VETERINARY ANESTHESIA AND ANALGESIA

THE SIXTH EDITION OF LUMB AND JONES

EDITED BY

LEIGH LAMONT • KURT GRIMM

SHEILAH ROBERTSON • LYDIA LOVE

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with website

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Veterinary Anesthesia and Analgesia

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The Sixth Edition of Lumb and Jones

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Dedication

The sixth edition of this text is dedicated to the many people who support and make up the specialty of veterinary anesthesia and analgesia and, specifically, the membership of the American College of Veterinary Anesthesia and Analgesia. Without their contributions and guidance, this book would not be possible, and without their participation in disseminating and implementing the knowledge contained in this book, it would be without purpose.

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Foreword

The extensively referenced content, important additions, and timely revisions of the sixth edition of *Veterinary Anesthesia and Analgesia* provide an impressive documentation of the basic and applied clinical science essential to the safe delivery of animal anesthesia and pain management. As such, this text continues to be the most comprehensive source of information for students, scientists, practitioners, and specialists alike. The sixth edition, once again, successfully chronicles the vital role that anesthesia and analgesia play in modern-day veterinary medicine.

As a previous editor of the third, fourth, and fifth editions of this text, and in memory of the three signees who penned the foreword to the fifth edition, Dr. William Lumb, Dr. Wynn Jones, and Dr. John Thurmon, I wish to acknowledge the efforts of the contributors, 104 in all, with special thanks to Dr. Lamont, Dr. Grimm, Dr. Robertson, Dr. Love, and Dr. Schroeder for assuming the editorship of such a large endeavor. Now, in the third decade of the 21st century, the publication of *Veterinary Anesthesia and Analgesia: The Sixth Edition of Lumb and Jones* continues to highlight the importance, significance, and necessity of continually improving animal anesthesia and analgesia. With their combined efforts, the contributing authors and editors have admirably upheld this text's long-standing reputation as an indispensable resource in advancing and improving animal care and the human animal bond.

William J. Tranquilli

Preface

The first edition of *Veterinary Anesthesia* was published in 1973, and the second edition followed in 1984. The third through fifth editions (*Lumb and Jones' Veterinary Anesthesia*, *Lumb and Jones' Veterinary Anesthesia and Analgesia*, and *Veterinary Anesthesia and Analgesia, the Fifth Edition of Lumb and Jones*) followed in 1996, 2007, and 2015, respectively. Now, in its 51st year, a sixth edition of this text is available with both editorial and content contributions from many new participants.

The sixth edition represents a generational change within the specialty of anesthesia and analgesia. Most of the early members of the Association of Veterinary Anaesthetists (AVA), the American College of Veterinary Anesthesia and Analgesia (ACVAA), and the European College of Veterinary Anaesthesia and Analgesia (ECVAA) have retired from clinical practice, and some are unfortunately no longer with us. However, as the membership of these specialty organizations continues to grow, and the demand for trained board-certified specialists in veterinary anesthesia and analgesia continues to outpace the supply, it is truly an exciting time to be a veterinary anesthesiologist. It is for those joining our specialty that this book is written, and we have intentionally tried to incorporate as many new voices as possible in the writing and editing of this text. It is our hope that the new generation will pick up the baton of advancing veterinary anesthesia, and continue to develop new ideas, disseminate new information, and carry on traditions such as *Lumb and Jones*.

We would like to personally thank our families and co-workers for allowing us the time necessary to complete this work, and the staff at Wiley for their ongoing support and encouragement.

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There you will find valuable materials, including:

- Videos

SECTION 1

General Topics

1 Overview, History, and Current Issues in Veterinary Anesthesia and Analgesia

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Chapter contents

Overview

Veterinary anesthesia continues to evolve as a science and specialty within the veterinary profession. The major drivers of change are advances in medical technology, development of evidence-based guidelines for patient care, and socioeconomic and demographic changes in countries where animals serve evolving roles. One thing that remains certain is that veterinary anesthesiologists will continue to be advocates for patient safety, humane care, and quality of life and serve as frontline educators for best practices in anesthesia, analgesia, and pain management.

Proper use of anesthetics, sedatives, and analgesics can alleviate pain, create amnesia, and produce muscle relaxation essential for safe and humane patient care [1]. Important uses include facilitation of immobilization for various diagnostic, surgical, and therapeutic procedures; safe transportation of wild and exotic animals; and euthanasia and the humane slaughter of food animals. Anesthesia, sedation, and analgesic drug administration are not without significant patient risk and are not recommended for trivial reasons. The continued development of better techniques and drugs along with continuing efforts to educate veterinary care providers has minimized the overall risk of anesthesia and pain alleviation in an ever-increasing and more sophisticated patient care environment. Any discussion with the animal-owning public, such as that occurring with owners when obtaining informed consent, requires the use of proper terminology and clear communication to convey the issues central to the safe delivery of veterinary anesthesia and pain therapy.

Terminology

The term *anesthesia*, derived from the Greek term *anaisthaesia*, meaning "insensibility," is used to describe the loss of sensation to the entire body or a specific portion of it. Anesthesia is induced by drugs that depress the activity of nervous tissue locally, regionally, or within the central nervous system (CNS). From a pharmacological viewpoint, there has been a significant redefining of the term *general anesthesia* [2], and both central nervous stimulants and depressants can be useful general anesthetics [3].

Management of pain in patients involves the use of drugs that are often called *analgesics*. The term is derived from *an*, which implies "negative" or "without," and *alges(is)*, meaning "pain" [4]. Clinical management of pain often results in varying degrees of effectiveness that represent states of hypoalgesia or decreased sensation of pain. It is important to understand that the administration of an analgesic drug does not necessarily create the state of analgesia.

The diverse uses for anesthesia (as it relates to immobilization, muscle relaxation, and antinociception) and the requirements peculiar to species, age, and disease state necessitate the use of a variety of drugs, drug combinations, and methods. Throughout this text and elsewhere, various terms are used to describe the effects of anesthetic drugs, pain-inhibiting drugs, and various techniques and routes of administration. Commonly used terms are defined below, and the reader is referred to other chapters for more details where appropriate.

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Companion website: www.wiley.com/go/lamont/anesthesia

Analgesia is the absence of pain in response to stimulation, which would normally be painful. The term is generally reserved for describing lack of pain in a conscious patient [5].

Acupuncture is a system of therapy using long, fine needles to induce hypoalgesia. Additional modalities of acupuncture point stimulation have been utilized, including mechanical and electrical stimulation. See Chapter 49.

Balanced anesthesia is achieved by the simultaneous use of multiple drugs and techniques. Different drugs contribute variably to specific components of the anesthetic state: amnesia, antinociception, muscle relaxation, and alteration of autonomic reflexes.

Dissociative anesthesia is induced by drugs (e.g., ketamine) that dissociate the thalamocortic and limbic systems. This form of anesthesia is characterized by a cataleptoid state, in which eyes remain open and swallowing reflexes remain intact. Skeletal muscle hypertonus persists unless a strong sedative or peripheral or central muscle relaxant is co-administered. See Chapter 27.

Electronarcosis, *electroanesthesia*, or *electrosleep* refers to the passage of electrical currents through the cerebrum to induce deep narcosis. Even though there have been successful studies, this form of anesthesia has never gained popularity and is rarely used in veterinary practice. Electronarcosis should not be confused with the inhumane practice of electroimmobilization.

General anesthesia is drug-induced unconsciousness that is characterized by controlled but reversible depression of the CNS and perception. In this state, the patient is not arousable by noxious stimulation. Sensory, motor, and autonomic reflex functions are attenuated to varying degrees, depending upon the specific drug(s) and technique(s) used.

Hypnosis is a condition of artificially induced sleep, or a trance resembling sleep, resulting from moderate depression of the CNS from which the patient is readily aroused.

Hypothermia refers to a decrease in body temperature, induced either locally or generally, to supplement insensitivity and decrease anesthetic drug requirements and reduce metabolic needs. It is primarily used in neonates or in patients undergoing cardiovascular surgery. See Chapter 34.

Inhalation or inhalant anesthesia refers to the practice of administering anesthetic gases or vapors via inhalation in combination with oxygen. See Chapter 28.

Injectable anesthesia refers to the practice of administering anesthetic solutions via intravenous, intramuscular, or subcutaneous injection. Other injectable routes include intraperitoneal and intrathoracic but, except for some laboratory animal species, these are not generally recommended. See Chapters 27 and 54.

Local and regional analgesia/anesthesia refers to loss of sensation, notably pain, in a particular area or region of the body, usually defined by the pattern of innervation of the affected nerve(s). Anesthetic drug may be applied topically or injected locally into or around the surgical site (variably referred to as "field block," "incisional block," or "infiltrative block"), perineurally around peripheral nerve(s), between fascial planes, or neuraxially (into the epidural or subarachnoid space). See Chapters 60, 63, and 66.

Narcosis is a drug-induced state of deep sleep from which the patient cannot be easily aroused. Narcosis may or may not be accompanied by antinociception, depending on the techniques and drugs used.

Nociception is the neural (physiologic) process of encoding noxious stimuli [5] that underlies the conscious perception of pain. Nociception does not require consciousness and can continue unabated during general anesthesia if techniques that interrupt or inhibit the transduction, transmission, and modulation of nociceptive stimuli are not utilized.

Oral (enteral) or rectal administration routes may be used to administer certain anesthetic or analgesic agents. There is often a greater degree of interspecies and interindividual variability in the dose–response relationship of orally administered drugs due to differences in absorption and first-pass hepatic metabolism.

Pain is an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage [5]. See Chapter 46.

Sedation is a state characterized by CNS depression accompanied by drowsiness and some degree of centrally induced relaxation. The patient is generally unaware of its surroundings but can become aroused and is responsive to noxious stimulation. Sedatives are not recommended to immobilize a patient when painful stimuli are likely to occur (e.g., surgery). See Chapter 22.

Surgical general anesthesia is the state/plane of anesthesia that provides unconsciousness, amnesia, muscle relaxation, and hypoalgesia sufficient for painless surgery.

Total intravenous anesthesia (TIVA), *partial intravenous anesthesia (PIVA)*, and *targeted controlled infusion (TCI)* describe anesthetic techniques that utilize intravenous infusion of one or more drugs to produce a suitable anesthetic state. Automated infusion systems are available that allow the input of patient parameters and pharmacokinetic information for specific drugs and allow the anesthesiologist to target a predetermined plasma drug concentration (TCI).

Tranquilization results in behavioral change wherein anxiety is relieved and the patient becomes relaxed but remains aware of its surroundings. Tranquilizers are drugs that result in tranquilization when administered; however, many prefer to use the term "anxiolytic" or "anti-anxiety" when describing drugs that decrease anxiety and induce relaxation. See Chapter 22.

Transcutaneous electrical nerve stimulation (TENS, TNS, or TES) is a technique that induces local analgesia by low-intensity, high-frequency electrical stimulation of the skin through surface electrodes. TENS has many similarities to electroacupuncture. See Chapter 49.

Twilight anesthesia is a state of heavy sedation where the patient is still conscious, but cooperative, and has limited or no recall (amnesia). This technique is popular for outpatient anesthesia in human medicine for diagnostic procedures and for minor surgical procedures when combined with local anesthetics and additional analgesic drugs. *Twilight anesthesia* is a term in common use by laypeople to connote heavy sedation and does not refer to a specific anesthetic procedure or technique.

History of veterinary anesthesia

While there are accounts in both ancient western and eastern historical texts chronicling various drugs and techniques used to achieve insensibility in humans and animals, little appears in the formal literature until the 19th century. Not surprisingly, the history of human and veterinary anesthesia is tightly interwoven, and the early timeline includes contributions from chemists, physicians, dentists, and veterinarians alike. Other authors have chronicled the early history and evolution of veterinary anesthesia at various points over the past 65 years, and a number of interesting reviews are available elsewhere for readers looking for more detail [6–14]. By taking the time to reflect on the history of our specialty, we are better able to appreciate its continued evolution.

Early milestones

In 1800, Humphrey Davy administered nitrous oxide to a guinea pig and suggested that it may have anesthetic properties. Twenty-four years later, Henry Hickman demonstrated that pain associated with surgery in dogs could be alleviated by inhaling a mixture of nitrous oxide and carbon dioxide. He reasoned that the latter increased the rate and depth of breathing, thus enhancing the effects of nitrous oxide. Much later, in the early 1990s, studies confirmed that unconsciousness could be induced in 30–40 seconds in piglets breathing carbon dioxide (50%) in oxygen (50%) [15].

It was not until 1842 that diethyl ether was used for human anesthesia, and within a year of William Morton's famous public demonstration of "etherization" at Massachusetts General Hospital in 1846, others began using ether to produce unconsciousness in animals. The Boston physician, Charles Thomas Jackson, was among the first to publish his findings about the use of ether in animals in 1853 [16]. In 1844, a dentist from Connecticut named Horace Wells rediscovered the anesthetic properties of nitrous oxide and recognized its potential for dental practice. While his work was neglected for a number of years, nitrous oxide was ultimately introduced to human anesthesia in 1862.

Chloroform was discovered by Justus Liebig in 1831, and in 1847, Marie Jean Pierre Flourens used it to induce anesthesia in animals. Around this time, British physician George H. Dadd had immigrated to the United States and begun practicing veterinary medicine where he routinely employed general anesthesia in his animal patients. He was one of the first veterinarians in the United States to advocate for the humane treatment of animals, including the use of anesthesia in veterinary surgery, and he vigorously promoted the application of sound scientific principles to the practice of veterinary medicine [17].

In 1875, Oré published the first monograph on intravenous anesthesia using chloral hydrate and, three years later, Humbert described its use in horses. Pirogoff was the first to attempt rectal anesthesia with chloral hydrate in 1847, and intraperitoneal injection was first described in 1892 in France. Thus, by the end of the 19th century, various routes of anesthetic administration had been identified, and rudimentary investigations into the safety and efficacy of multiple anesthetics had been undertaken.

After the initial isolation of cocaine by Albert Niemann in Germany in 1860, Anrep suggested the possibility of using cocaine as a local anesthetic in 1878. In 1884, Koller used cocaine for local anesthesia of the eye, and Halsted described cocaine regional anesthesia a year later. Its use was subsequently popularized by Frederick Hobday, an English veterinarian. In 1885, James Leonard Corning was credited for using cocaine for spinal anesthesia in dogs. From his description, however, it would appear that he induced epidural anesthesia. In 1898, August Bier induced true spinal anesthesia in animals and then in himself and an assistant [18].

While local infiltration was first popularized by Reclus in 1890 and Schleich in 1892, conduction regional anesthesia had been earlier introduced by Halsted and Hall in New York in 1884. These techniques increased in popularity with the discovery of local anesthetics less toxic than cocaine. Local anesthetics were used by Cuille and Sendrail in 1901 in France to induce subarachnoid anesthesia in horses, cattle, and dogs. That same year, Cathelin reported epidural anesthesia in dogs, but it remained for Retzgen, Benesch, and Brook to utilize this technique in larger species during the 1920s. Although paralumbar anesthesia was employed in humans by Sellheim in 1909, it was not until the 1940s that Farquharson and Formston applied this technique in cattle. Despite all these promising advances in the latter half of the 19th century, and presumably due in large part to many unfavorable side effects, general anesthesia was not broadly adopted by the veterinary profession until well into the 20th century. Unfortunately, a "heavy hand," without analgesia/anesthesia or even sedation, was the stock-in-trade of many "large animal" practicing veterinarians well into the latter half of the 20th century.

Although diethyl ether and chloroform were utilized in pets in the early part of the 20th century, general anesthesia was not widely accepted until the discovery of barbiturates in the late 1920s, in particular, the introduction of pentobarbital in 1930 and thiopental in 1934. Because of rough, prolonged recoveries, the acceptance of barbiturate general anesthesia in larger species was delayed until phenothiazines were introduced by Charpentier in France in 1950.

General anesthesia of large farm animals was further advanced by the discovery of fluorinated hydrocarbons and the development of "large animal" inhalant anesthetic equipment. Since the 1970s, the introduction of newer classes of drugs together with techniques for their safe co-administration (e.g., phenothiazines, benzodiazepines, α_2-adrenergic receptor agonists, opioids, guaifenesin, and dissociatives) has further advanced the safety and utility of anesthesia for both large and small animal species [8].

The modern era of veterinary anesthesia began during the last three decades of the 20th century facilitated by the establishment of anesthesia specialty colleges within North America and Europe. Stated organizational missions were the improvement of patient safety and the development of new techniques and knowledge paralleling the advances made in human anesthesia. These organizations promoted new drug development and techniques with clinical utility in a variety of species and individual patient pathologies. In addition, an emphasis on patient monitoring for improved safety led to the adaptation of technologies such as pulse oximetry, capnography, and blood pressure measurement, which are now considered standard. The veterinary anesthesiologist's value as a member of the patient care team has led to their increased presence in private veterinary practice. The need for more sophisticated approaches to anesthesia care continues to grow with an increasing patient age demographic and medical and surgical advances. This demand will continue to expand the anesthesiologist's importance beyond the traditional roles of university instructor and pharmaceutical researcher. Demand has also been bolstered by the veterinary profession's quest to improve patient quality of life through better pain management. Many anesthesiologists have become leaders in pain management through their continued research and the creation of evidence-based species-specific pain assessment scales and therapeutic guidelines.

Conceptualizing depth of anesthesia

During the early years of ether administration to human and veterinary patients alike, the assessment of anesthetic depth was a learned skill, appreciated most fully by individuals with much experience and the courage to learn from trial and error. John Snow was the first physician to attempt to classify the depth of anesthesia based on observation of the patient [19]. Teaching new anesthetists how much anesthetic to administer required close oversight by an experienced individual.

Dr. Arthur Guedel, a physician from Indianapolis, Indiana, serving in the First World War, was tasked with training orderlies and nurses to administer diethyl ether to wounded soldiers. To facilitate this, he developed guidelines summarized on a wall chart that could be used by anesthetists to gauge the depth of anesthesia.

While Guedel's original observations were made in human patients anesthetized with ether, they were subsequently adapted for use with newer inhalant anesthetics. Modern anesthetic techniques seldom utilize inhalants alone, and the incorporation of other drugs (notably antimuscarinics and dissociative anesthetics) greatly influences the reflexive and autonomic responses, making Guedel's classification less relevant. Greater reliance on the monitoring of physiologic parameters, such as blood pressure, respiration, and neuromuscular tone evolved over time, and the use of processed electroencephalographic (EEG) signals (i.e., "depth-of-anesthesia" devices) has become increasingly common in human anesthesia. Nevertheless, despite the incorporation of new monitoring modalities, the anesthetist should continue to have a solid understanding of changing physical signs with anesthetic depth. Thus, Guedel's early observational classification will likely continue to have some relevancy. For more information on the physical signs relating to anesthetic depth, as well as EEG-derived indices of CNS activity, the reader is referred to Chapter 10.

Evolution of veterinary anesthesia as a specialty

In North America, during the late 1960s and early 1970s, a small group of physician anesthesiologists made it possible for a number of future diplomates of the American College of Veterinary Anesthesiologists (ACVA), now the American College of Veterinary Anesthesia and Analgesia (ACVAA), to participate in their training programs and to learn about the development of new anesthetic drugs and techniques. Among these physicians were Robert Dripps, University of Pennsylvania; Arthur Keats, Baylor University; Mort Shulman and Max Sadolv, University of Illinois; and Edmond I. Eger, University of California Medical College. During this same period, E. Wynn Jones (Oklahoma State University) and William Lumb (Colorado State University) were making significant contributions to the field of veterinary anesthesiology. Jerry Gillespie had made significant contributions through his work on the respiratory function of anesthetized horses and William Muir was reporting on the cardiopulmonary effects of anesthetic drugs in various species.

Even though there were many dedicated faculty within North American veterinary colleges and research laboratories, it was not until 1970 that a major effort was made to organize a stand-alone specialty. Initially, the American Society of Veterinary Anesthesia (ASVA) was established, and membership was open to all individuals working in the veterinary profession who had an interest in veterinary anesthesiology. In 1970, the first organizational meeting was held in conjunction with the American Veterinary Medical Association (AVMA) to coordinate the efforts and interests of all those wishing to develop the specialty of veterinary anesthesiology. Their primary goal was to improve anesthetic techniques and to disseminate knowledge whenever and wherever possible. Charles Short was elected the first President of the new society. Of major emphasis was the selection of individuals to speak at the ASVA and other scientific and educational meetings. As the ASVA developed, publication of original research and review articles seemed in order. Bruce Heath accepted editorial responsibilities for manuscripts submitted for the ASVA journal. In 1971, John Thurmon chaired the Ad Hoc Committee to establish the ACVA. Based on guidelines defined by the AVMA for new specialty colleges, the Ad Hoc Committee defined the requirements for ACVA founding charter diplomates, which included 10 years of active service in the specialty, significant publication in the discipline, intensive training, and either being a recognized head of an anesthesiology program or spending the majority of one's professional time devoted to anesthesia or a closely related subject area. Seven members of the ASVA were found to meet these qualifications and became the founding diplomates of the ACVA.

Between 1970 and 1975, the constitution and bylaws were drafted and formalized. In 1975, the AVMA Council on Education recommended preliminary approval of the ACVA, and it was confirmed by the AVMA House of Delegates that same year. Of importance throughout this process were the insights and efforts of William Lumb and E. Wynn Jones. They greatly assisted in the establishment of the ACVA because of their sincere interest in the sound principles of veterinary anesthesiology. During this same period, several didactic texts had been published further establishing anesthesia as a stand-alone discipline within veterinary medicine. The first edition of this text, *Lumb and Jones' Veterinary Anesthesia*, was published in 1973, *Clinical Veterinary Anesthesia*, edited by Charles Short, was published in 1974, and the *Textbook of Veterinary Anesthesia*, edited by Larry Soma, was published in 1971.

During the late 1970s, many of the founding diplomates established residency training programs in their respective veterinary colleges. From 1975 to 1980, the ACVA developed continuing education programs, programs in self-improvement, and guidelines for testing and certification of new diplomates. Along with residency training programs, anesthesiology faculty positions were created in a number of universities across North America. In 1980, an effort headed by the then president Eugene Steffey sought and achieved the full accreditation of the ACVA by the AVMA.

During the past 50 years, a number of organizations outside North America have promoted and contributed greatly to the advancement of veterinary anesthesia. They include the Association of Veterinary Anaesthetists of Great Britain and Ireland (AVA) and the Veterinary Anesthesia and Surgery Association in Japan. These associations, along with the ACVA, were instrumental in organizing the first International Congress of Veterinary Anesthesiology with its stated objective of globally advancing the field of veterinary anesthesiology. The first International Congress was held in Cambridge, England, in 1982 and has been held continually on a triannual basis around the world and on nearly every continent.

During the latter decades of the 20th century, anesthesiologists in the United Kingdom had established the Association of Veterinary Anaesthetists and awarded the Diploma of Veterinary Anaesthesia to those with advanced specialty training. Later, interest in board specialization became increasingly evident in the United Kingdom and many European countries, resulting in the establishment of the European College of Veterinary Anaesthesiologists (ECVA). In order to better recognize the central role anesthesiologists have in providing and advancing pain management, both the ECVA and the ACVA sought and were granted approval to incorporate the word "analgesia" into their names. Thus, the colleges were renamed the European College of Veterinary Anaesthesia and Analgesia (ECVAA) and the American College of Veterinary Anesthesia and Analgesia (ACVAA). Currently, a number of veterinary anesthesiologists are boarded by both the ACVAA and the ECVAA. Both the organizations recognize the legitimacy of either credential, allowing residency training programs supervised by ACVAA Diplomates to qualify candidates to sit the ECVAA Board Examination and vice versa. Interested readers are referred elsewhere for further information concerning the early history of both veterinary [6–14] and human [20–22] anesthesia.

The establishment of the ACVAA and the ECVAA helped to advance veterinary anesthesia and pain management on a global scale through promotion of quality research and dissemination of knowledge via scientific meetings and peer-reviewed publications. The ACVAA and the AVA have their own official scientific publication, the *Journal of Veterinary Anaesthesia and Analgesia*, which also serves as the official publication of the ECVAA and the International Veterinary Academy of Pain Management (IVAPM).

During the early 2000s, in an effort to improve outreach to practitioners interested in humane care and to increase pain management awareness, the IVAPM was initially conceived at an annual Veterinary Midwest Anesthesia and Analgesia Conference Scientific Meeting. The IVAPM's stated mission was to advance the multidisciplinary approach to pain management and was supported by an ongoing academic–pharmaceutical industry partnership, the Companion Animal Pain Management Consortium, led by ACVAA Diplomates Charles Short, William Tranquilli, and James Gaynor. The first president-elect of the IVAPM was the then current president of the ACVA, Peter Hellyer. In 2017, the North American Veterinary Anesthesia Society (NAVAS) was incorporated to improve ACVAA Diplomate continuing education outreach in coordination with private and public partners that share a common goal of advancing quality anesthesia and analgesia care. Alleviating animal pain and suffering is an increasingly important and defining issue for 21st century veterinary medicine. Today, anesthesiologists, practitioners, veterinary technicians, research and industry veterinarians, and animal scientists alike are working collaboratively through organizations such as the ACVAA, ECVAA, IVAPM, AVA, AVTAA (Academy of Veterinary Technicians in Anesthesia and Analgesia), and NAVAS to improve our knowledge and coordinate educational programs.

Anesthesiologist defined

A *boarded anesthesiologist* is a veterinarian who has been certified by either the ACVAA or ECVAA. The term *anesthetist* has more variable meaning because in some European countries, an anesthetist is equivalent to an anesthesiologist. In North America, however, anesthetist refers to a person who administers anesthetics but is not a physician or veterinarian (board-certified or otherwise). A veterinary anesthesiologist has completed a rigorous training program under the supervision of either ACVAA or ECVAA Diplomates and has passed a veterinary certifying anesthesia and analgesia specialty examination (i.e., either the ACVAA or ECVAA Certifying Board Examination). Board-certified anesthesiologists are considered experts at assessment and mitigation of anesthetic risks, delivery of anesthetic and analgesic drugs, maintenance and monitoring of physiologic well-being in anesthetized patients, and provision of the highest levels of perioperative patient care, including pain management, across a wide array of species and medical circumstances [23].

Current issues in veterinary anesthesia and analgesia

Environmental impact of anesthesia

Concerns about potential adverse effects associated with the use of anesthetic drugs fall into three general categories: (1) patient-experienced adverse drug reactions (ADRs); (2) occupational exposure experienced by anesthesia care providers; and (3) environmental impacts of inhalation anesthetics.

Regarding the first category, while the definition of an ADR remains largely unchanged over the past 50 years, the classification systems and nomenclature used to describe such reactions change frequently. Specific patient-experienced ADRs are discussed in other areas of this text, and reviews of ADRs as they relate to anesthesia are available elsewhere [24,25]. Regarding the second category of adverse effects, anesthesia care providers may be sporadically and acutely exposed to both injectable and inhalant anesthetics via accidental needle penetration or drug spillage. This highlights the importance of staff training and implementation of health and safety standard operating procedures to minimize the risk of exposure in the first place and reduce negative outcomes in the event an exposure occurs. In addition, chronic workplace exposure to low levels of inhalant anesthetic agents (waste anesthetic gases) has been a concern since their use began. Although studied repeatedly, questions still exist about the relative risk of inhalant anesthetic toxicity and their potential to cause infertility, miscarriage, cancer, and other chronic health problems. Part of the difficulty in determining safe levels of exposure is related to the apparently low incidence of adverse effects and the potentially long lag period between exposure and expression of toxicity. Usually, the question is approached through large epidemiological studies of healthcare providers that are administering anesthetics. This introduces many confounders such as provider age, agents in use, co-existing health problems, and measurement of actual provider exposure, which may make interpretation and generalization of results problematic. Further information on occupational exposure to waste anesthetic gases is available in Chapter 28.

The third type of anesthetic adverse effect is environmental. Historically, drug development and clinical use of anesthetic agents did not consider the resources consumed to produce drugs or their ultimate fate once eliminated by the patient. Nitrous oxide and the chlorine- or bromine-containing halogenated inhalants (i.e., isoflurane and halothane) are both greenhouse gases and ozone depleters [26]. While the other halogenated agents that lack chlorine or bromine (i.e., sevoflurane and desflurane) do not catalytically destroy ozone, they remain important greenhouse gases as trace amounts in the atmosphere absorb and reduce outgoing infrared thermal energy and contribute to global warming [27]. Of the inhalant anesthetics in clinical use, desflurane is responsible for the largest greenhouse gas emissions during its atmospheric lifecycle. On a MAC-hour basis, desflurane's emissions are approximately 15 times that of isoflurane and 20 times that of sevoflurane. The concurrent use of nitrous oxide to facilitate delivery of inhalant anesthetics further increases emissions. Further information on the environmental impact of inhalation anesthetics is available in Chapter 28.

As the most widely used injectable anesthetic, propofol's impact on greenhouse gas emissions is much smaller, by nearly four orders of magnitude, than that of desflurane or nitrous oxide. Greenhouse gas emissions associated with propofol and many other injectable anesthetic drugs are primarily related to the production and consumption of fossil fuels needed to manufacture and deliver the drugs [28]. Although the contribution of volatile anesthetics to total greenhouse gas emissions remains relatively small (0.1%) compared to that of carbon dioxide (82%), it is still important to consider the long-term, cumulative impact of inhaled anesthetics on climate change and pursue strategies to minimize the introduction of these agents into the environment [27]. Increasingly, anesthesia professional organizations as well as governmental and intergovernmental bodies are moving from knowledge to action to address environmental stewardship and greenhouse gas mitigation [29].

Impact of the opioid epidemic on veterinary anesthesia

According to the United States Centers for Disease Control and Prevention, the number of drug overdose deaths in the United States increased by nearly 30% from 2019 to 2020 and has quintupled since 1999 [30]. Three waves of opioid overdose deaths are recognized. The first wave began in the late 1990s corresponding with the development of extended-release formulations of potent opioid medications (e.g., Oxycontin® and Vicodin®) coupled with aggressive marketing to physicians and significant increases in opioid prescribing activity. The second wave began in 2010 and was associated with a rapid increase in overdose deaths involving the illicit opioid, heroin. The third wave began in 2013 with significant increases in deaths involving synthetic opioids, particularly those involving illicitly manufactured fentanyl. In the United States and elsewhere, the market for illicit fentanyl continues to change and the drug is now commonly found in combination with heroin, counterfeit pills, cocaine, and other drugs particularly relevant to veterinarians including xylazine and ketamine.

As licensed prescribers of controlled substances, veterinarians have an important role to play in combating the opioid epidemic. As researchers, policymakers, and public health professionals struggle to identify and implement strategies to mitigate misuse and abuse of opioids, veterinarians are increasingly feeling the impacts of this public health crisis [31,32]. Despite the overuse and abuse of opioids in humans, veterinarians paradoxically have found themselves facing shortages of opioids for legitimate clinical use. Reasons for this are not always readily apparent but may be related to institution of production limits by some regulatory bodies on opioids approved for humans, as well as tightening of bureaucratic regulations.

In addition to drug shortages, veterinarians are confronting increasing and rapidly evolving legal restrictions and requirements around the management of controlled drugs. In the United States, for example, numerous states now mandate continuing education relating to opioids for veterinarians applying for or renewing licensure. Media reports involving drug-seeking individuals turning to veterinary practices have resulted in increased scrutiny on the profession [33], and a number of jurisdictions have introduced legislation requiring veterinarians to participate in prescription drug monitoring programs (PDMPs) [34]. The AVMA has expressed support for veterinary continuing education programs addressing the judicious use, compliance, security, and prescribing of opioids, but it does not support mandatory controlled drug electronic prescribing systems or veterinary practitioner participation in PDMPs [35].

In a concerning new development, xylazine has been increasingly identified as an adulterant in illicit preparations of heroin and fentanyl in the United States and Canada. This trend has more recently expanded to other jurisdictions including the United Kingdom and Europe. As xylazine's effects are obviously not reversed by opioid antagonists, and because α_2-adrenergic receptor antagonists have not been available to first responders, illicit xylazine is implicated as a cause of increased overdose deaths [36,37]. The United States federal government has recently identified the combination of illicit fentanyl and xylazine as an "emerging threat" [38] and has proposed federal legislation to combat diversion of xylazine from veterinary sources. This may have significant implications, especially for those veterinarians in large animal practice. More information is available elsewhere on these regulatory changes within the United States, as well as the position statement from the AVMA, which supports the legislation while highlighting the need for continued veterinary access to this critically important drug [39].

Finally, veterinarians are also impacted by diversion of controlled drugs both by individuals working within a veterinary practice as well as those not affiliated with the practice (e.g., drug-seeking clients and outright drug theft). "Vet shopping" refers to the practice of soliciting multiple veterinarians under false pretenses to obtain prescriptions for controlled drugs [31,34]. In general, the best way for veterinarians to protect themselves, their staff, and their clients is to: (1) remain up-to-date and follow all regulations (both regional and federal) regarding the prescription of controlled substances in their jurisdiction; (2) exercise extreme caution when prescribing and dispensing opioids to clients for at-home pain medication and provide education on safe storage and disposal of their pet's medications; (3) embrace opioid-sparing techniques for in-hospital pain management where appropriate; (4) recognize the signs of opioid intoxication in pets and know how to treat it; and (5) recognize the signs of opioid abuse in clients and colleagues [40]. Additional resources to assist veterinarians in navigating the opioid epidemic are available from a number of national veterinary organizations such as the AVMA [41]. Further information on the opioid crisis is available in Chapter 23.

Emerging role of technology

The role of technology in human healthcare has expanded exponentially over the last two decades beginning with the transition to electronic health records and spawning the development of an entirely new subspecialty within anesthesia known as "anesthesia informatics." Collaboration between motivated anesthesiologists and software developers resulted in commercial Anesthesia Information Management Systems (AIMS) that are now used in both community hospitals and referral centers [42]. The ongoing need to adapt and optimize these sophisticated systems means that "anesthesiologist-informaticists" will likely play an increasing role in electronic anesthesia records, perioperative computerized decision-making support, and virtual patient care [43].

In veterinary medicine, the transition from paper to electronic management systems is underway and software has now evolved from primarily practice management tools (i.e., scheduling, inventory, billing, etc.) to capturing most aspects of the patient's medical record. While veterinary-specific anesthetic monitoring technology has made considerable advances, technology to capture and record that information has, until recently, lagged behind [42]. Several veterinary-specific anesthesia electronic medical record (AEMR) applications are available including the SurgiVet™ Advisor® Veterinary Data Logger (Smiths Medical), the SmartFlow® Patient Workflow Anesthetic Sheet (IDEXX Laboratories), and the Veterinary Digital Anesthesia Record, VetDAR® (Dimple Hill Software). Further information about each of these products, as well as the advantages and disadvantages of AEMRs more generally, is available elsewhere [42,44]. As these applications become more widely used in primary care veterinary practice, new opportunities for veterinary anesthesiologists to expand their scope of practice have emerged through both synchronous and asynchronous teleconsulting services. In the near future, it seems likely that an alternative care model may evolve whereby veterinary anesthesiologists are able to remotely monitor patients and consult from afar using cloud-based technologies [44].

Another emerging technology in veterinary anesthesia involves the use of simulation as an education and training tool. While simulation has been used in pre-clinical medical training for decades, development of applications for veterinary medicine, specifically anesthesia, is more recent. At least one veterinary simulation program is commercially available (Stage III Veterinary Education Simulation software, WholeLogic Inc.), and it is reportedly used by several veterinary medical colleges as part of their anesthesia curriculum [45]. A number of recent publications indicate that veterinary anesthesia simulation-based training has the potential to enhance cognitive and affective outcomes and better prepare students for patient care experiences [46–48].

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2 Anesthetic Risk and Informed Consent

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Chapter contents

Assessing anesthetic risk

Perioperative assessment of anesthetic risk is a valuable exercise in order to minimize complications and optimize anesthetic safety. A number of studies have been published in relation to anesthetic morbidity and mortality in both small and large animals. Based on this evidence, improved recognition of the risks of anesthesia and those patients that require the greatest care and preoperative management could help improve standards of veterinary anesthesia and patient outcome. For more information on related topics, the reader is referred to Chapters 3 and 5.

Preoperative patient risk assessment

Patient health assessment

The preoperative assessment of an animal's health status is valuable to acknowledge preanesthetic risks, to identify management priorities, and to advise clients appropriately prior to anesthesia and surgery. Health status has been consistently reported to be associated with anesthetic death in humans and in the spectrum of species commonly seen in veterinary anesthesia. Increased American Society of Anesthesiologists (ASA) physical status grade [1,2] (see Table 2.1) has been associated with an increased risk of death in a number of anesthetic studies in small animals [3–14], horses [15–18], and humans [19–39].

Anesthetic agents cause cardiopulmonary depression, and the presence of concurrent pathology involving the major body systems is likely to predispose to greater anesthetic-induced physiologic disturbance [40]. Pre-existing cardiopulmonary pathology is particularly relevant in the immediate preoperative period, as anesthetic-related mortality is likely to involve respiratory or cardiovascular compromise, and most anesthetics depress one or both systems at clinical levels of anesthesia [40].

Hematologic and biochemical abnormalities may also be a significant consideration. In particular, anemia will reduce oxygen-carrying capacity and predispose to hypoxia, and hypoproteinemia has been theorized to increase the response of the patient to highly protein-bound drugs and result in relative overdose [40]. Renal disease is also important, particularly if dehydration or uremia is present, as under these conditions, the renal system will have a lower tolerance to anesthesia and the patient may be more sensitive to some anesthetics and perioperative drugs such as non-steroidal anti-inflammatory agents. Neurologic disease may be relevant with respect to the occurrence of postoperative seizures, increased sensitivity to anesthetics, and when cardiopulmonary function is affected, e.g., medullary pathology can depress ventilation and cardiovascular function. Additionally, liver and endocrine disease may influence the response to anesthesia, with diabetes mellitus and potential intraoperative cellular changes in glucose concentrations being particularly relevant [41].

Hence, some form of physical health status assessment is an important preanesthetic consideration. Most frequently, ASA grade [1,2] has been utilized for this purpose, and there is some evidence that this can identify patients at increased risk of mortality until 24–72 h postanesthesia [42]. However, the repeatability and agreement between observers of such scoring systems have been questioned, and evidence suggests that interobserver agreement in ASA health status classification is poor in veterinary anesthesia [43]. Other assessment systems exist in human medicine, including the Acute Physiology and Chronic Health Evaluation (APACHE),

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Companion website: www.wiley.com/go/lamont/anesthesia

Table 2.1 Classification of physical status[a].

Category	Physical status	Possible examples of this category
1	Normal healthy patients	No discernible disease, e.g., animals scheduled for elective ovariohysterectomy, or castration
2	Patients with mild systemic disease	Skin tumor, fracture without shock, uncomplicated hernia, or compensated cardiac disease (e.g., stage B1 mitral valve disease)
3	Patients with severe systemic disease	Moderate anemia or hypovolemia, moderate renal or hepatic dysfunction
4	Patients with severe systemic disease that is a constant threat to life	Sepsis, marked hyperkalemia (e.g., urinary obstruction), end-stage organ disease (e.g., renal, hepatic, or cardiac), marked hypovolemia, or severe anemia
5	Moribund patients not expected to survive 24 h without the operation	Massive trauma

[a] This classification is the same as that adopted by the American Society of Anesthesiologists.

the Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM), and, in pediatric practice, the Neurological, Airway, Respiratory, Cardiovascular and Other (NARCO) score, and all were observed to predict perioperative risk [44–46]. However, these systems are complex, require more time to complete, and have yet to be evaluated for agreement between observers in a veterinary context. Hence, at present, there appears to be little consensus as to the optimal method of patient health status assessment for consistent and efficient classification across observers, and caution should be exercised in overinterpreting individual health status assessments. Nonetheless, there is a body of evidence that highlights that sicker patients are more likely to die perioperatively, and therefore, some form of preoperative patient assessment would be advisable to distinguish sick from healthy patients, to identify those at greater risk, and to manage patients appropriately in order to try to minimize risk prior to, during, and after anesthesia.

Preanesthetic blood testing

Given the fact that organ dysfunction and various pathologic conditions such as anemia or hypoproteinemia may contribute to increased anesthetic morbidity or mortality, it would seem sensible to make every effort to detect these prior to general anesthesia. For this reason, routine preanesthetic blood screening is commonly recommended by many veterinary practitioners and, indeed, some anesthesia specialists. However, although there is no doubt that prior biochemical and hematologic analyses are of definite value in certain patient groups, the question remains as to whether their use can be justified for every patient, in particular healthy animals undergoing elective procedures.

An internet search for "Preanesthetic blood screening in animals" (www.google.com, accessed July 2022) returned over 18 million hits, of which a substantial proportion appeared to be veterinary practices each detailing their reasons and prices for carrying out such a procedure; interestingly, the search term returned virtually no scientific papers relating to the practice. In addition, as with much information to be found on the internet, many of the relevant web pages providing advice on the subject were written by people with no apparent scientific background or credentials for discussing such a topic, with the majority of these being pet owner discussion forums. Although there may be no genuine scientific or clinical background behind these types of discussion groups, they almost certainly help perpetuate the need for ubiquitous preanesthetic blood testing, but given that many veterinary professionals also recommend its routine use, it obviously cannot all be dependent on owner perceptions. So, is there actually a sound rationale upon which the need for preanesthetic biochemical and hematologic sampling is based?

There are numerous studies in human anesthesia now questioning the necessity for preanesthetic laboratory testing in healthy patients [47–49], with each of these demonstrating that, for subjects with no demonstrable abnormalities on the basis of history and clinical examination, there appears to be no reduction in perianesthetic complications if prior blood sampling has been carried out. The United Kingdom (UK) National Institute for Health and Care Excellence (NICE) gathers evidence from a variety of sources and then produces recommendations for human clinicians for various medical and surgical interventions. In terms of preanesthetic blood testing, NICE subdivides its recommendations based on both the age of the patient and the grade of surgery the subject is undergoing (minor, intermediate, or major/complex). Based on this system, NICE does not recommend preanesthetic biochemical or hematological screening for ASA 1 or 2 human patients undergoing minor or intermediate grades of surgery, although assessment of renal function should be considered in ASA 2 subjects having intermediate surgery if they have some predisposition to development of possible acute kidney injury; in other words, unless the patient is sick, preanesthetic blood tests would only be recommended for humans undergoing major/complex surgery. Unsurprisingly, NICE does suggest considering preanesthetic blood screening for ASA 3–5 patients undergoing intermediate or major procedures [50].

As a result of the NICE recommendations, the guidelines of the Association of Anaesthetists of Great Britain and Ireland (AAGBI) [51] for human anesthesia conclude: "Routine preoperative investigations are expensive, labor intensive, and of questionable value, especially as they may contribute to morbidity or cause additional delays due to spurious results."

Aside from the issue of erroneous results impacting on the efficiency of case throughput, it is also important to remember that the reference ranges established for most laboratory tests incorporate only approximately 95% of the population, i.e., around one in 20 animals that are perfectly healthy will return laboratory results that are outside a "normal" range, which may then lead to further unnecessary investigations being carried out, in addition to delaying the planned procedure; the more tests that are run, the greater the likelihood of this occurring. Hence, it is important to carefully interpret test results obtained and to view them as part of the overall assessment of the patient.

The AAGBI also takes the view that history and examination performed by appropriately trained and competent personnel remain the most efficient and accurate way of initially detecting significant morbidity: "Thus, it is important that, where preanesthetic blood screening is carried out, it is seen as an adjunct to a full clinical examination, rather than an alternative." While this is undoubtedly the case in both veterinary and human anesthesia, the results from human studies relating to preanesthetic blood screening of healthy patients may not be directly applicable to animals. This is because the majority of humans are both cognitive and verbal and are able to self-report health issues. Veterinary clinicians, on the other hand, obtain the relevant health information by proxy (from the owner), which may mean that important details are not identified. Thus, it is possible that a higher incidence of abnormalities may be detected on preanesthetic screening of animals than has been reported for humans.

Given that the consensus opinion from human anesthesia seems to be that preanesthetic blood sampling appears to be justifiable only in sicker patients, and that healthy individuals undergoing elective procedures do not benefit from this practice, what recommendations should be put in place for veterinary anesthesia? There appear to be only a small number of studies relating to the validity of routine preanesthetic blood screening in animals [52]. Toews and Campbell [53] performed a complete blood count in 102 horses undergoing cryptorchidectomy and then determined whether any abnormalities detected impacted on the risk of surgical complications. They found that 55 animals had results outside the reference range for at least one hematologic parameter, but there was no correlation between those demonstrating abnormal values and the likelihood of either intra- or postoperative surgical complications, nor did these abnormalities dictate alterations in patient management. Alef *et al.* [54] analyzed results from over 1500 dogs undergoing anesthesia at the University of Leipzig and reported that if no potential issues were identified in either the animal's history or clinical examination, "the changes revealed by preoperative screening were usually of little clinical relevance and did not prompt major changes to the anesthetic technique." They concluded that preanesthetic blood screening is, therefore, unlikely to yield additional important information in most cases. However, the same study also documented that of those dogs where the history and clinical examination would not normally have resulted in preanesthetic laboratory testing being performed at their institution (equivalent to 84% of the dogs recruited), 8% demonstrated biochemical or hematologic abnormalities that would have reclassified them as a higher ASA status, even if this may not necessarily have altered the anesthetic protocol. In addition, they also identified that surgery would have been postponed due to the laboratory findings in 0.8% of these dogs where preanesthetic blood screening would not usually have been performed, while 1.5% would have received additional preanesthetic therapy. Although the authors concluded that only 0.2% of dogs in the study would have required an alteration to their proposed anesthetic protocol based on the biochemical or hematologic results, the implication that undiagnosed pathology may be detected prior to anesthesia using "routine" screening may have implications for whether the owner decides to proceed with anesthesia/surgery and may also alter the expected prognosis for the animal. Thus, from this study, despite the fact that preanesthetic biochemical and hematologic testing may not necessarily alter how the subsequent anesthetic would actually be performed in most animals, it may, in reality, be the deciding factor as to whether the procedure goes ahead. Davies and Kawaguchi [55] conducted a retrospective study of almost 800 dogs and cats of varying ASA status which underwent preanesthetic blood screening at a UK veterinary group practice and showed that 97% of cats and 95% of dogs had at least one result from the screening panel that was outside the reference interval (although not necessarily clinically significant). Almost 1% of cases had problems identified by the preanesthetic blood results that were not evident from the history or physical examination, while 4% of dogs and 9% of cats had their anesthetic protocol altered based on abnormalities in the blood work, although these cases were being anesthetized by first opinion practitioners rather than specialist anesthesiologists. A more recent study by Mitchell *et al.* [52], which presented five Diplomates of the American College of Veterinary Anesthesia and Analgesia with the medical records from 100 randomly selected previously presented cases, subsequently followed by the relevant results from preanesthetic blood screening tests for these animals, resulted in a change in the proposed anesthetic protocol in 79% of patients, based on abnormalities in the blood results. Of note is that 64% of changes were made by only one of the anesthesiologists, which suggests that there may be significant variability in whether alterations in certain preanesthetic tests are considered clinically relevant even between specialists.

While it is often said that "old age is not a disease," it might be intuitive to assume that older patients may require more intensive preanesthetic screening compared to those who are younger. However, with the exception of recommending a preanesthetic electrocardiogram (ECG) in patients greater than 65 years old undergoing major/complex surgery, NICE does not differentiate the requirements for preanesthetic assessment based on age alone, i.e., they do not suggest blood testing older patients of ASA 1 or 2 undergoing minor or intermediate procedures unless there are certain comorbidities (e.g., diabetes mellitus and cardiovascular or renal disease). In animals, Joubert [56] assessed whether hematologic and biochemical analyses were of value in geriatric dogs (> 7 years of age) presented for anesthesia. Of the 101 dogs recruited to the study, 30 new diagnoses (e.g., neoplasia and hyperadrenocorticism) were made on the basis of the blood sample, with 13 animals not undergoing general anesthesia as a result of the new diagnosis. However, similar to the conclusions of the study by Alef *et al.* [54], Joubert [56] suggested that although preanesthetic screening had revealed the presence of subclinical disease in almost 30% of the dogs in the study, and that screening of geriatric patients is important, "the value of screening before anesthesia is perhaps more questionable in terms of anesthetic practice, but it is an appropriate time to perform such an evaluation." In other words, although preanesthetic blood testing may be of value in uncovering undiagnosed pathology in geriatric patients, there was little evidence that what was detected would actually impact either how the subsequent anesthetic was managed, or the overall outcome from it. However, this study did identify that over 10% of the dogs had their anesthesia canceled due solely to the findings of the preanesthetic blood screening, which is obviously of significance.

Interestingly, and somewhat in contrast to the previous studies, work within the Confidential Enquiry into Perioperative Small Animal Fatalities (CEPSAF) highlighted a reduction in risk when preoperative blood work was performed in higher ASA grade patients. CEPSAF was a multicenter study undertaken in the UK between 2002 and 2004 and involved over 100 practices and data from approximately 200,000 dogs and cats [7]. When analyzing risk factors for anesthetic death in sick dogs (ASA grade 3–5), having a preoperative blood test was associated with reduced odds of death, particularly in ASA grade 4–5 dogs [57]. This association was not detected in the overall analyses where ASA grade 1–5 dogs were considered together or in cats but does suggest that preoperative biochemistry and hematology are most likely to be merited in the sicker animals that are anesthetized.

Thus, based on the evidence from human anesthesia, and from a smaller number of published veterinary studies, there would appear to be negligible benefit to apparently healthy animals (ASA 1 or 2, regardless of age) of biochemical or hematologic screening prior to anesthesia in terms of either anesthetic risk reduction or alteration of the anesthetic protocol; however, given that a significant percentage of animals may have the procedure canceled based on the results of these tests (due either to a worsened prognosis or the need for further treatment prior to anesthesia), this may counterbalance the preceding argument. Overall, the requirement for preanesthetic