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NEUROSURGERY IN VETERINARY MEDICINE: PRINCIPLES AND PERSPECTIVES

Elias Victor Figueiredo dos Santos

Jadenn Rúbia Lima Costa

Bruna Katarine Beserra Paz

Carla Karine Figueiredo Lopes

Maria Bernardete Barros Figueiredo

Ana Maria Monteles Silva

Walérya Lima Silva Santos Mendonça

Anali Linhares Lima

Herlane De Olinda Vieira Barros

Bruno Demétrio Carvalho

Matheus Levi Tajra Feitosa

Luiz Carlos Rêgo Oliveira

Abstract: Veterinary neurosurgery works to diagnose and treat neurological disorders in animals, such as brain tumors and spinal cord injuries. A detailed anamnesis and a precise neurological examination help determine the appropriate surgical approach. Surgery, combined with post-operative rehabilitation, aims to restore neurological function and improve patients' quality of life, guaranteeing positive long-term results. This work aims to provide a broad overview of the principles, techniques and perspectives of veterinary neurosurgery, thus contributing to the advancement and improvement of healthcare for animals with nervous system disorders. This study was conducted by means of a bibliographical review, following a qualitative and descriptive approach. This study concludes that veterinary neurosurgery is an area in constant evolution, where the integration of multidisciplinary knowledge, including neuroanatomy, advanced surgical techniques and post-operative rehabilitation, aim to guarantee better clinical results.
Keywords: Neurological Diagnosis; Treatment; Rehabilitation.

INTRODUCTION

According to Fortuna (2018), veterinary neurosurgery is the branch of medicine that deals with the diagnosis and surgical treatment of animals with diseases of the nervous system. This discipline deals with some of the pathologies that affect the brain, spinal cord and peripheral nerves, such as: brain tumors, intracranial hematomas, skull fractures, hydrocephalus, intervertebral disc herniations with spinal cord compression, cervical spondylomyelopathy, degenerative stenosis lumbosacral, tumors or lesions of the spine, spinal cord and peripheral nerves.

According to Dro, a complete anamnesis and a neurological examination are the most essential aspects when approaching a patient with some alteration of the nervous system, as it is essential to correctly identify the problem and its exact anatomical location. During the neurological examination, the animal's behavior, posture, spinal reflexes, postural reactions, cranial nerves, skin sensation, tone and muscle mass should be observed. Lesions in the midbrain, caudal brainstem, cerebellum, spinal cord and peripheral nerves usually cause changes in gait, such as ataxia (proprioceptive, vestibular or cerebellar) or paresis (NELSON; COUTO, 2019).

According to a retrospective study carried out between 1989 and 2000 at the Small Animal Hospital of the Faculty of Veterinary Medicine at the University of Bern, Switzerland, it was found that the most frequent neurological pathologies in dogs were intervertebral disc disease and idiopathic epilepsy (LEANDRO, 2016).

According to *Deer et al.* (2019), spinal cord compression and damage can be caused by intervertebral disc disease, spinal fractures or dislocations, neoplasms or hematomas, some of which require surgical intervention. The clinical symptoms of spinal cord compression will depend on the extent, dynamics and location of the lesion. Patients may present with anything from signs of pain on paravertebral palpation to complete absence of motor function, with or without deep sensitivity.

In neurosurgery, extensive knowledge of surgical technique and neuroanatomy aims to ensure that procedures are precise and safe. In addition, proper maintenance of anesthesia during surgery minimizes risks and ensures patient comfort. Surgery is the first step on the road to recovery. However, post-operative physical rehabilitation contributes to restoring neurological function and optimizing the patient's quality of life, ensuring long-lasting and successful results (DE LAHUNTA *et al.*, 2020).

In this context, the problem is: How can we optimize the effectiveness and safety of veterinary neurosurgery to deal with the challenges encountered in clinical practice, while ensuring better diagnostic methods, prognosis and postoperative rehabilitation for animals with nervous system disorders?

This work is justified by the growing field of neurosurgery in veterinary medicine, both in diagnostic and therapeutic terms. With increasing awareness of animal welfare and advances in surgical and diagnostic imaging techniques, there is a growing demand for trained professionals in this area. In addition, studies into the prevalence of neurological diseases in pets are on the rise, making the dissemination of up-to-date knowledge on the subject even more relevant.

This work aims to provide a broad overview of the principles, techniques and perspectives of veterinary neurosurgery, thus contributing to the advancement and improvement of healthcare for animals with nervous system disorders. In addition, it will identify the challenges faced in the practice of veterinary neurosurgery, analyze the diagnostic and prognostic methods used in this area and investigate approaches to post-neurosurgical animal rehabilitation.

DEVELOPMENT

METHODOLOGY

This study was conducted by means of a literature review, following a qualitative and descriptive approach. The aim of the research was to analyze the available literature on the subject in question. To this end, we consulted books, dissertations and scientific articles selected by searching relevant databases such as Scielo, Google Scholar and Scopus.

The period of the articles searched included papers published in the last ten years. The keywords used in the search included veterinary neurosurgery, veterinary medicine, neurological pathologies, among others pertinent to the subject under study. This methodology provided a broad and up-to-date analysis of the existing literature on the subject, allowing for a more in-depth understanding of the subject.

RESULTS AND DISCUSSIONS

The history of veterinary neurosurgery is linked to the development of veterinary medicine over the centuries. As discussed by Shores and Brisson (2023), this field dates back to the human need to guarantee the health of animals, which is vital for subsistence, the economy and society. The first efforts in veterinary medicine were aimed at the diseases of cattle, sheep and horses, which were essential for food and transportation.

The first school of veterinary medicine was founded in Lyon, France, in 1762. Educational progress and the institutionalization of veterinary practice gave impetus to veterinary neurosurgery, based on a growing understanding of animal anatomy and physiology. This history of continuous evolution aims to improve animal health and welfare through the intersection of veterinary medicine and neuroscience (SHORES; BRISSON, 2023).

This area of veterinary neurosurgery works on the health and well-being of animals, as many neurological conditions can be debilitating and even fatal if not treated properly. As mentioned by Fortuna (2018) in his dissertation on feline intestinal mastocytoma, veterinary neurosurgery offers a specialized approach to dealing with a wide range of neurological conditions, from brain tumors to spinal cord injuries.

Proper understanding and application of the principles of neurosurgery are key to the success of surgical procedures and to improving patients' quality of life. In addition, technological developments and improvements in neurosurgical techniques have broadened the

treatment options available to veterinarians, allowing for more accurate diagnosis and more effective interventions.

Despite advances in veterinary neurosurgery, challenges remain. Intraoperative complications, complex conditions and individual patient variations can affect the expected results. Limitations in the availability of resources, such as advanced equipment and specialists, in some regions or clinics, can impact diagnosis and treatment, compromising the validity of the results obtained (FEITOSA, 2023).

The principles of a complete anamnesis and neurological examination are fundamental in veterinary practice, as highlighted by Nelson and Couto (2019). The anamnesis gathers information about the patient's history, symptoms and exposures. The neurological examination identifies alterations in the nervous system, from subtle deficits to obvious dysfunctions. It assesses reflexes, posture, gait, sensitivity and cranial nerves, allowing the veterinarian to locate and assess the severity of the problem.

In some findings, such as those of Pires (2018), it was possible to ascertain that it is sometimes difficult to differentiate whether a change in gait is caused by an orthopedic disease or a neurological alteration. To differentiate between them, Leandro (2016) mentions that postural reactions and cranial and spinal nerves should be assessed. Once the neuroanatomical location has been determined, complementary tests must be carried out to reach a diagnosis. Complementary tests include magnetic resonance imaging, cerebrospinal fluid analysis and myelography.

The prognosis of patients with neurological injuries due to trauma depends on the severity of the clinical presentation, reflecting tissue damage, and the start of treatment. The modified Glasgow coma scale is used to predict prognosis in animals with head trauma, especially to determine survival in the first 48 hours. Scores in three categories determine favorable, reserved or severe prognoses (ASH *et al.*, 2018).

One of the main challenges faced when dealing with a patient with acute head trauma is identifying an increase in intracranial pressure (ICP). In clinical practice, recognizing the Cushing's reflex (hypertension and bradycardia) helps to identify elevated ICP, as it is a compensatory mechanism in the face of decreased cerebral blood perfusion (LA RU *et al.*, 2020).

Hasegawa *et al.* (2022) explain that increased intracranial pressure (ICP) reduces cerebral perfusion, raising CO2. This stimulates the cerebral vasomotor centers to release catecholamines, inducing peripheral vasoconstriction. This response can lead to complications such as myocardial necrosis, arrhythmias (brain-heart syndrome) and hyperglycemia. The rise in blood pressure triggers a reflex bradycardia by the carotid sinus baroreceptors.

Alizadehet al. (2019) describe that after a spinal cord injury, events are divided into secondary, consisting of acute (0-48 h), subacute (48 h to 2 weeks) and chronic (more than 2 weeks) phases. And primary damage results from the initial traumatic injury, causing cell disruption due to continuous compression by elements such as herniated disc material and displaced vertebrae, leading to impaired perfusion and direct damage to myelin and axons. In severe cases, complete sectioning of the spinal cord can occur.

According to Joaquim *et al.* (2019), primary damage generates a series of secondary events that cause an expansive zone of tissue destruction. These events include hemorrhage, destruction of the microvascular bed, rapid changes in the concentration of intracellular ions, production of free radicals, inflammation and apoptosis. The approach to patients with spinal fractures or dislocations with spinal cord compression should be immediate, as the time it takes to treat them will directly influence the prognosis.

Although studies on spinal cord injuries provide a clear framework, unexpected results can occur. For example, the urgency of treatment does not always correspond to the extent of the damage. Conflicting explanations suggest variability in individual response to injury. Limitations include microvascular complexity and variation in the extent of cell damage, impacting the validity of conclusions.

Spinal cord compression, due to various conditions such as disc disease or neoplasms, can cause a variety of symptoms, from pain to paralysis. The clinical test of deep pain perception is considered the gold standard for assessing prognosis in paraplegic patients. Although other tools have been sought for a more objective assessment, none have demonstrated sufficient specificity or sensitivity to replace clinical assessment (VINICKI *et al.*, 2018).

Another common neurological pathology, as observed in the studies by Deer *et al.* (2019), in which the treatment of choice is surgery, is lumbosacral degenerative stenosis. This degenerative pathology is characterized by degeneration and protrusion of the intervertebral disc, subluxation or inflammation of the articular facets with thickening of the joint capsule and hypertrophy of the interarcuate ligament. It is important to differentiate this from any alteration of the hip joint, such as hip dysplasia, and from other less common causes, such as infections or neoplasms.

According to *Deer et al.* (2019), treatment can be surgical or non-surgical, depending on the nature of the lesion produced in the cauda equina (static or dynamic, central or lateralized, acute or chronic), the chronicity and severity of the clinical signs. The prognosis for lumbosacral decompression, with or without stabilization, is favourable and 75% of animals recover completely, unless they have had urinary and faecal incontinence for more than 6 weeks prior to surgery.

In neurosurgery, the integration of surgical technique and neuroanatomy is crucial for successful interventions. De *LaHunta et al.* (2020) point out that this synergy ensures precision and safety. Understanding the anatomy of the nervous system, both macro- and microscopically, is essential. Navigating the brain, spinal cord and nerves requires familiarity with their topography and relationship to surrounding structures. Precise knowledge of surgical technique minimizes risks during the procedure.

During the research, another point that was mentioned a lot was anesthetic practice in different clinical and surgical contexts. In the context of cranioencephalic trauma, authors such as Dias (2022) emphasize the need for targeted anesthetic management, highlighting the need to prevent changes in blood pressure, central venous pressure, PaO2, PaCO2 and blood pH. This aims to prevent cerebral perfusion pressure from being compromised, thus ensuring adequate oxygenation and nutrition of brain tissue in patients affected by this condition.

According to La Ru *et al.* (2020), the use of drugs that cause an increase in intracranial pressure should be avoided due to the risk of cerebral herniation. During the perioperative period, pain management and the implementation of adequate antibiotic therapy contribute to the animal's well-being. Patients with head trauma and skull fractures with persistent CSF leaks for more than 24 hours are at risk of developing meningitis, many require surgical intervention and the administration of prophylactic antibiotics has been shown to halve the risk of meningitis in these cases.

It was noted that in neurosurgery, anesthesia is maintained by inhalation, but that inhalation anesthetics cause cerebral vasodilation and therefore affect intracranial pressure. In this case, assessing the patient using a multi-parameter monitor represents an advance in veterinary clinical practice, especially in complex cases such as cranioencephalic trauma.

As highlighted by Feitosa (2023) in his case report, the use of this type of monitoring allows for a broad and continuous analysis of different physiological parameters, such as heart rate, respiratory rate, blood pressure, oxygen saturation and body temperature. Integrating this information in real time enables a more accurate assessment of the patient's condition, quickly identifying possible complications and guiding therapeutic intervention. In addition, the multi-parameter monitor operates in the early detection of alterations that may indicate clinical deterioration, allowing proactive intervention to prevent serious complications and improve the patient's prognosis.

In the literature, extensive documentation on the post-surgical context highlights its influence on the patient's prognosis and well-being. In addition to adequate pain management, there is a variety of information on aspects such as infection control, nutrition, early mobilization and monitoring of vital signs, all of which help to optimize post-operative recovery.

As exemplified by Wagner *et al.* (2022), after any surgical intervention, physical rehabilitation contributes to patients' recovery and quality of life. In their study of patients undergoing neurosurgical resection to treat central nervous system (CNS) tumors, the authors highlight the relationship between length of stay and mortality. They show that effective rehabilitation can reduce the length of stay, thus minimizing the risk of complications associated with prolonged hospitalization and contributing to a faster and more complete recovery for patients.

The post-neurosurgery perspectives most addressed by the authors include approaches such as thermotherapy, aquatic therapy, massage, electrotherapy and controlled walks. Thermotherapy and aquatic therapy are emerging as promising therapeutic modalities in animal rehabilitation, as highlighted by Madeira (2020). Thermotherapy, which involves the use of heat or cold to relieve pain and promote recovery, has been recognized for its benefits in reducing inflammation, relieving muscle stiffness and stimulating blood circulation.

On the other hand, aquatic therapy offers another approach, taking advantage of the physical properties of water to provide a low-impact environment that facilitates movement and muscle strengthening, as well as promoting cardiovascular conditioning. Both modalities offer significant potential in animal rehabilitation, offering safe alternatives to improve the quality of life and functionality of animals in the process of recovery (MADEIRA, 202O).

Massage, electrotherapy and controlled walks represent other approaches to animal rehabilitation, and are cited by Caramico (2019) in his thesis on the rehabilitation of dogs with severe spinal cord injury in the thoracolumbar vertebrae, without surgical intervention. Massage therapy, for example, promotes muscle relaxation, improves blood circulation and helps reduce pain (LIEBANEO, 2021).

Electrotherapy, on the other hand, uses electric currents to stimulate the muscles, promoting recovery of muscle function and pain relief. Controlled walking aids rehabilitation by providing a gradual and supervised means of exercise, strengthening muscles and improving coordination. These therapeutic modalities, combined with thermotherapy and aquatic therapy, offer a complete approach to animal rehabilitation, maximizing recovery potential and improving patients' quality of life.

The study by Las Casas *et al.* (2022) represents a breakthrough in veterinary neurosurgery by creating a computational surgical guide for the precise insertion of implants into canine vertebral bodies. This approach reflects the growing trend in veterinary medicine to adopt innovative methods to improve clinical outcomes, offering advantages such as reducing surgical time and personalizing treatment for each patient.

The applicability of video neurosurgery in the treatment of compressive myelopathy due to disc herniation in dogs and cats, as discussed by Siqueira *et al.* (2022), stands out as another example of technological progress in veterinary medicine. This approach offers an enlarged and detailed view of the surgical field, allowing for a more precise and less invasive intervention. By combining the precision of video imaging with high-tech surgical instruments, veterinarians can perform procedures more safely and effectively, minimizing damage to surrounding tissues and improving post-operative results.

Video neurosurgery offers the additional advantage of allowing complex procedures to be transmitted in real time, facilitating continuing education and collaboration between professionals. Thus, both the study by Las Casas *et al.* (2022) and the research by Siqueira *et al.* (2022) highlight the value of increasing technology in promoting animal welfare and improving veterinary medical care.

CONCLUSION

This study sought to address the challenges faced in veterinary neurosurgery, with the aim of optimizing the effectiveness and safety of procedures, as well as improving methods of diagnosis, prognosis and post-operative rehabilitation for animals with nervous system disorders. Throughout the work, the main challenges in the practice of veterinary neurosurgery were identified, from the complexity of neurological conditions to resource limitations and unexpected results in certain cases. Despite technological advances and improved neurosurgical techniques, there are still situations in which surgical intervention does not produce the expected results, highlighting the relevance of a multidisciplinary and adaptive approach.

An analysis of the diagnostic and prognostic methods used in veterinary neurosurgery revealed the importance of a complete anamnesis and neurological examination in the initial assessment of patients, as well as the relevance of complementary tests, such as magnetic resonance imaging and cerebrospinal fluid analysis, for an accurate diagnosis.

In addition, an understanding of the principles of neuroanatomy and the ability to apply appropriate surgical techniques were highlighted as crucial to the success of the procedures. With regard to post-neurosurgery rehabilitation, different therapeutic modalities were explored, such as thermotherapy, aquatic therapy, massage, electrotherapy and controlled walks, which showed significant potential for improving the quality of life and functionality of animals in the process of recovery.

It is therefore concluded that veterinary neurosurgery is an area in constant evolution, where the integration of multidisciplinary knowledge, including neuroanatomy, advanced surgical techniques and post-operative rehabilitation, aims to guarantee better clinical results. Despite the challenges and limitations faced, this study highlights the continuity of research and collaborative clinical practice to improve the healthcare offered to animals with nervous system disorders. By sharing knowledge and experiences, it is possible to overcome obstacles, identify gaps in knowledge and develop new strategies to improve the efficacy and safety of veterinary neurosurgical procedures, providing a better quality of life for patients and their guardians.

A suggestion for future work would be to investigate the impact of artificial intelligence and virtual reality in veterinary neurosurgery, exploring how these technologies can improve preoperative planning, precision during procedures and postoperative rehabilitation of patients. This would include the analysis of machine learning algorithms for diagnosis and prognosis, as well as the development of virtual simulation environments for training veterinary surgeons. This research could provide new insights into the potential of these technological innovations to optimize healthcare for animals with nervous system disorders.

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