited by Luis Campoy and Matt R. Read



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Small Animal Regional Anesthesia and Analgesia

Dedication

To my dearest wife Ewa for being the most understanding and supportive person in the whole wide world and to my children Kyla and Kian who I love to bits.

Luis Campoy

To my wife, Emma, and my children Grace and Kate for their support and encouragement. There were many days and nights spent working on this book and without their understanding, this project would not have been possible. I also extend my gratitude to Ban Tsui, MD and Vincent Chan, MD for opening the world of regional anesthesia to me and for sharing their enthusiasm for this wonderful specialty. Finally, I would like to thank my partner in this project, Luis Campoy, for his friendship and tireless efforts in getting this book to publication. Cheers!

Matt Read

Small Animal Regional Anesthesia and Analgesia

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Foreword

I am a medical anesthesiologist. My first meeting with veterinary anesthesiology was in 1997. A pet falcon belonging to a medical anesthesiologist friend needed an anesthetic for the fitting of a radio transmitter. The veterinarian who did the anesthetic was Dr. Lynette Bester. The falcon-owning friend next introduced Dr. Bester to me and we began an enduring scientific liaison of lecturing and teaching at scientific meetings we respectively organized. We developed an anesthetized pig workshop as a tool for teaching regional anesthesia techniques to both medical and veterinary anesthesiologists in South Africa.

In 2003 Dr. Bester and I were invited to present a regional anesthesia course in Knoxville Tennessee at the World Congress of Veterinary Anesthesiology.

Attending that WCVA-2003 regional anesthesia course were Drs. Luis Campoy and Matt Read, both of whom I met for the first time. Luis and Matt have told me that the Knoxville WCVA regional anesthesia course was a milestone in their growing passion for regional anesthesia. Subsequently Luis and I jointly organized a veterinary regional anesthesia skills course in Iowa and we lectured together at the regional anesthesia meetings of ISVRA in Italy. It seems a few blinks later Luis and Matt were producing this book and honoring me with an invitation to contribute a chapter and write this foreword. There is a warm story of professional bonds between all of this book's authors and their passion for their work and for regional anesthesia. I hope this book transmits that passion onto the readers.

There are many good reasons to perform regional anesthesia on our patients, both medical and veterinary. The primary outcome is postsurgical analgesia. This reduces patient suffering and facilitates faster return to normal eating, earlier mobilization, and swifter general recovery, which are in turn additional secondary outcome benefits. There are, however, many more secondary outcome benefits. In human studies, evidence strongly suggests that regional anesthesia diminishes chronic pain syndromes, diminishes cancer recurrences, reduces surgical infection, and reduces cardiovascular and pulmonary complications. The addition of regional anesthesia to a general anesthetic also allows significant anesthetic drug dose reduction. Reduced general anesthetic drug doses allow faster patient recovery from the general anesthetic. General anesthesia may seem to be a nontherapeutic specialty that only exists to make surgery possible. Regional anesthesia is different, however, as it offers significant benefits that endure after the surgery.

The first book in medicine devoted solely to regional anesthesia was published in 1917 by Victor Pauchet. Gaston Labat translated Pauchet's book into English in 1924. A generation later in

1953, Daniel Moore took the science further with his legendary book titled *Regional Block*. Moore's book was continually reprinted for another generation of anesthesiologists. The use of ultrasound guidance for peripheral nerve block needle placement became popular after 2005 and this hugely accelerated medical regional anesthesia's growth in popularity. Veterinary regional anesthesia's development is running parallel to medical regional anesthesia development. The two biggest limiting factors in regional anesthesia are lack of technical skill among practitioners and ignorance of surgeons on the risks and benefits. Education is the solution to both. This book will greatly help with that.

The growth in public sentiment and concern for the suffering of animals will also drive the popularity of regional anesthesia as a form of pain control for small animals with injuries and postsurgical pain. Every reason that exists to promote the use of regional anesthesia in humans is as valid to promote the use of regional anesthesia in animals.

Apart from being the historic book it is, I am sure this book by Drs. Campoy and Read will also long remain a definitive text book on veterinary regional anesthesia. The science of veterinary regional anesthesia will accelerate from now forward as much medical regional anesthesia did after the publication of each book by Pauchet, Labat, and Moore. The honor of publishing the first veterinary regional anesthesia book will always belong to editors Campoy and Read and their writing team.

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Preface

Small Animal Regional Anesthesia and Analgesia was written with a wide audience in mind. For many years, local and regional anesthesia in animals was considered to be an "art," with techniques that were developed decades ago still being used without any particular attention being made to advancing the "science" behind the different procedures. Over the last 10 years, rapid advances in human regional anesthesia have started to carry over into veterinary medicine. Recently, many studies have been conducted in small animals to document, describe, and improve local and regional anesthetic blocks in our small animal patients.

The primary goal of this text is to put a large body of information in one place for the first time. Interest in regional anesthesia in animals is not limited to one particular geographic area; as a result, we have invited an international group of authors to share their experience and expertise with us. This text will hopefully have something for everyone – it can be used as a text with complete reference lists and extensive discussion of different topics, or as a quick source of information with procedural checklists, pictures, and diagrams to assist with performance of the various blocks. Our hope is this book will serve as the impetus to standardize the various procedures that are used clinically (so we are all speaking the same language when we talk about these blocks), and will stimulate continued interest in this particular subspecialty of anesthesia and pain management in veterinary medicine.

Although our understanding of regional anesthesia in small animals still has a long way to go, we are on the cusp of some exciting new developments that will undoubtedly contribute to better outcomes and improved patient care.

Luis Campoy and Matt Read

Acknowledgments

We would like to acknowledge the contributions of our coauthors, all of whom had great enthusiasm for seeing this project come to fruition. The energy and time that they poured into this book is easy to see.

We also want to thank the team at Wiley, who provided us with support and mentoring through the entire process. We would like to especially thank Ms. Erica Judisch, commissioning editor at Wiley, for her tireless assistance, patience, and understanding. Without her, this book would never have been completed. We are also grateful for the help of Ms. Susan Engelken and Ms. Carrie Horn at Wiley, Ms. Eilidh McGregor for copyediting, Mr. Pascal Raj Francois for production, and the proofreaders and indexers who helped in the final stages. Finally, we would like to acknowledge our colleague, Dr. Bernd Driessen, for initially bringing us together on this exciting project.

Part 1

Considerations for Loco-regional Anesthesia

1 History of Regional Anesthesia

Kristopher Schroeder

History

The history of regional anesthesia and pain management is filled with fabulous stories and great characters. Ancient Egyptians used a variety of analgesics including hyoscyamine, scopolamine, opium poppy, beer, juniper, and yeast to treat a variety of ailments including "pains within the body." Ancient Indian culture used herbal medicine and yoga to overcome pain and create internal balance, and the ancient Chinese used acupuncture to properly channel negative energies and treat pain. The ancient Greeks gave the world Hippocrates (460–370 BC) who believed in the healing power of nature and focused on a rational approach to diagnosis and treatment rather than one based on superstition (Raj 2010).

Early giants in the field of medicine and philosophy were concerned with characterizing and understanding pain. Early teachings from Aristotle (384–322 BC) described pain as an emotion that was situated in the heart and it was not until Galen of Pergamon (AD 130–201) that people recognized that the brain was the organ responsible for pain sensation. Avicenna (AD 980–1037) described how pain sensation could be altered in various disease states, and Newton (1642–1727) and Hartley (1705–1757) described the potential role of nerves in transmitting noxious stimuli from the periphery to the brain (Perl 2007). Despite these advances in knowledge, the Middle Ages remained an unpleasant period of time in which to require a surgical procedure when even invasive surgeries were performed without anesthesia.

Early attempts at medicinal pain control typically originated from plant material and included opium (*Papaver somniferum*), alcohols, mandrake (*Atropa mandragora*), belladonna (*Atropa belladonna*), and marijuana (Cannabis). Freidrich Wilhelm Sertürner (1783–1841) isolated morphine from the opium plant in 1803. Aspirin (acetylsalicylic acid) was released in 1899 by the Bayer Company and quickly became the common man's "go to" therapy for mild to moderate pain relief (Raj 2010).

The natives of Peru are attributed with being the first to "use" a local anesthetic—the cocoa leaf, known for both its analgesic and hallucinatory properties. During surgical procedures, they obtained local anesthesia by chewing the leaves of the plant and allowing the resulting saliva to run into the fresh incisions. Chewing the leaves of the cocoa plant was also reported to "assuage the hungry,

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invigorate the weary and brighten the depressed." The cocoa plant was also important in the Peruvian natives' religious and political lives (Keys 1942; Fink 1985). The Spaniards who conquered the native Incan people initially described chewing cocoa leaves as the "work of the devil," but when they recognized the profit that could be made, they legalized it and taxed the revenue from plant sales. Bernabe Cobo described the first analgesic use of cocaine in 1653 when he discussed the native Incan practice of using the cocoa leaves to cure a toothache. In 1859, Paolo Mantegazza described Peruvian natives using cocoa leaves for the treatment of "a furred tongue in the morning, flatulence and whitening the teeth." While on a trip to South America, Scherzer noticed that the leaves numbed the tongue when they were chewed, and he went on to become the first person to make a report in the literature about its anesthetic qualities (Keys 1942; Deschner et al. 2007).

A necessary prerequisite to performing regional anesthesia was the development of the hypodermic needle and syringe. In 1836, Lafargue reported injection of morphine paste subcutaneously using a needle trocar. In 1839, Taylor and Washington began the practice of using hypodermic medication for relief of pain when they punctured the skin using lancets followed by injection of morphine solutions using syringes. In 1845, Francis Rynd described the potential benefits that could be obtained from perineural injections of opioids. In 1853, Alexander Wood invented the hollow needle and in that same year Charles Gabriel Pravaz attached an improvised hollow needle to a specially constructed syringe, completing the combination of equipment that we still use today (Raj 2010; Deschner et al. 2007).

In 1855, Friedrich Gaedcke was the first to isolate the active alkaloid from the cocoa plant, naming it "erythrolyxin." In 1860, Albert Nieman (1834–1861) isolated this ingredient in crystalline form (naming it "cocaine") and reported anesthesia of the tongue when it was tasted (Cousins and Bridenbaugh 1988; Deschner et al. 2007). In 1872, Theodor Aschenbrandt, an Austrian army officer, secretly put cocaine into the water of his soldiers and found that it improved endurance (Fink 1985). In 1880, Vasili Konstantinovich Von Anrep (1854–1925) thoroughly studied the pharmacology of cocaine. He developed a solution of cocaine and found that it could both abolish the sensation of taste and create anesthesia when applied to the tongue. Von Anrep also injected cocaine subcutaneously under the skin of his own arm and discovered that he created an area of anesthesia that lasted about 35 minutes. At the same time, others were experimenting with use of cocaine solutions for blocking corneal reflexes in animals and for treating painful diseases of the larynx and pharynx (Keys 1942; Deschner et al. 2007).

With the groundwork completed, all that was now needed was for someone to apply what had been learned about cocaine and apply it to the surgical arena. The development and use of cocaine as a local anesthetic agent is primarily attributed to Karl Koller. While Koller was practicing as a house surgeon at the Vienna General Hospital, his friend Sigmund Freud happened upon the beneficial reports of cocaine and studied its use for curing patients with morphine addiction (Fink 1985). Koller wanted to be accepted into an ophthalmology training program and was well aware of the search for a topical anesthetic to allow surgery to be performed on the eye. Prior to the introduction of cocaine anesthesia into clinical practice, eye surgery was nearly impossible to perform, given that general anesthesia typically induced coughing and vomiting, consequences to be avoided during eye surgery. He had read the reports of cocaine causing anesthesia of the tongue and had even tried it on his own tongue before arriving at the realization that cocaine could be topically applied to the eye. He first applied topical cocaine to the eye of a frog and when the frog did not move in response to touching of its cornea, regional anesthesia was truly born. He reported these findings to the Ophthalmological Congress in Heidelberg in September 1884, and the world's first surgery performed under regional anesthesia was completed as Koller anesthetized a patient's eye with cocaine for glaucoma surgery. Dr. Koller's assistant later wrote of the discovery:

> "We could make a dent in the cornea without the slightest awareness of the touch, let alone any unpleasant sensational reaction."

With that demonstration, the discovery of local anesthesia was complete and cocainization of the eye for production of local anesthesia was generally adopted. "I rejoice that I was the first to congratulate Dr. Koller as a benefactor of Mankind," wrote an assistant of Koller's (Fink 1985; Leonard 1998; Deschner et al. 2007). Freud referred to his former colleague Koller as "Coca Koller" and Koller described Freud as his "muse" (Fink 1985; Deschner et al. 2007).

In 1884, William Halsted (1852–1922) was the first to describe cocaine application to accessible peripheral nerves to perform dental blocks, thus obtaining "conduction" anesthesia in peripheral regions. The mandibular nerve was the first nerve he blocked. Halsted and Hall also performed a variety of other peripheral nerve blocks on themselves and medical student "volunteers" (Cousins and Bridenbaugh 1988). The next challenge in the evolution of regional anesthesia was to locate and inject a peripheral nerve percutaneously and blindly.

G.L. Corning, a neurologist, was the first to report an intravenous injection of local anesthetic with proximal venous occlusion for distal anesthesia. Corning is also credited with inducing the first spinal anesthesia in a dog, when he injected cocaine into the space between two adjoining spinous processes in a dog in 1885 and uncovered the possibilities of spinal anesthesia. He reported that the injection of a cocaine solution into the space between the spinous processes of two inferior dorsal vertebrae resulted in anesthesia of the dog's hind legs without affecting the anterior extremities. He subsequently performed a similar procedure in a man, resulting in anesthesia to the subject's legs and genitalia (Cousins and Bridenbaugh 1988). He later pondered:

> "Whether the method will ever find an application as a substitute for etherization in genitourinary or other branches of surgery, further experiments alone can show."

Corning is also credited with the first regional anesthetic peripheral nerve block after injecting a solution of cocaine around the median cutaneous antibrachii nerve in 1887 (Fink 1985; Ball and Westhorpe 2003; Deschner et al. 2007).

Carl-Ludwig Schleich (1859–1922) first described a technique for infiltration anesthesia to the German Congress of Surgeons in 1892. Previously in 1869, Pierre Edouard Potain used subcutaneous injections of water to provide skin anesthesia and Schleich described how both water and saline had weak anesthetic properties. Subcutaneous injections of water were associated with significant pain so Schleich took the next step and added cocaine to his injectate solution. Using his low-concentration cocaine solution for subcutaneous infiltration, Schleich was able to perform a variety of peripheral surgical procedures. Two years later, his methods had been widely adopted and were being used in the United States (Cousins and Bridenbaugh 1988; Deschner et al. 2007).

In 1897, Braun demonstrated that the toxicity of cocaine was in proportion to its rate of absorption, and recommended the addition of epinephrine to the solution of cocaine in order to decrease its rate of absorption and increase the duration of anesthesia—something anesthetists still commonly perform today (Braun 1914).

August Bier performed the first spinal anesthetics in 1898 when he injected the spinal canals of animals, himself, and an assistant (August Hildebrandt) with a solution of cocaine. Bier described the procedure of spinal anesthesia on six patients and one colleague in a manuscript written in 1899. First, Bier performed spinal anesthesia with intrathecal cocaine on his colleague Hildebrandt. Bier then subjected Hildebrandt to a series of painful insults including making a small skin incision on his thigh, applying a burning cigar to his legs, and applying strong blows to his shin with an iron hammer, without any apparent perception of pain on the part of Hildebrandt. Bier then went on to describe the problems associated with experimenting on himself and Hildebrandt when he detailed how Hildebrandt later developed pain in the distribution of his legs where "sensibility had been tested by crushing and heavy blows." Bier also described what we would now recognize as postdural puncture pain but attributed it to:

> "…Treating our bodies too lightheartedly. Instead of laying down and resting following the lumbar puncture and injection of cocaine, we went about our avocations, drank and smoked more than was good for us, and performed our normal work the next day."
>
> (Wulf 1998)

Between the time that Bier first performed spinal anesthesia and 1910, the techniques must have become widely adopted, because in 1909–1910, Tyrell Gray described performing spinal anesthesia in children and explained that his patients were comfortable enough to "eat cake throughout the duration of the surgical procedure" (Brown 2012).

In 1908, August Bier described the first use of intravenous regional anesthesia, the "Bier block" that still bears his name (van Zundert et al. 2008). In 1911, Georg Hirschel described the axillary brachial plexus block and D. Kulenkampff described the supraclavicular brachial plexus block (Cousins and Bridenbaugh 1988). Louis Gaston Labat (1877–1934) further popularized the use of regional anesthesia in the United States by authoring the text *Regional Anesthesia: Its Technic and Clinical Application* in 1920. Despite Labat himself commenting that the text was likely as popular as it was secondary to "the clear, concise descriptions carefully illustrated by half-nude women," his text served as the definitive text on regional anesthesia for 30 years and clearly helped to expand and advance the practice of regional anesthesia (Cousins and Bridenbaugh 1988; Cote et al. 2003).

One of the dangers associated with cocaine regional anesthesia is that the drug has euphoric, hallucinogenic, and, ultimately, addictive properties. Sadly, many of the early names in regional anesthesia that experimented on themselves developed addictions to cocaine. Due to these properties, and with the advances in chemistry and manufacturing, alternative local anesthetic molecules were subsequently developed. Amylocaine was developed as an early alternative to cocaine but it was abandoned when it was found to be an irritant. Procaine was developed in 1904 and was introduced into clinical practice in 1905. Procaine very quickly replaced cocaine in practice but its use was limited by its short duration and the potential for it to produce allergic reactions. Dibucaine (1925) and tetracaine (1928) were synthesized to create local anesthetics of longer duration, but they continued to have unacceptably high allergenic potential. Lidocaine was developed in the mid-1940s, a revolutionary new amide local anesthetic with decreased potential for allergic reactions. Mepivacaine (1957), bupivacaine (1957), prilocaine (1969), and etidocaine (1972) were all subsequently released into clinical practice. Mepivacaine and bupivacaine are still commonly used. Recently, ropivacaine has been developed as another long-acting local anesthetic agent, and, compared to other agents, has less motor blockade and decreased potential for cardiac toxicity (Brown et al. 2010).

The use of regional anesthetic techniques in animals started near the turn of the twentieth century (Lumb and Jones 1973). Cuille and Sendrail induced subarachnoid anesthesia in horses, cattle, and dogs in France in 1901. Cathelin reported the use of epidural anesthesia in dogs in 1901, but it took until the 1920s for this technique to be adapted by Retzgen, Benesch, and Brook for use in large animals. Later, in the 1940s, Farquharson and Formston developed paravertebral techniques for cattle. By the 1960s, local anesthetic techniques were commonplace in veterinary practice and chapters that described their pharmacology and use were included in many veterinary textbooks. Many of the drawings and images that we still use today are based on figures from Wright's *Veterinary Anaesthesia and Analgesia* (first published in 1941, Hall 1966) and Lumb and Jones' *Veterinary Anesthesia* (first published in 1973). Today, the science is catching up to the art, and local and regional anesthetic techniques continue to have an ever more important role in acute and chronic patient management of veterinary species.

Peripheral nerve blocks

Although the practice of neuraxial (spinal, epidural) anesthesia has changed minimally over the years, peripheral nerve blockade has undergone multiple shifts in both philosophy and technique. Originally, correct needle positioning was simply approximated by anesthesiologists who would use their knowledge of anatomy to estimate the locations of target nerves. Later, techniques involved asking the patient to report "paresthesias"—the nerve tingling in the distribution of the target nerve to be blocked after the needle had been inserted close to the target nerve. Anesthesiologists at that time were governed by the words of Moore "No paresthesia, no anesthesia," and they relied heavily on patient feedback to finalize needle position prior to drug administration. Traditional techniques also relied upon the anesthesiologist sensing palpable and subjective "pops" or "clicks" as their needles traveled through various fascial planes, and detecting arterial pulsations transmitted along the length of their needles as they came in close proximity to major arteries (Dillane and Tsui 2012).

Nerve stimulation

In 1780, Luigi Galvani applied static electricity-charged metal electrodes to frog sciatic nerves and showed that electrical stimulation of peripheral nerves would result in muscle contractions. In 1850, H. von Helmolz investigated isolated nerve-muscle specimens. Based on those studies, he formed the concept that when an electrical stimulus is applied to a nerve, a threshold must first be reached before an action potential can result in creation of a muscle contraction. Georg Perthes first reported the clinical use of electrical nerve stimulation for nerve blocks in 1912 in Germany. In 1962, Greenblatt and Denson reported their use of a portable nerve stimulator for nerve localization, and in 1966, battery powered portable nerve stimulators first appeared in clinical practice (Dillane and Tsui 2012). In 1984, specially designed needles became available for electro-stimulation of nerves. These needles had electrically insulated shafts but naked metal tips that served as electrodes during nerve stimulation (Ford et al. 1984). This technological development resulted in worldwide growth and interest in medical nerve blocks. By being able to "find" target nerves through visualization of motor responses prior to injection of local anesthetic solutions, nerve stimulation was reported to increase the chances of successful nerve blockade while at the same time reducing the volume of local anesthetic that was required. There was a belief that at certain stimulating currents, target nerves could be identified before the needle tip contacted the nerve itself, thus minimizing the risk of patient injury during needle placement and/or injection of the local anesthetic. Nerve stimulation for nerve localization was found to be associated with a decreased incidence of nerve trauma and Gentili and Wargnier coined the phrase "no paresthesia, no dysesthesia" (Dillane and Tsui 2012).

Ultrasound visualization

Ultrasound guidance has become popular as a nerve localization tool in people, and its use during regional anesthesia has recently been called the "new gold standard." The advantage of ultrasound guidance is that variation in individual patient anatomy no longer negatively affects block success rates. As target nerves can be "seen," they can more effectively be located with a needle tip prior to injection of the local anesthetic solution. Compared with the use of nerve stimulation alone, ultrasound guidance has been shown to result in a higher rate of successful peripheral nerve blockade, decreased block set-up times and longer block durations. When Orebaugh et al. (2007, 2009) studied the use of ultrasound guidance versus nerve stimulation for peripheral nerve blockade performed by anesthesia residents, they found that ultrasound guidance resulted in decreased procedure times, needle insertions, and inadvertent vascular punctures (Orebaugh et al. 2007, 2009).

A study by Robards et al. (2009) demonstrated that nerve stimulation might not confer the added safety benefits with which it was initially credited. In their study using combined ultrasound guidance and nerve stimulation to perform sciatic nerve blocks in the popliteal fossa, they found that in 4/24 patients a current of 1.5 mA (a typical current used during regional anesthesia) failed to produce a visible motor response even though needles were placed intraneurally (Robards et al. 2009). Ultrasound guidance has the added benefit of being able to visualize vascular or other anatomical structures that should be avoided during needle placement (i.e. pleura, peritoneum, etc.), but its use is limited by equipment availability and operator skill. In theory, the decreased volume of local anesthetic that is required to block a nerve when ultrasound guidance is used should confer added safety to the patient. However, despite all of these reported advantages, in people there is no definitive evidence to support a safety benefit of using ultrasound guidance versus nerve stimulation, and the debate continues over the role of nerve stimulation and ultrasound guidance in the performance of regional anesthesia (Chin and Chan 2008; Griffin and Nicholls 2010).

Rationale for loco-regional anesthesia and analgesia

Why all of this excitement and interest in the field of regional anesthesia? For many practitioners, regional anesthesia offers the potential to put the anatomical knowledge that they have acquired throughout the years into practice. The use of regional anesthesia is intellectually challenging and incredibly rewarding. The benefits for your patients are often quite obvious as you take a patient in excruciating pain and make them comfortable when they are in the vulnerable postoperative period.

The anesthesia literature is filled with studies further demonstrating the benefits of regional anesthesia. The list of indications for regional anesthesia continues to expand as the number of regional techniques expands or is improved upon to allow more peripheral techniques to be performed. Pain itself has been demonstrated to have a number of adverse effects throughout the body. It impacts the respiratory system by promoting atelectasis, ventilation-to-perfusion mismatching, arterial hypoxemia, hypercapnia, and pneumonia. In the cardiovascular system, pain has been shown to produce hypertension, tachycardia, myocardial ischemia, and cardiac dysrhythmias. Pain impacts the endocrine system by promoting hyperglycemia, sodium/water retention, and protein catabolism. It can cause urinary retention, decreased clotting ability, impaired coagulation, and decreased immune function (Stoelting and Miller 2007).

Decreases in morbidity and mortality, improved postoperative pain control and decreases in perioperative complications have been listed as potential benefits of regional anesthesia in people. A meta-analysis that compared intraoperative neuraxial to general anesthesia (141 randomized controlled trials, 9559 patients) demonstrated that neuraxial anesthesia was associated with a decrease in mortality from 2.8% to 1.9% (Rodgers et al. 2000). A study evaluating the Medicare claims database found that when an epidural was used for postoperative analgesia, mortality was reduced at 7 days (0.5% vs. 0.8%) and 30 days (2.1% vs. 2.8%) postoperatively (Wu et al. 2004). Another database analysis of 259,037 patients found that epidural anesthesia reduced 30-day mortality from 2.0% to 1.7% (Wijeysundera et al. 2008). Despite the exciting findings of the above-mentioned studies, other investigations have failed to find mortality benefits and it is likely that mortality benefits truly exist only for the sickest patients undergoing high-risk procedures (Peyton et al. 2003). Thoracic epidural anesthesia has been demonstrated to have more clear benefits with regard to perioperative cardiovascular (myocardial infarction and dysrhythmias) and pulmonary (postoperative pulmonary complications, pulmonary infections, and respiratory failure) events. Thoracic epidural and regional anesthesia has been associated with faster recovery of bowel function, improved postoperative rehabilitation, improved pain control, decreased opioid requirements, and fewer opioid-related side effects (Hanna et al. 2009). An exciting frontier of investigation in the world of regional anesthesia focuses on the ability of nerve blockade to attenuate the amount of perioperative immunosuppression typically encountered in the perioperative period. This may have important implications with regard to the incidence of recurrence or metastatic cancer following cancer resection surgery (Exadaktylos et al. 2006).

As with all areas of veterinary medicine, local and regional anesthetic techniques have evolved rapidly over the last 20 years. Veterinarians and their staff are very interested in techniques that contribute to pain management and patient care, and as a result, the use of local anesthesia is being "rediscovered" after playing a secondary role in pain management due to the widespread development and use of opioids and NSAIDs over the last few years. If what physicians have learned about the benefits of local and regional anesthetic techniques has any application to animals (which they would be expected to), then we can look forward to an exciting few years to come!

References and further reading

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2 General Considerations

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Loco-regional anesthesia is used extensively in human medicine to provide intra- and postoperative pain control. The American Society of Regional Anesthesia (ASRA) was founded in 1975 and currently boasts 5000 members in 60 countries. ASRA is the largest subspecialty organization in anesthesia and currently hosts two separate annual meetings that focus on either acute or chronic pain control. Accredited fellowship programs in chronic pain management have been available for a number of years, and recently, fellowship training has become available in regional anesthesia and acute pain management (Neal and Baker 2006).

In recent years, loco-regional anesthesia has also gained popularity in veterinary medicine. With a growing emphasis on improving pain management for animals, loco-regional anesthetic procedures that were originally described for use in people are now being adapted to different animal species with positive results (Campoy et al. 2008; Figueiredo et al. 2008; Bardell et al. 2010; Mosing et al. 2010; Zarucco et al. 2010; Watts et al. 2011). However, the extrapolation and safe use of loco-regional anesthetic techniques (either neuraxial or peripheral) that are designed and reported for one species requires a thorough understanding of the relevant regional anatomy of the new species of interest.

Outline of central anatomy

For the purposes of local anesthetic classification, the nervous system can be conveniently divided into the central (neuraxial) and peripheral nervous systems. The vertebral canal contains the epidural space and the intrathecal structures, which include the spinal cord, the meninges, and the cerebrospinal fluid (CSF). Two distinct nerve roots emerge from each spinal level. The dorsal nerve roots provide afferent information to the spinal cord, whereas the ventral nerve roots provide efferent information from the spinal cord to the effector organs in the body.

The anatomic area that is innervated by an individual nerve root is referred to as a "dermatome." Dermatome maps exist and thorough knowledge of this innervation allows anesthetists to more appropriately deliver their drugs in the epidural or intrathecal spaces (Stoelting and Miller 2007; Cousins and Bridenbaugh 1988).

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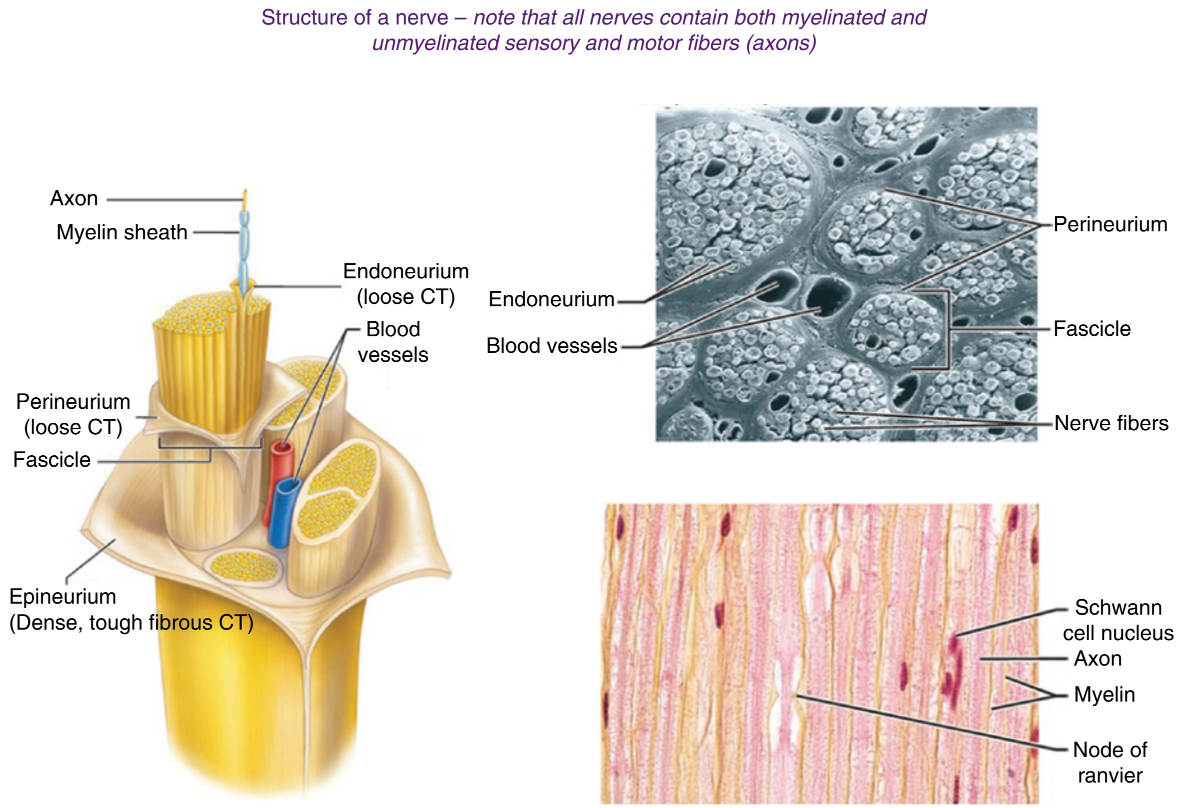

Figure 2.1 Microanatomy of a peripheral nerve. (From: A. Kizirian. http://antranik.org/wp-content/uploads/2011/10/structure-of-a-nerve-perineurium-endoneurium-epineurium-perineurium-fascicle-1024x731.jpg. Used with permission.)

Peripheral nerve anatomy and pain

Individuals who perform regional anesthesia should have a thorough understanding of the microanatomy of peripheral nerves. Although nerves may appear grossly to be large, distinct structures, they are actually made up of many components (Figure 2.1). A peripheral nerve is a structure consisting of nerve fascicles that are held together by the *epineurium*, the outermost layer of connective tissue surrounding a peripheral nerve. The epineurium not only holds the fascicles together in a grossly identifiable structure, but also contains the blood vessels that supply the peripheral nerve. Individual nerve fascicles with in the peripheral nerve are surrounded by the *perineurium*, a multilayered epithelial sheath consisting of several layers of perineural cells. Each fascicle contains many individual nerve fibers and capillary blood vessels. The fascicular bundles are not continuous throughout the peripheral nerve and they divide and anastomose with one another as frequently as every few millimeters (Stoelting and Miller 2007; Cousins and Bridenbaugh 1988). The *endoneurium* is the layer of delicate connective tissue made up of endoneurial cells that encloses the myelin sheath surrounding each nerve fiber.

Loco-regional anesthetic terminology

Topical or surface anesthesia

Topical or surface anesthesia has great theoretical appeal as pain transmission could be halted before it even starts at the site of peripheral injury. Unfortunately, local anesthetics are not readily absorbed across the skin surface, and special formulations are needed for them to be used in this way.

A Eutectic Mixture of Local Anesthetics (EMLA® cream or patches) has been used to decrease pain for a variety of dermal procedures in people, and has been studied in cats to minimize pain associated with jugular puncture (Wagner et al. 2006). EMLA® is a eutectic mixture of equal quantities of lidocaine and prilocaine (2.5% each) and is approved for application to intact, non-mucosal skin (Kundu and Achar 2002). EMLA® is indicated for dermal anesthesia and is reportedly useful for preventing pain associated with peripheral intravenous catheter placement, blood sampling, and superficial skin closure in people. When used correctly, the cream is applied to the skin and it is then covered with an occlusive dressing to facilitate absorption of the local anesthetics. Local anesthetic efficacy is achieved after approximately 60 minutes and lasts up to two hours after the dressing is removed.

Transdermal lidocaine patches (Lidoderm®) were originally developed for treating postherpetic neuralgia pain in people, and their use has recently been studied in horses (Bidwell et al. 2007). The patches contain 5% lidocaine and the penetration of lidocaine into intact skin is sufficient to produce a local analgesic effect, but is less than the amount necessary to produce a complete sensory block. Clinical trials in people have demonstrated that lidocaine patches placed near the site of incision are able to produce prolonged dynamic pain control and can reduce the amount of systemic opioids required for postoperative analgesia (Saber et al. 2009; Habib et al. 2009).

Local or infiltration anesthesia

Local or infiltration anesthesia is an old concept which has gained new followers recently (see Chapter 8). Historically, infiltration of local anesthetics into surgical sites simply involved the one-time injection of the drug into the planned surgical field. Recently, development and use of wound infusion catheters has allowed also for the continuous or intermittent delivery of local anesthetics into surgical wounds postoperatively, greatly improving patient comfort. Use of these techniques following abdominal procedures has been studied in people, with reductions in diaphragmatic dysfunction, rest pain, dynamic pain, opioid consumption, duration of ileus, and duration of hospital admission being reported as benefits (Ganapathy et al. 2011).

Regional or nerve (plexus) block anesthesia

Regional anesthesia is the injection of a local anesthetic solution in the vicinity of a peripheral nerve to temporarily block sensory and/or motor functions for intraoperative and postoperative pain control. There are many peripheral nerves that can be blocked, depending on the region of interest in the body (see Chapters 9–13).

Neuraxial anesthesia

The spinal cord and nerve roots are housed within the bony vertebral canal. Epidural (extradural) anesthesia refers to the administration of a local anesthetic (or other drug) into the epidural space outside of the dura, whereas the administration of a drug into the subarachnoid space is known as spinal, subarachnoid, or intrathecal anesthesia (see Chapter 14).

Intravenous regional anesthesia (IVRA)

Intravenous regional anesthesia involves administration of a local anesthetic into a peripheral vein (see Chapter 15). Prior to drug administration, the distal extremity is exsanguinated by elevating the limb and wrapping it in a tight bandage. A tourniquet is then inflated proximal to the surgical site and the bandage is removed. The local anesthetic solution is then injected intravenously. Anesthesia will soon take place covering an area distal to the tourniquet. Intravenous regional anesthesia has many applications for distal limb surgery of limited duration and, although it was originally described in 1908, it remains elegantly reliable, quick, and simple to perform.

Complications

With proper training and equipment, complications arising from the use of loco-regional anesthetic techniques for pain control are rare. Potential complications must be fully understood by the clinician and strategies to minimize their incidence, including good record keeping, should be implemented during each and every nerve block.

A number of studies investigating the complications associated with regional anesthesia have been conducted in people (Cazzuffi et al. 1982; Fortuna and Fortuna 1989; Auroy et al. 1997; Brull et al. 2007). Auroy et al. (1997) analyzed the records from 21,278 peripheral nerve blocks to investigate the incidence and characteristics of serious complications in human patients following a variety of regional anesthetic procedures. The incidence of complications was as follows:

- three cardiac arrests (0.014%);
- one death (0.005%);
- 16 seizures (0.075%);
- four neurological injuries (0.019%); and
- four radiculopathies (0.019%).

The incidence of serious complications in veterinary patients is not known, and as we continue to develop these techniques for clinical use, prospective studies should be performed to better identify the risks to our patients.

Complications of loco-regional anesthetic techniques can be broadly categorized as being either systemic toxicities or nerve injuries.

Systemic toxicity

The most devastating complication during the performance of a peripheral nerve block is the intravascular injection of local anesthetic with subsequent signs of systemic toxicity such as muscle twitches, tremors, seizures, tachycardia, hypotension, arrhythmias, cardiovascular collapse, and even death (see Chapter 4). Central nervous system symptoms (i.e. muscle twitches, tremors, or seizures) usually occur before cardiovascular changes take place (i.e. tachycardia, hypotension, arrhythmias, cardiovascular collapse, cardiac arrest), but these changes are usually only going to be observed in awake patients. Under general anesthesia, early neurological warning signs of local anesthetic toxicity are masked by sedatives and inhalant anesthetics, and this manifestation of toxicity will often be missed. For this reason, in people there is controversy over whether or not peripheral nerve blocks should be performed under sedation rather than general anesthesia.

Giaufre et al. (1996) reported no complications relating to intravascular injection of local anesthetic in children following 9396 peripheral nerve blocks, despite the fact that the majority of these procedures were performed under general anesthesia. However, even with recent advances in the use of ultrasonography during performance of regional blocks in people, a recent case report by Loubert et al. (2008) showed that severe adverse toxic effects are still possible as a result of intravascular injections. The authors described how even the slightest amount of pressure applied by the ultrasound transducer can cause veins to collapse and vanish from sonographic view. When this occurs it is possible to inadvertently inject local anesthetic solutions into a vein without knowing.

In veterinary medicine, this controversy becomes moot—we are often forced to perform these blocks in heavily sedated or anesthetized animals because our patients do not typically tolerate these blocks being performed while they are awake. As a result, monitoring of patients for neurological or cardiovascular signs of local anesthetic toxicity during and after performance of the regional block is strongly recommended.

Neurological injuries

In people, the most severe complication of using loco-regional analgesic techniques for analgesia is the risk of permanent neurologic injury. For this reason, a great deal of research has been dedicated towards minimizing this risk. When it occurs, peripheral nerve injury often presents as "neuropraxia," with persistent numbness in the affected area. Fortunately, most of these injuries self-resolve and very few have been found to persist beyond a few months. Short-term complications regarded as being more trivial include: temporary dysesthesias, localized tenderness, and hematoma formation.

Neurological complications are believed to result from one or more of the following causes:

- needle/mechanical trauma;
- neuronal ischemia;