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Benefits and Challenges of Laparoscopic Surgery in Veterinary Medicine

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Abstract Laparoscopic surgery has gained widespread application in veterinary medicine as a minimally invasive technique in recent years. This technology not only significantly reduces postoperative pain and accelerates recovery but also improves surgical outcomes by enhancing visualization and precision. However, challenges such as the technical complexity, high equipment costs, and potential complications still hinder its broader adoption in the veterinary field. This study aims to systematically explore the benefits and challenges of laparoscopic surgery in veterinary medicine, using case studies to conduct a detailed comparison between laparoscopic and traditional surgery, and to examine future development directions. The research is expected to provide valuable insights for improving veterinary surgical practices and animal care quality.

Keywords Laparoscopic surgery; Veterinary medicine; Minimally invasive technique; Surgical outcomes; Technical challenges

1 Introduction

Laparoscopic surgery, a minimally invasive surgical technique, has become increasingly widespread in veterinary medicine. By inserting a camera and specialized instruments into the animal's body through small incisions, veterinarians can perform various diagnostic and therapeutic procedures. Compared to traditional open surgery, laparoscopic surgery offers several advantages, including reduced postoperative pain, shorter recovery times, and a lower risk of infection (Tapia-Araya et al., 2015; Rosewell et al., 2016; Bianchi et al., 2021). Although the adoption of laparoscopic techniques in veterinary medicine lagged behind human medicine by about 10 to 15 years, it has developed rapidly. Since the first laparoscopic sterilization procedure in dogs in 1985, this technique has been widely applied in surgeries such as ovariectomies, biopsies, and more complex procedures like adrenalectomies and pericardiectomies (Manas sero and Viateau, 2018). Despite the initial high cost of equipment and the need for specialized training, the benefits of laparoscopic surgery have led to its gradual acceptance as a routine procedure in veterinary practice (Rosewell et al., 2016; Saber et al., 2017).

Minimally invasive techniques are increasingly recognized as essential in veterinary care due to their ability to significantly reduce surgical trauma, minimize stress, and accelerate postoperative recovery, which are critical for the overall well-being of pets and the satisfaction of their owners (Rosewell et al., 2016; Fernández-Martín et al., 2022). Laparoscopic surgery, a key minimally invasive approach, offers enhanced visualization of the surgical field, allowing for more precise and safer procedures (Manassero and Viateau, 2018; Bianchi et al., 2021). Beyond clinical advantages, these techniques also lead to shorter hospital stays and decreased postoperative care needs (Chao et al., 2015; Manassero and Viateau, 2018), which not only improve the quality of life for pets but also provide economic benefits for both veterinary practices and pet owners by reducing overall costs and recovery time (Steffey et al., 2016; Lacitignola et al., 2021). As the demand for advanced, less invasive procedures continues to grow, these techniques are becoming a cornerstone of modern veterinary medicine, setting new standards for effective, safe, and compassionate care (Monnet, 2019; Lacitignola et al., 2021; Bianchi et al., 2021).

This study conducts a systematic review of current literature to analyze the benefits and challenges associated with laparoscopic surgery in veterinary medicine. The study covers the advantages of minimally invasive techniques, such as reduced postoperative pain and faster recovery times, while also discussing the challenges

related to equipment requirements and specialized training. By synthesizing findings from various studies, this research aims to provide new perspectives on the current state of laparoscopic surgery in veterinary medicine and to identify areas for future research and improvement.

2 Benefits of Laparoscopic Surgery

Laparoscopic surgery offers numerous benefits over traditional open surgery, including reduced postoperative pain, faster recovery, enhanced visualization and precision, decreased risk of infection and complications, and improved patient outcomes and quality of life.

2.1 Reduced postoperative pain and faster recovery

Laparoscopic surgery (LS) is associated with significantly reduced postoperative pain and faster recovery times compared to open surgery. This is primarily due to the minimally invasive nature of the procedure, which results in less tissue trauma and smaller incisions. Studies have shown that patients undergoing LS experience less postoperative pain, which contributes to a quicker return to normal activities and shorter hospital stays (Mandrioli et al., 2016; Bianchi et al., 2021; Basunbul et al., 2022). For instance, a study comparing laparoscopic and open pancreatoduodenectomy found that although the median time to functional recovery was similar, the overall recovery experience was better for laparoscopic procedures due to less pain and discomfort (Hilst et al., 2019).

2.2 Enhanced visualization and precision

One of the key advantages of laparoscopic surgery is the enhanced visualization and precision it offers. The use of high-definition cameras and specialized instruments allows surgeons to have a magnified view of the surgical area, leading to more precise and controlled movements. This improved visualization is particularly beneficial in complex surgeries, such as those involving the gastrointestinal tract or urology, where precision is crucial for successful outcomes (Figure 1) (Mandrioli et al., 2016; Basunbul et al., 2022). The magnification of the surgical field also aids in the identification and preservation of critical structures, reducing the risk of inadvertent damage (Bianchi et al., 2021).

Figure 1 illustrates the application process of systematic review and meta-analysis in laparoscopic surgery. The detailed diagram explains the various factors involved in the laparoscopic surgery process. Particularly in terms of enhanced visualization and precision, laparoscopic surgery is significantly superior to traditional surgery. This figure demonstrates how operating through small incisions can reduce postoperative pain, accelerate patient recovery, and thereby improve overall treatment outcomes, making it an essential reference for discussing the benefits of laparoscopic surgery(Bianchi et al., 2021; Cerullo et al., 2022).

2.3 Decreased risk of infection and complications

Laparoscopic surgery is also associated with a reduced risk of postoperative infections and complications. The smaller incisions in laparoscopic surgery (LS) decrease the chance of internal tissues being exposed to external contaminants, thereby lowering the risk of infection. Additionally, minimal tissue trauma and reduced handling of organs contribute to fewer complications, such as wound infections and intra-abdominal abscesses (Bianchi et al., 2021). A meta-analysis of laparoscopic gastrointestinal surgeries in patients with chronic obstructive pulmonary disease (COPD) showed lower rates of wound infections and intra-abdominal abscesses compared to open surgery, highlighting the safety and effectiveness of LS in reducing postoperative complications (Guo et al., 2019).

2.4 Improved patient outcomes and quality of life

The cumulative benefits of reduced pain, faster recovery, enhanced precision, and lower risk of complications translate into improved overall patient outcomes and quality of life. Patients undergoing laparoscopic surgery often experience shorter hospital stays, quicker return to daily activities, and better cosmetic results due to smaller scars (Seishima et al., 2015; Mandrioli et al., 2016; Basunbul et al., 2022). For elderly patients, in particular, LS has been shown to significantly reduce perioperative mortality and postoperative complications, making it a preferable option for this vulnerable population. The improved outcomes and quality of life associated with LS underscore its growing acceptance and application in various surgical fields, including veterinary medicine.

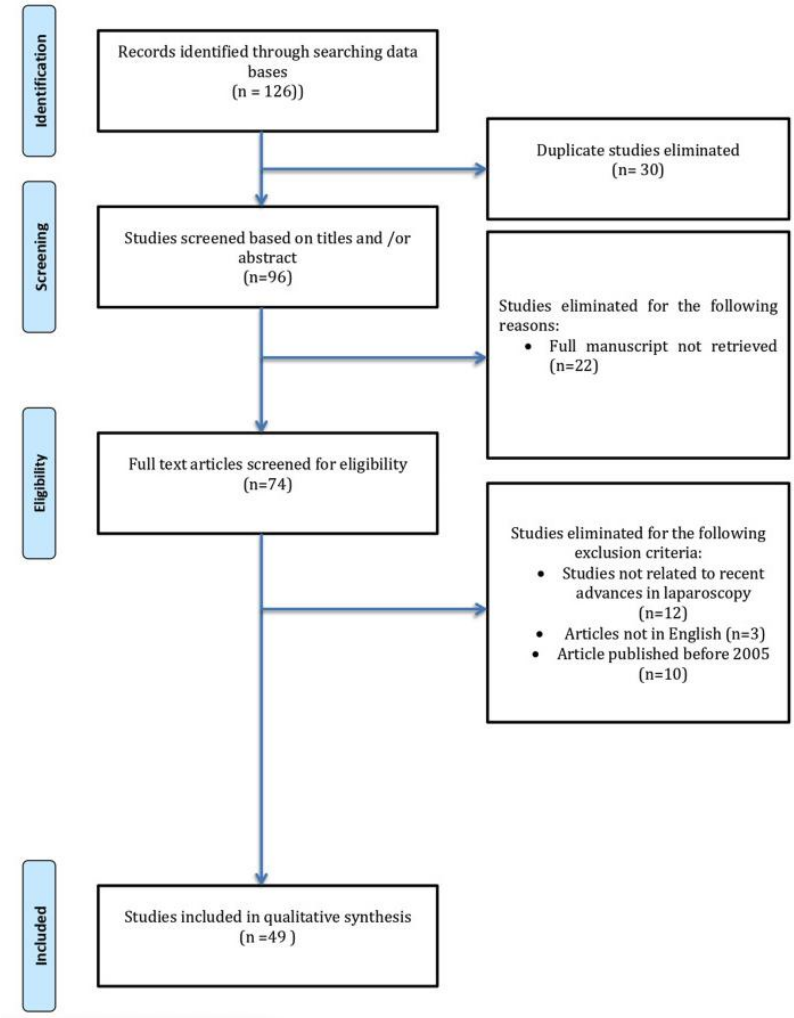

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for laparoscopic surgeries (Adopted from Basunbuli et al., 2022)

3 Challenges of Laparoscopic Surgery

3.1 Technical complexity and skill requirements

Laparoscopic surgery in veterinary medicine demands a high level of technical skill and precision. The complexity of the procedures requires extensive training and practice to achieve proficiency. Current training methods often rely on simulators designed for human surgery, which may not adequately replicate the anatomical and procedural nuances of veterinary applications (Oviedo-Peñata et al., 2020). Additionally, the transition from simulated environments to actual surgical settings can be challenging, as skills acquired in one plane may not transfer effectively to another, highlighting the need for diverse and comprehensive training models (Lencioni et al., 2017). The steep learning curve associated with laparoscopic techniques can also lead to increased risk of complications, as evidenced by higher complication-related mortality rates in complex procedures like laparoscopic pancreatoduodenectomy.

3.2 High equipment costs and maintenance

The financial burden of laparoscopic surgery is significant, encompassing the costs of specialized equipment, maintenance, and training programs. In low- and middle-income countries, these costs can be prohibitive, limiting the adoption and sustainability of laparoscopic techniques (Bawa et al., 2023). Even in more affluent settings, the high initial investment and ongoing maintenance expenses can be a barrier for veterinary practices. The need for advanced imaging systems, such as three-dimensional (3D) vision, which has been shown to improve performance and reduce errors, further adds to the financial strain (Sørensen et al., 2015).

3.3 Limited availability and accessibility

The availability of laparoscopic surgery in veterinary medicine is often restricted by geographic and economic factors. In many regions, there is a lack of trained surgeons and adequate facilities to perform these procedures. This limitation is exacerbated in low- and middle-income countries, where the introduction of laparoscopic surgery faces numerous challenges, including reliance on foreign trainers and limited access to surgical kits and equipment (Bawa et al., 2023). The scarcity of structured training programs tailored to veterinary needs further hinders the widespread adoption of laparoscopic techniques (Oviedo-Peñata et al., 2020).

3.4 Potential complications and limitations

Laparoscopic surgery, while minimally invasive, is not without risks. Complications can arise from the initial entry into the abdomen, with potential injuries to the bowel, bladder, or major blood vessels. The choice of entry technique, whether open or closed, can influence the risk of these complications, but no single method has been proven superior in preventing major injuries (Ahmad et al., 2015; Monnet, 2019). Additionally, the creation of pneumoperitoneum, a critical step in laparoscopic procedures, can prolong operation times and increase the risk of complications such as organ perforation and subcutaneous emphysema (Bianchi et al., 2021). The limitations of current training models, which often do not adequately replicate in vivo conditions, further contribute to the potential for errors and adverse outcomes (Chen et al., 2017; Oviedo-Peñata et al., 2020).

4 Case Study in Place

4.1 Introduction to the case study

Laparoscopic surgery has become increasingly prevalent in veterinary medicine due to its numerous benefits, including reduced post-operative pain, lower infection rates, and shorter recovery times (Rosewell et al., 2016; Lacitignola et al., 2021). This case study focuses on a laparoscopic ovariectomy performed on a female dog, comparing two different techniques for creating pneumoperitoneum: the Veress needle technique (VNT) and the modified Hasson technique (MHT). The aim is to highlight the procedural details, outcomes, and implications for veterinary practice.

4.2 Description of the procedure and patient

The patient was a 3-year-old female dog scheduled for an elective laparoscopic ovariectomy. The procedure began with the creation of a pneumoperitoneum, a critical step that allows for the insertion of laparoscopic instruments into the abdominal cavity. Two techniques were considered: the Veress needle technique (VNT) and the modified Hasson technique (MHT) (Figure 2). The dog was randomly assigned to the MHT group. The MHT involves a small incision through which a blunt-tipped cannula is inserted, allowing for direct visualization and minimizing the risk of organ injury (Bianchi et al., 2021).

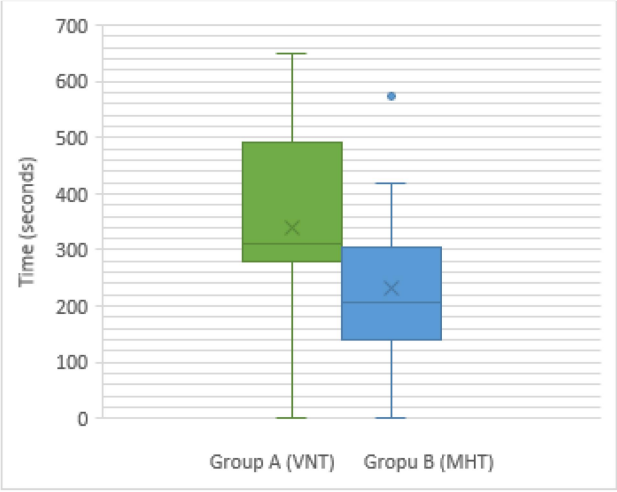

Figure 2 A box plot showing the distribution of times taken for the placement of the first portal and the establishment of a pneumoperitoneum in groups A (VNT) and B (MHT) (Adopted from Bianchi et al., 2021)

In the description of the surgery and patient, the Veress Needle Technique (VNT) and the Modified Hasson Technique (MHT) are two commonly used methods for creating pneumoperitoneum. VNT is often chosen for its simplicity and faster operation time, but it may carry a higher risk of complications. MHT, on the other hand, is favored for its safer and more stable abdominal entry, especially in cases with complex anatomical structures or high-risk patients. By comparing these two techniques, a deeper understanding of their advantages and challenges in different surgical scenarios can be gained, helping to determine the optimal surgical method to improve patient outcomes and surgical success rates.

4.3 Outcomes and observations

The MHT was found to be faster and safer compared to the VNT. Specifically, the time required for the first portal placement and the establishment of pneumoperitoneum was significantly shorter with the MHT (242.9 seconds) compared to the VNT (374.0 seconds). Additionally, the MHT had a lower rate of major complications (0%) compared to the VNT (20%). Minor complications, such as subcutaneous emphysema and gas leakage, were observed in both techniques but were more frequent in the MHT group (35%) compared to the VNT group (20%) (Bianchi et al., 2021). No surgical procedures required conversion to laparotomy, indicating the overall safety and efficacy of the laparoscopic approach.

4.4 Lessons learned and implications for practice

This case study underscores the advantages of the modified Hasson technique in reducing both the time required for the first portal placement and the risk of major complications. The findings suggest that the MHT should be considered the preferred method for creating pneumoperitoneum in laparoscopic procedures in veterinary practice. The reduced operation time and lower complication rates associated with the MHT can lead to better patient outcomes and increased efficiency in veterinary surgical practices (Tapia-Araya et al., 2015; Rosewell et al., 2019; Bianchi et al., 2021). Additionally, the study highlights the importance of continuous training and the adoption of advanced laparoscopic techniques to further minimize risks and improve surgical outcomes (Manassero and Viateau, 2018; Monnet, 2019; Fernández-Martín et al., 2022).

5 Comparative Analysis: Laparoscopic vs. Traditional Surgery

5.1 Comparison of outcomes

Laparoscopic surgery has been shown to offer several perioperative advantages over traditional open surgery. For instance, studies have demonstrated that laparoscopic major hepatectomies result in shorter hospital stays and lower overall morbidity compared to open procedures, although the operative time tends to be longer (Kasai et al., 2018). Similarly, laparoscopic distal gastrectomy for advanced gastric cancer is associated with lower postoperative complication rates, reduced blood loss, and shorter hospital stays, despite longer surgical times (Chen et al., 2020). In the context of colorectal surgery, laparoscopic approaches have been found to confer lower mortality and morbidity rates, particularly in elderly patients (Antoniou et al., 2015). However, the long-term survival rates between laparoscopic and open surgeries for conditions such as colorectal liver metastases and hepatocellular carcinoma appear to be comparable (Kasai et al., 2018; Syn et al., 2019).

5.2 Cost-benefit analysis

The cost-benefit analysis of laparoscopic versus traditional surgery is multifaceted. While laparoscopic procedures often involve higher initial costs due to longer operative times and the need for specialized equipment, these costs can be offset by shorter hospital stays and reduced postoperative complications. For example, laparoscopic gastrectomy for locally advanced gastric cancer has shown similar short-term mortality and serious adverse event rates compared to open surgery, but with less intraoperative blood loss and shorter hospital stays, potentially leading to overall cost savings (Beyer et al., 2019). Additionally, the reduced morbidity associated with laparoscopic procedures can translate into lower long-term healthcare costs due to fewer complications and readmissions (Antoniou et al., 2015).

5.3 Patient and owner satisfaction

Patient and owner satisfaction is an important consideration in veterinary surgery. Training veterinary students in laparoscopic techniques has been shown to improve their confidence and skills, which can positively impact the

quality of care provided (Levi et al., 2015). Moreover, the minimally invasive nature of laparoscopic surgery often results in better cosmetic outcomes and less postoperative pain, which can enhance owner satisfaction (Li et al., 2022). In human medicine, robotic-assisted surgeries, which are an extension of laparoscopic techniques, have been associated with improved quality of recovery and pain scores, further suggesting that minimally invasive approaches are well-received by patients (Muaddi et al., 2020).

5.4 Long-term effects and follow-up

The long-term effects and follow-up outcomes of laparoscopic versus traditional surgery are generally comparable in terms of survival rates and disease recurrence. For instance, studies have shown no significant difference in long-term survival between laparoscopic and open surgeries for colorectal liver metastases and advanced gastric cancer (Kasai et al., 2018; Syn et al., 2019; Chen et al., 2020). However, laparoscopic surgery has been associated with a lower hazard rate of death and a higher fraction of long-term cancer survivors in some cases, indicating potential long-term benefits (Syn et al., 2019). Additionally, the long-term weight loss outcomes of laparoscopic bariatric procedures, such as Roux-en-Y gastric bypass, have been found to be superior to those of traditional methods (Shoar and Saber, 2017).

While laparoscopic surgery offers several perioperative advantages and potential long-term benefits, the choice between laparoscopic and traditional surgery should be based on a comprehensive evaluation of the specific clinical scenario, patient characteristics, and available resources.

6 Future Directions in Laparoscopic Veterinary Surgery

6.1 Technological advances and innovations

The future of laparoscopic veterinary surgery is likely to be shaped by ongoing technological advancements. Innovations such as three-dimensional (3D) vision systems have been shown to improve surgical performance and reduce stress and workload for surgeons (Margallo et al., 2020). Additionally, the development of more sophisticated simulators and augmented reality systems can provide more effective training environments, allowing veterinarians to practice complex procedures in a controlled setting (Levi et al., 2016; Oviedo-Peñata et al., 2020).

6.2 Training and education for veterinarians

Effective training programs are crucial for the successful implementation of laparoscopic techniques in veterinary practice. Studies have demonstrated that both skill-based and procedural-based training curricula can significantly improve basic laparoscopic skills in veterinary students (Chen et al., 2017). However, there is a need for more structured and validated training models that can simulate real-life scenarios and provide comprehensive feedback. Incorporating advanced simulators and telemedicine into training programs can enhance the learning experience and ensure that veterinarians are well-prepared for laparoscopic procedures (Figure 3) (Chao et al., 2015; Oviedo-Peñata et al., 2020).

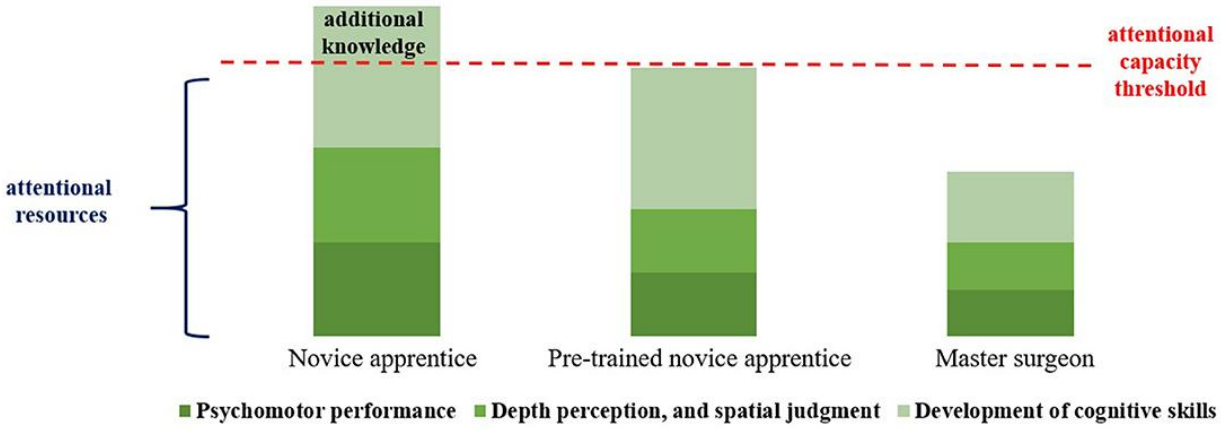

Figure 3 Benefits of hypothetical attentional resources of simulation training described (Adopted from Oviedo-Peñata et al., 2020)

Oviedo-Peñata et al. (2020) detailed the benefits of potential attentional resources in simulation training, emphasizing that effective training programs are crucial for the successful implementation of laparoscopic surgery. Through simulation training, surgeons can practice in a safe and controlled environment, reducing the error rate and risk of complications during actual surgeries.

6.3 Expanding applications and new procedures

As technology and training methods improve, the range of applications for laparoscopic surgery in veterinary medicine is expected to expand. Currently, laparoscopic techniques are primarily used for procedures such as ovariectomies and gastrointestinal surgeries. However, with better training and more advanced equipment, veterinarians may be able to perform a wider variety of procedures, including more complex surgeries like pancreatoduodenectomies and tumor resections (Xiong et al., 2017; Hilst et al., 2019). This expansion will not only improve animal welfare but also enhance the capabilities of veterinary surgeons.

6.4 Addressing current challenges and barriers

Despite its benefits, laparoscopic surgery in veterinary medicine faces several challenges. These include the high cost of equipment, the need for specialized training, and the potential for increased operation times and complications. Addressing these barriers will require a multifaceted approach. For instance, developing cost-effective training models and simulators can make laparoscopic training more accessible (Levi et al., 2016). Additionally, adopting adaptive strategies such as the use of cheaper instruments and telemedicine for training can help overcome some of the logistical and financial challenges (Chao et al., 2015). Finally, ongoing research and collaboration between veterinarians, policymakers, and manufacturers will be essential to ensure the sustainable development and implementation of laparoscopic techniques in veterinary practice.

7 Concluding Remarks

Laparoscopic surgery in veterinary medicine has shown significant advantages, particularly in reducing wound complications, alleviating postoperative pain, shortening hospital stays, and speeding up recovery times. Studies indicate that the modified Hasson technique is faster and safer for creating pneumoperitoneum in canine ovariectomy compared to the Veress needle technique, with lower rates of major complications. As single incision laparoscopic surgery (SILS) becomes increasingly popular in small animal surgery, further research is needed to fully understand its potential advantages over multiport techniques.

The adoption of laparoscopic techniques in veterinary practice can significantly improve patient outcomes, especially for elderly patients with higher surgical risks. These minimally invasive techniques not only reduce surgical trauma but also enhance the precision of procedures due to the magnification provided by laparoscopic equipment. However, the choice of entry technique remains crucial, as it significantly impacts the safety and success of the procedure.

Future research should focus on large-scale randomized controlled trials to compare the complication rates of different laparoscopic entry techniques, providing clearer guidelines for laparoscopic surgery in veterinary medicine. Additionally, further evaluation of the long-term outcomes of single incision laparoscopic surgery is necessary, particularly in terms of postoperative pain, surgical times, and complication rates. Comprehensive laparoscopic skills training should be incorporated into veterinary training programs to ensure that practitioners are well-prepared to perform these advanced surgical techniques safely and effectively.

Lastly, exploring alternative methods for creating pneumoperitoneum, such as gasless laparoscopy or the use of different insufflation gases, could further enhance the safety and efficacy of laparoscopic procedures in veterinary practice. These research efforts will likely lead to broader applications of laparoscopic techniques in veterinary medicine, offering more benefits to animal healthcare.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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