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Research Article

Laparoscopy in Veterinary Abdominal Surgery: Techniques, Applications, and Future Perspectives

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ABSTRACT

Laparoscopy has revolutionized veterinary abdominal surgery by offering minimally invasive approaches that reduce postoperative pain, enhance recovery, and improve surgical outcomes. This review provides a comprehensive analysis of laparoscopic techniques, their applications, and future perspectives in veterinary medicine. The primary focus is to explore the versatility and efficacy of laparoscopic procedures in the management of various abdominal pathologies in animals. The key procedures covered include laparoscopic treatments for pancreatic diseases, cryptorchidism, and ovariectomy, with a focus on their technical implementation and clinical importance. The application of laparoscopy in addressing small bowel obstruction and gastric dilatation-volvulus (GDV), along with the utilization of gastropexy, highlights its role in managing life-threatening conditions. Splenectomy and diagnostic laparoscopy, including hepatic examinations, are reviewed for their diagnostic and therapeutic potentials. Furthermore, advancements in laparoscopic techniques for gallbladder and biliary tract pathologies are evaluated, demonstrating the breadth of their applicability. The review also addresses the advantages of laparoscopy in veterinary practice, such as reduced invasiveness, shorter hospital stays, and reduction of postoperative complications. However, challenges like the steep learning curve, high equipment costs, and limitations in certain patient populations are critically analyzed. Prospects in the field, including innovations in instrumentation and integration of robotics, are explored to illustrate the potential for enhancing surgical precision and expanding applications. In conclusion, laparoscopy represents a transformative advancement in veterinary abdominal surgery, providing numerous benefits while posing unique challenges. Continued research and technological progress hold the promise of overcoming existing limitations and further optimizing outcomes, paving the way for broader adoption and innovation in the veterinary field.

1. Introduction

Laparoscopy in veterinary medicine is a minimally invasive surgical technique that allows clinicians to examine the internal structures of the abdominal cavity with minimal trauma[1]. The procedure begins by inflating the abdominal cavity with gas, creating a clear field of vision and space to work within. A rigid telescope, known as a laparoscope, is then inserted through a small incision in the abdominal wall, providing a detailed and direct view of the peritoneal cavity and its contents. This approach enables veterinarians to observe and assess the condition of internal organs without the need for open surgery[1]. Once the laparoscope is in place, additional instruments, such as biopsy forceps or other surgical tools, can be inserted through adjacent small incisions. This allows for a variety of diagnostic or therapeutic procedures, such as tissue biopsies or removal of abnormal growths. By minimizing tissue trauma, laparoscopy significantly reduces postoperative pain, infection risk, and recovery time in

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animals, making it a highly effective and low-risk option for veterinary diagnostics and treatments[2].

One of the primary advantages of laparoscopy is that it allows for direct visualization of internal organs while significantly reducing the need for traditional exploratory surgery. This technique offers enhanced control and precision for the clinician, surpassing non-invasive imaging techniques such as X-rays, ultrasound, and MRI in providing a clear and comprehensive view of the abdominal viscera[1]. Additionally, the minimally invasive nature of laparoscopy not only minimizes patient discomfort and recovery time but also allows for repeated examinations if required, providing a practical approach to ongoing abdominal assessments[3].

Over the past 15 years, laparoscopy has rapidly evolved and is now considered the gold standard for a wide range of diagnostic and therapeutic procedures in human medicine[4]. Its popularity stems from several significant advantages, including minimal surgical trauma, which translates into reduced pain, reduced morbidity rates, and fewer complications. Patients undergoing laparoscopic surgery generally experience low infection rates, quicker recovery times, and enhanced visualization due to the magnification provided by the laparoscope, which allows for better identification of vessels and anatomical structures, thereby increasing the precision of the procedure[4].

Despite its many benefits, laparoscopic surgery is not without risks. Although it is often suggested that closing the 5-mm portal site muscle layer is unnecessary, cases of omental herniation through these small portal sites have been documented, particularly in veterinary applications, such as in dogs[5]. Additionally, subcutaneous emphysema a condition where air becomes trapped under the skin can occur due to the unintentional insufflation of gas into subcutaneous tissue, either through the veress needle (VN) or a laparoscopic port. Other complications may arise from the use of electrosurgical or electrocautery devices, while effective in coagulating tissue and controlling bleeding, can inadvertently cause thermal injury to surrounding organs. Operative risks also include hypothermia, which can result from the continuous insufflation of cool gas into the abdominal cavity. Severe complications linked to gas insufflation may include gas embolism, where gas enters the bloodstream, or pneumothorax, which is the unintended entry of gas into the chest cavity, potentially compromising lung function. Overall, while laparoscopy offers a safer and more effective alternative to traditional open surgery, careful procedural management and awareness of potential complications are essential to ensure patient safety and optimal outcomes[5].

A study comparing the outcomes of minimally invasive surgery (MIS) with open surgery (OS) in animals found a notable reduction in surgical site infection (SSI) rates in the MIS group, with only 1.7% of animals experiencing infection compared to 5.5% in the OS group. This finding was supported by univariate analysis, which confirmed the low SSI rate in minimally invasive procedures. Further multivariable analysis suggested that factors such as longer surgery durations and earlier hair clipping in the OS group may have contributed to the increased infection risk observed in open surgeries. These results underscore the potential benefits of MIS in reducing postoperative complications and improving recovery outcomes in veterinary surgery[6]. Although laparoscopy is often seen as a less invasive procedure, it may not be appropriate for every patient. Laparoscopy should not be performed in patients who have diaphragmatic hernia and significant intra-abdominal adhesions. Avoid doing laparoscopic procedures in animals that are obese, have respiratory problems, or are in a generally unhealthy condition while pyometra is typically seen as a reason to avoid laparoscopy, there have been documented cases of laparoscopy-assisted ovariohysterectomy being performed successfully in two female dogs with pyometra[7].

This article aimed to review and summarize current knowledge on laparoscopy in the abdominal cavity, highlighting its advantages, applications, and potential complications in veterinary medicine. Through an in-depth exploration of laparoscopy.

2. Techniques and instruments for laparoscopy in abdominal surgery

In animal laparoscopic surgery, the techniques and instruments must be specifically tailored to accommodate the unique anatomical and physiological characteristics of each species. The physical differences, such as size and body structure, require precise adjustments in angles and settings to ensure optimal access and visibility for the surgeon. Additionally, some instruments need subtle modifications to allow safe entry into the body and maneuverability within the surgical site without damaging sensitive tissues. The appropriate selection of port diameter and instrument length is tailored to the size and tissue sensitivity of the species being treated, ensuring both the safety of the procedure and precise control of the tools. With these precise adjustments, minimally invasive surgeries can be performed successfully across different animal species. The tower and monitor must be aligned directly with the surgeon's body and the telescope's angle for optimal visualization and ergonomics. Minimally invasive abdominal surgery techniques vary depending on the specific treatment being performed, with the number and positioning of portals often tailored to the surgeon's discretion. These portals are typically placed on the front side of the abdomen in an arrangement similar to a baseball field, aiding in the triangular positioning of instruments for precise control. Alternative methods should also be explored to improve the visibility of specific organs during certain procedures[8].

For direct visualization of target tissues or organs, a 0° telescope inserted into a threaded, screw-in trocar is often used. Surgical instruments, characterized by their extended shape and specific functions, are introduced through sealed ports of either 5 or 10 mm in diameter. These ports protect the instruments and maintain a hermetic seal for consistent access during the procedure. Instruments designed for intra-corporeal suturing, grasping, cutting, and tissue sampling are common in laparoscopic surgeries[9]. Conventional laparoscopic needle holders differ from most other laparoscopic tools by their fixed orientation, which stabilizes the instrument for suturing. The handles are usually straight, aligning the needle with the surgeon's hand for natural wrist movement and enhanced maneuverability. Multiple handle types are available. Studies indicated that experienced surgeons often prefer a pistol grip, while novices favor a palmed straight grip. A thumb–ring finger grip is generally less effective and comfortable for both groups. Needle driver jaws come in various designs straight, curved left, curved right, or self-righting. Straight jaws are particularly versatile, suitable for use in both left and right-hand positions[9]. For intra-corporeal suturing in minimally invasive surgery, synthetic absorbable sutures are commonly used, with braided sutures generally preferred over monofilament types. Braided sutures are easier to handle due to their reduced memory, and they are also more resistant to damage from instruments during knotting, enhancing overall control and precision[10].

Conventional 1/2 and 3/8 suture needles are commonly used in minimally invasive surgery (MIS)[11]. Specialized half-curved ("ski") needles can be particularly advantageous when working in limited operative space, while the J needle is often beneficial for closing port incisions. For optimal instrument handling, an inter-cannula distance of at least 5 cm is recommended for the needle driver and accessory instruments[12]. The working tips of these instruments should meet at oblique angles, ideally forming a wide angle of 60 degrees or more. The distance between the cannula entrance and the operative field should be about half the length of the instrument (for instance, for 30 cm instruments, the cannula should be placed approximately 15 cm from the target field). It is also important that the instruments and camera be directed along the same axis as the surgeon's view toward the screen to prevent mirrored vision, ensuring clear visualization. The basic video endoscopy imaging system comprises a light source, light-transmitting cable, endoscope, camera, and monitor[13]. Standard surgical telescopes come in a variety of sizes, with the most versatile and commonly used rigid telescopes for small animal laparoscopy and thoracoscopy being 5 mm in diameter and around 30 cm in length. Smaller rigid endoscopes, ranging from 2.7 to 3 mm in diameter and 14 to 18 cm in length, are ideal for cats, puppies, and toy breeds[14]. These smaller telescopes are easier to maneuver in smaller patients but may be too short for larger animals, and their light-carrying capacity may be insufficient for larger cavities. Telescopes larger than 5 mm in diameter have become less popular, primarily due to advancements in the image size and brightness of 5-mm telescopes[15]. A CO2 insufflator is essential for creating and maintaining a working space between the telescope and the target tissues during minimally invasive surgery. It regulates the flow rate and pressure of CO2 throughout the procedure to ensure a stable and optimal operating environment. The carbon dioxide is typically supplied from a pressurized tank, which is connected to the insufflator via a high-pressure hose, allowing for precise control of the insufflation process. This enables clear visualization and proper instrument maneuvering by distending the abdominal cavity and providing better access to the surgical site[16, 17].

Instruments for minimally invasive surgery (MIS) are similar in structure to traditional surgical instruments but are designed with longer, thinner shafts to enable passage through instrument portals into body cavities. Some of these shafts are insulated to allow for monopolar or bipolar electrosurgical applications. It is crucial to regularly inspect the shafts for any cracks or signs of wear when using insulated shafts with electrosurgery to ensure safe operation. Laparoscopic needle holders typically feature a straight handle design, with either a hemostat-style or disengageable ratchet locking mechanism, providing easier manipulation of sutures and needles within the body cavity[11]. Instrument jaws vary in shape and size depending on their intended use, such as graspers, dissectors, scissors, retractors, biopsy forceps, or needle holders. The working end of an endoscopic instrument may feature a single- or double-action mechanism for efficient handling. A basic laparoscopic instrument pack for a beginner endoscopic surgeon utilizing a multiple-port approach typically includes a 5-mm, 0-degree telescope or a 10-mm, 0-degree telescope; a light cable; insufflator tubing; an endoscopic video camera; a VN (if needed for entry); three 5-mm cannulas (two sharp-tipped trocars and one blunt-tipped trocar); one or two 10-mm cannulas (with one sharp and one blunt trocar, designed for use with a 10-mm telescope, instruments, or energy devices); two reducer caps; 10-mm double-action Babcock or Duval grasping forceps; a 5-mm double- or single-action Babcock forceps; two 5-mm curved Kelly or Maryland grasping-dissecting forceps; 5-mm Metzenbaum dissecting scissors; 5-mm cup biopsy forceps (with or without spikes); 5-mm punch biopsy forceps; a 5-mm palpation probe; and an ovariectomy hook[15,16]. For more advanced surgeons, this basic pack can be expanded to include additional tools such as right-angle dissecting forceps, atraumatic tissue graspers, bullet-nosed graspers, or bowel graspers. Needle holders (straight or curved); additional suturing equipment like a knot pusher or Suture Assistant; hook scissors; a suction and lavage device; a fan retractor; a 5-mm, 30-degree telescope; bipolar electrosurgical instrumentation; mini-laparoscopic telescopes and instrumentation; and single-port access cannulas with articulating or reticulating instruments[18].

Veterinary surgeons work with a wide variety of species, each possessing unique anatomical structures. This variability complicates the standardization of laparoscopic techniques, as what works for one species may not be suitable for another[19]. Another issue is the limitations of equipment. Many laparoscopic tools are specifically designed for human use, and as a result, they may not be appropriately sized or tailored for animals, particularly smaller or exotic species. This equipment mismatch can hinder the surgeon's ability to perform procedures efficiently and safely[20]. Additionally, there are challenges related to training and expertise. Laparoscopic surgery requires specialized skills that many veterinarians may not possess, and the complexity of the procedure can create a steep learning curve. This, in turn, leads to a significant financial barrier for veterinary clinics, as specialized equipment and training are often costly[21]. Cost constraints also play a major role in limiting the widespread use of laparoscopy in veterinary practice. The high price of laparoscopic equipment, combined with the expense of the procedures themselves, can be prohibitive for many veterinary clinics and pet owners[22]. Anesthetic management is another critical concern. Positioning animals, particularly large ones, during laparoscopic surgery can lead to respiratory and cardiovascular complications, making it essential for veterinary surgeons to be highly skilled in anesthesia management to avoid any adverse outcomes[23]. Finally, post-operative management presents its own set of challenges. Unlike human patients, animals may be more likely to disrupt their incision sites due to movement or behavioral tendencies, making it more difficult to manage post-operative care effectively and ensuring proper healing[24]. Therefore, while laparoscopy offers significant benefits, such as less invasive procedures and quicker recovery times, these challenges must be carefully addressed to ensure its success in veterinary surgery.

3. Clinical applications of laparoscopy in the abdominal cavity of animals

3.1. Ovaries and reproductive tract

Laparoscopic procedures for the reproductive system include ovariectomy and cryptorchidectomy. These procedures can be performed with the patient in either a standing or dorsal recumbency position, depending on the surgeon's preference, the patient's condition, and the specific procedure being performed[25].

3.2. Abdominal and gastrointestinal system

Adhesiolysis and herniorrhaphy are also among the laparoscopic techniques used in abdominal surgeries. These can similarly be conducted in standing or dorsally recumbent positions based on the same factors of surgeon preference, patient status, and procedural requirements[26].

3.3. Pancreas

Laparoscopy provides a minimally invasive approach for obtaining pancreatic biopsies. The results of this retrospective study suggest that laparoscopy is a safe and potentially underutilized diagnostic tool in animals with exocrine pancreatic disease as a prominent differential diagnosis, such as in dogs and cats presenting with vomiting, anorexia, or both[26].

Figure 1. Locating an intra-abdominal testicle of dog. The gubernaculum (black arrow) or ductus deferens (black arrowhead) can be followed cranially to locate the testicle. The white arrowhead indicates the epididymis immediately adjacent to the testicle[31].

3.4. Cryptorchidism and laparoscopy in dogs

Cryptorchidism is the most common congenital defect of the testes in dogs, with a reported prevalence as high as 10% in adult dogs. This condition is most often unilateral, with the right testicle being the one most frequently retained[27]. Traditional methods for addressing cryptorchidism include the use of small laparotomy incisions and a spay hook to retrieve testicles retained within the abdomen[28]. Laparoscopy offers significant advantages for cryptorchid animals. By inserting the laparoscope through a 0.5-cm incision, rapid exploration of the inguinal ring can be performed to determine whether the testicle has exited the abdomen. If testicular vasculature and the ductus deferens are observed exiting the inguinal ring, exploration can be limited to the inguinal region[29]. For animals with intra-abdominal testes, laparoscopic-assisted techniques provide excellent visibility of critical structures while minimizing trauma to the patient. Traditionally, remove of abdominally retained testicles requires a combined ventral median and parapreputial abdominal skin incision[30].

Figure 2. Percutaneous suture placement in a testicle of dog. If bilateral, the first testicle can be located and secured to the body wall using a percutaneous stay suture to allow for easy retrieval after the removal of the contralateral testicle. This technique can also be used to secure the testicle for dissection if using a limited access technique[31].

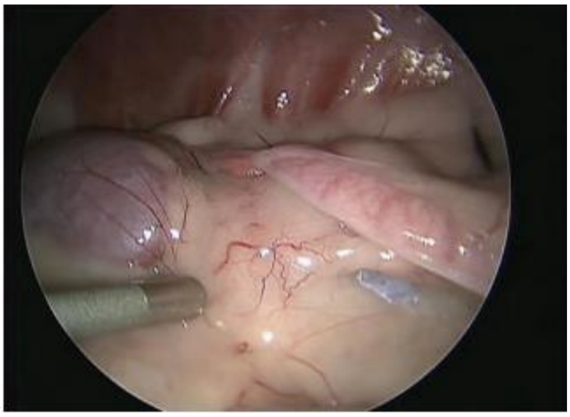

Figure 3. Intraoperative view from a 0-degree, 5-mm telescope view of the left ovary in a dog[31].

3.5. Ovariectomy and its applications

Ovariectomy is performed for various reasons, including eliminating the negative effects of cyclic estrous behavior on performance, preventing estrous and pregnancy, allowing exogenous hormonal manipulation of the estrous cycle, and removing pathologic ovaries. Laparoscopic ovariectomy (LO) has been successfully applied in humans and large animals such as mares[32,33].

A comparative evaluation of three laparoscopic ovariectomy techniques was conducted in 33 healthy female rabbits. The techniques including resection and removal of the ovary after clip application, electrocautery of the ovary followed by resection and removal, ligation with silk, followed by resection and removal of the ovary.

Laparoscopy allowed superior visualization of the ovaries and associated structures, enabling the successful application of all three techniques including laparoscopic ovariectomy, laparoscopic ovariohysterectomy, and laparoscopic-assisted procedures. Most rabbits recovered well post-operation and were monitored a month. However, two rabbits due to bleeding and one from unknown causes were died. General anesthesia using ketamine-xylazine intramuscularly provided effective analgesia and muscle relaxation. CO_2 insufflation was used to create pneumo-peritoneum. In conclusion, the resection and removal of ovaries following clip application were found to be superior to the other two techniques in terms of their outcomes[34].

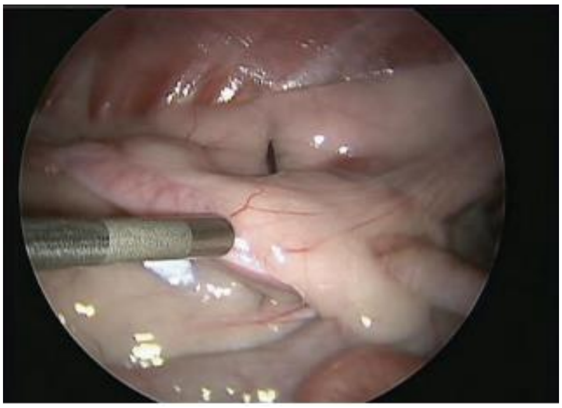

Figure 4. Intraoperative view from a 0-degree, 5-mm telescope of the left uterine horn in a dog[31].

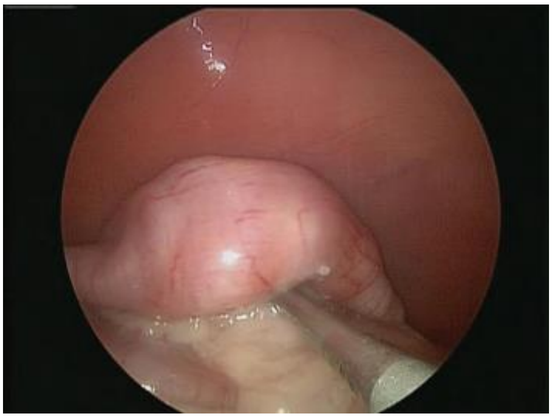

Figure 5. Intraoperative view of solitary small intestinal mass with no evidence of metastatic peritoneal lesions in a dog[31].

3.6. Small bowel obstruction

The specific standards should be followed when considering laparoscopic treatment for small bowel obstruction in human medicine[35]. However, such guidelines are not yet established in veterinary practice[35]. These standards include factors such as proximal obstruction, small bowel dilation measuring less than 4 cm, the presence of a single adhesion band, mild abdominal distension, partial obstruction, and a history of previous appendectomy.

The reported success rates for laparoscopic management of small bowel obstruction range from 46% to 84%, with an overall intestinal damage rate of 5.8% during the procedure[36]. It is important to maintain a low threshold for conversion to open surgery, particularly during the initial cases. Preoperative decompression of the gastrointestinal tract, such as placing an orogastric tube after induction of anesthesia, is also recommended to improve outcomes[37-39].

3.7. Gastric dilatation-volvulus and gastropexy techniques

Gastropexy is a surgical procedure that creates a permanent adhesion between the stomach and the body wall, most commonly performed to prevent gastric dilatation-volvulus (GDV). This procedure may be carried out during an active episode of GDV or prophylactically in animals at high risk but not yet affected. Gastric dilatation-volvulus is a life-threatening condition of uncertain etiology, affecting approximately 60,000 dogs annually. It is characterized by gastric distension, mal-positioning of the stomach, and compression of the portal, splanchnic, and caudal vena cava blood flow. These complications can result in hypotensive and cardiogenic shock, gastric necrosis, tissue acidosis, cardiac arrhythmias, disseminated intravascular coagulation, and possibly death[40, 41].

Identified risk factors for GDV include being underweight, male gender, and certain concurrent medical conditions, such as inflammatory bowel disease, gastric foreign bodies, or a history of splenectomy. Despite these associations, direct causal relationships have not been fully

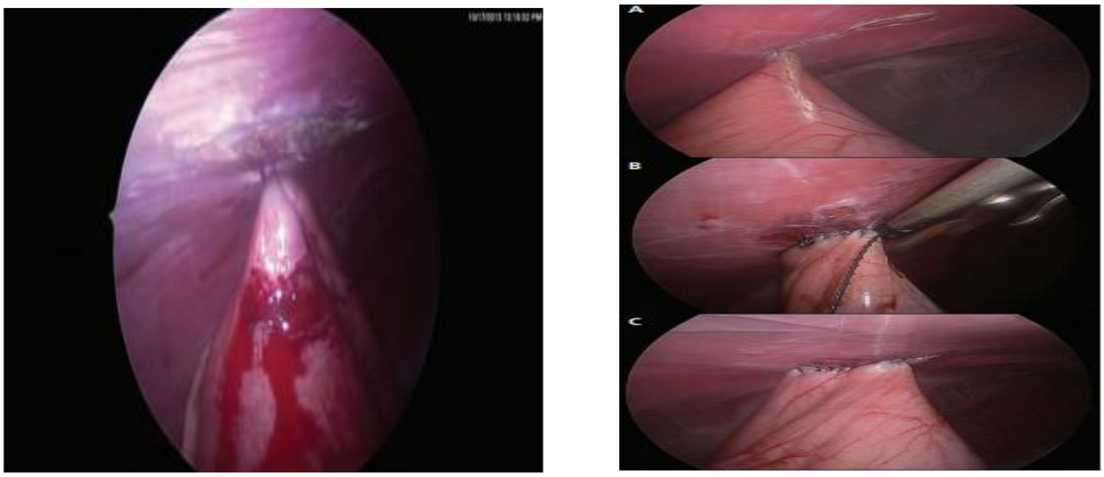

Figure 6. Procedure and Technique of Monopolar Electrosurgery and Knotless Suture Application in Gastropexy. Monopolar electro-surgery is used to score a 3 to 4-cm line into both the transversus abdominis and adjacent seromuscular layer of the antrum in a dog (A). Continuous bites are then taken with the knotless-barbed suture, with slight tension being applied to each bite so the barbs can seed maintaining suture tension (B). View of the gastropexy after knotless suture application (C)[31].

established. Additionally, environmental factors, such as experiencing a stressful event within eight hours prior, may contribute to an increased risk of GDV[42].

Multiple techniques for gastropexy have been described, including incisional, belt loop, circumcostal, incorporating, and fundic gastropexy. More rarely used methods include gastric fixation via gastrojejunostomy and gastrocolopexy. Minimally invasive approaches such as right-sided grid mini-laparotomy, endoscopic-assisted gastropexy, totally laparoscopic gastropexy, and laparoscopic-assisted gastropexy have gained popularity for their reduced invasiveness and shorter recovery times.

Right-sided percutaneous endoscopic gastrostomy (PEG) has also been reported as a technique for permanent gastropexy. This method is generally not recommended because it often results in inconsistent and weak adhesions, as well as a higher risk of complications related to the procedure[43].

3.8. Splenectomy in dogs

Splenectomy in dogs is performed for various diagnostic and therapeutic reasons, including benign and malignant splenic masses, torsion, infarction, diffuse neoplastic disease, trauma, and immune-mediated disorders. One of the earliest reports of laparoscopic splenectomy (LS) in human medicine utilized porcine and canine models to refine the procedure before its widespread application in humans[44]. Initial reports described a four- to seven-port procedure with prolonged surgical times but minimal morbidity. Subsequent experimental studies refined the technique, introducing three-port or single-incision laparoscopic approaches[45,46].

In canine patients, total splenectomy is often performed via a standard ventral midline laparotomy, with ligation of vessels along the splenic hilus. Alternatively, ligation of the left gastroepiploic artery, short gastric arteries, and splenic vessels distal to the pancreatic blood supply may also be performed. The laparoscopic approach is typically suited to hilar splenectomy due to the easy identification of hilar vessels during the procedure[31].

Figure 7. A vessel-sealing device can be seen sealing and dividing the final attachments at the splenic head in a dog. A small amount of hemorrhage can be seen because of minor inadvertent trauma to the splenic capsule during dissection[31].

3.9. Diagnostic and hepatic laparoscopy

Laparoscopy is a minimally invasive abdominal surgical

Figure 8. During laparoscopic multiport splenectomy, the spleen is retracted laterally to expose the splenic hilum in a dog[31].

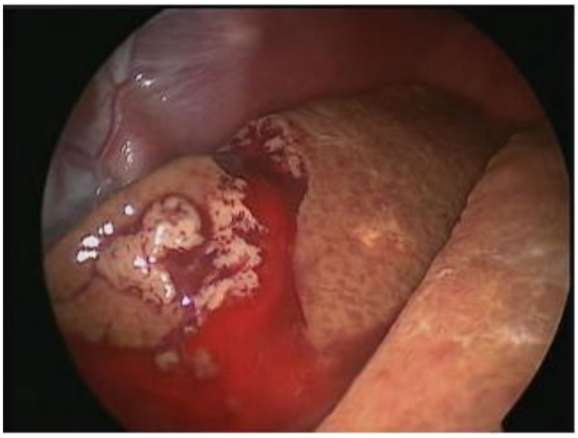

Figure 9. Intraoperative view of excessive arterial bleeding in a liver biopsy site in a dog[31].

technique offering benefits such as enhanced visualization of abdominal organs, reduced postoperative pain, and improve the recovery. Diagnostic laparoscopy is commonly performed in both human and veterinary medicine for obtaining tissue biopsies, assessing lesion respectability, and staging neoplasia[48-50]. For laparoscopic liver biopsy in dogs, the procedure involves anesthesia, dorsal recumbency, and insertion of a trocar cannula through the ventral midline caudal to the umbilicus using the Hasson technique. After insufflation of the peritoneal cavity with carbon dioxide (≤12 mmHg), additional trocars are placed to allow the insertion of biopsy instruments. The liver lobes are inspected for gross lesions before obtaining 3 to 6 biopsy samples from multiple lobes. Hemorrhage is controlled with blunt probes or absorbable gelatin material if necessary[51].

3.10. Gallbladder and biliary tract pathologies

Laparoscopic cholecystectomy (LC) in small animals is often contraindicated in cases of bile peritonitis or extrahepatic biliary obstruction (EHBO). However, it is indicated in uncomplicated gallbladder mucoceles (GBMs)

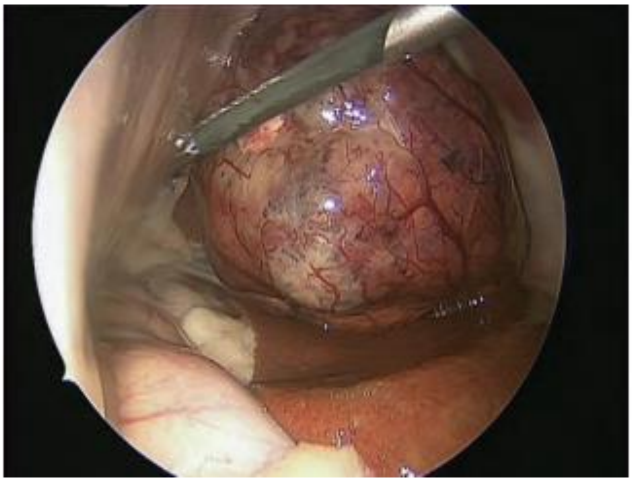

Figure 10. Intraoperative view of large hepatic mass being manipulated by a blunt probe in a dog. It was pedunculated and easily moveable, and no other metastatic disease was found, so the decision to convert for a liver lobectomy was made[31].

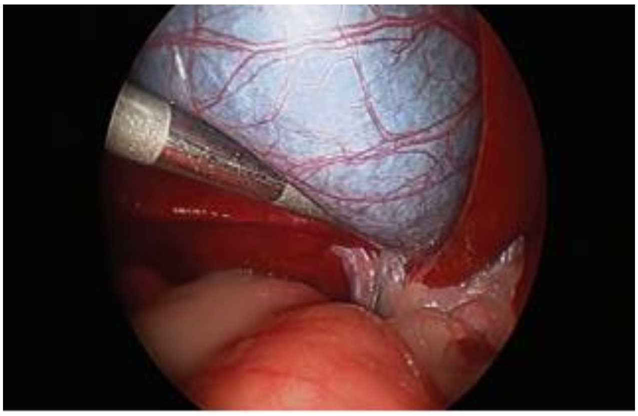

Figure 11. The gallbladder is elevated using a blunt probe in this laparoscopic image to allow for evaluation of the common bile duct in a dog[31].

or symptomatic cholelithiasis without choledochal stones. The prognosis for surgical treatment of GBMs is fair, with perioperative mortality rates between 22% and 40%, primarily due to complications like EHBO and systemic compromise at presentation[52,53].

The gallbladder lies within the hepatic fossa, bordered by the right medial and quadrate liver lobes. Ligation of the cystic duct is performed during LC at the junction of the cystic and hepatic ducts. The common bile duct continues toward the duodenum and receives two-eight tributary hepatic ducts in dogs[54]. Laparoscopic cholecystectomy has replaced open cholecystectomy as the gold standard surgical procedure for majority of patients with gallstone disease[55]. Conventional laparoscopic cholecystectomy is done using four ports. With an effort to minimize the number of ports, single-incision laparoscopic surgery (SILS) has come into practice[56]. It has also been suggested as a bridge between traditional laparoscopy and natural orifice transluminal endoscopic surgery[57].

3.11. Pancreatic laparoscopy

The use of laparoscopic surgery for the pancreas in companion animals remains limited to diagnostic biopsies. The complexity of pancreatic surgeries and associated morbidity have contributed to the slow adoption of laparoscopic techniques in both human and veterinary fields, and no consensus guidelines exist for their use[58].

In cases of pancreatitis, autodigestion begins following glandular inflammation. Common clinical signs in dogs include anorexia, vomiting, weakness, abdominal pain, and diarrhea, whereas in cats, anorexia and lethargy are more prevalent, with vomiting and diarrhea less commonly observed[59,60]. The most frequent disease of the endocrine pancreas in dogs is insulinoma, an insulin-secreting β-cell tumor leading to hyperinsulinemia and hypoglycemia[61]. Clinical signs include seizures, weakness, ataxia, and muscle tremors. Insulinomas are rare in cats[62]. Laparoscopic exploration of the pancreas typically uses three portals, with the first placed sub-umbilically in the midline to reduce muscle trauma, and others positioned laterally. For more complex procedures, a fourth portal may be required for organ retraction[63,64].

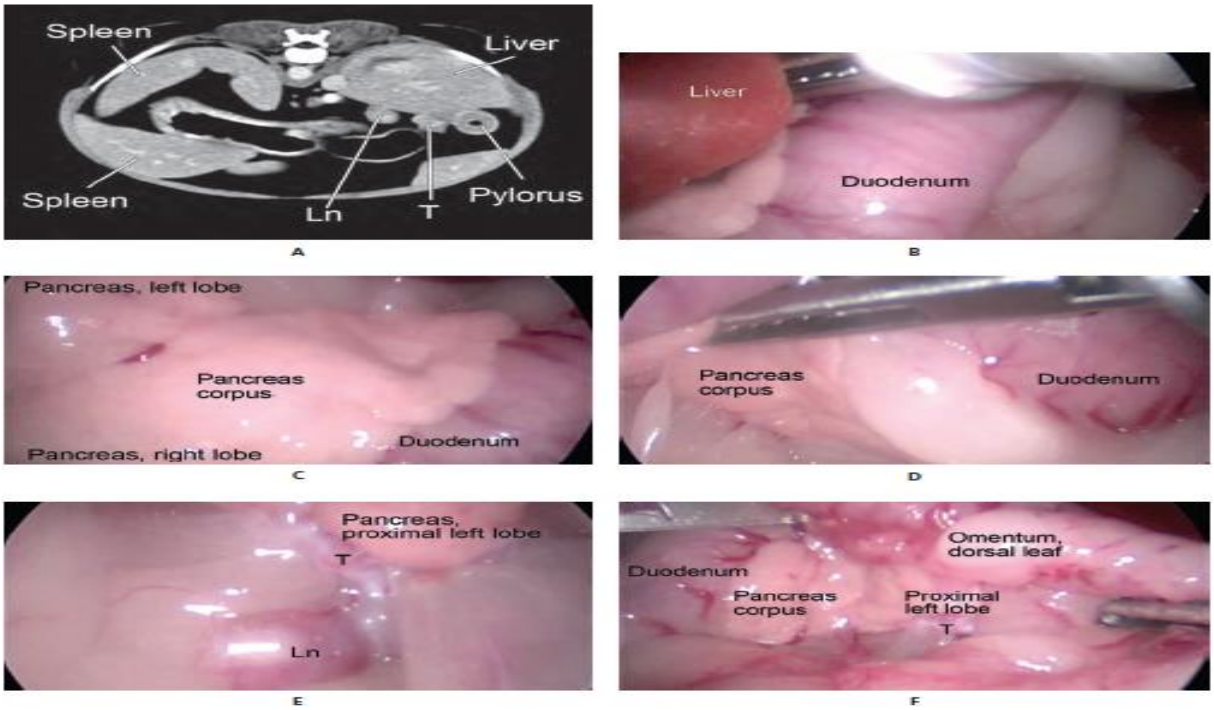

Figure 12. Laparoscopic images of the right lateral approach in sternal recumbency and ventral midline approach in dorsal recumbency in a dog with insulinoma. A: Computed tomography image of insulinoma (T) in the dorsal edge of the pancreatic corpus and an adjoining metastatic lymph node (Ln). B: Right lateral flank laparoscopic approach in sternal-oblique recumbency. The liver has to be manipulated craniodorsally so the corpus of the pancreas can be visualized. C: Corpus and proximal left lobe of the pancreas, dorsal surface. D: Dorsal retraction of the duodenum gives access to the ventral surface of the corpus and proximal left lobe. E: A small insulinoma (T) is located at the edge of the corpus/proximal left lobe. A metastatic lymph node (Ln) lies just distal to it. F: The same insulinoma (T) at the edge of the corpus/proximal left lobe of the pancreas as seen from a ventral midline laparoscopic approach with the patient in dorsal recumbency. The omentum is retracted cranially. The metastatic lymph node is not easily visualized in this approach[31].

4. Advantages and disadvantages of laparoscopy in the abdominal cavity

The application of laparoscopy in veterinary medicine, particularly in abdominal surgeries, has led to numerous benefits for both animal patients and veterinarians. However, it also comes with certain limitations and challenges that need to be considered.

4.1. Advantages

One of the primary advantages of laparoscopic surgery in veterinary abdominal procedures is the reduction in postoperative pain[65]. Traditional open abdominal surgeries often require large incisions, which can cause significant damage to tissues and muscles, resulting in substantial pain and discomfort during recovery. In contrast, laparoscopic surgery uses small incisions, which causes minimal trauma to the surrounding tissues. This reduction in tissue disruption leads to less pain after surgery, making pain management easier for veterinarians and reducing the need for strong painkillers. This is particularly important in veterinary patients, as it allows for a smoother and faster recovery, reducing the stress and discomfort associated with lengthy recovery periods. Additionally, laparoscopic surgery results in a much faster recovery time compared to traditional open surgery[65]. The smaller incisions allow the animal's body to heal more quickly, and the risk of complications such as infections and internal bleeding is minimized. This leads to shorter hospital stays and a quicker return to normal activity, which is beneficial not only for the animal's well-being but also for the overall efficiency of veterinary practice. For pet owners, this means reduced veterinary care costs and less disruption to the animal's normal routine. Another significant advantage of laparoscopy in veterinary medicine is the reduced risk of infections. In traditional open surgeries, large incisions expose internal organs to potential contamination, which increases the likelihood of infections[66]. However, with laparoscopy, the small incisions limit the exposure of the internal cavity to the external environment, reducing the risk of bacterial contamination. Additionally, the shorter duration of exposure during the procedure also helps lower the chances of infection. In veterinary practice, this is especially crucial for animals with pre-existing conditions or weakened immune systems, as they are more susceptible to infections. Blood loss is also significantly minimized in laparoscopic surgeries[67]. Open surgeries often require cutting through blood vessels, leading to greater blood loss, which can complicate the recovery process. In laparoscopic procedures, the smaller incisions and the use of specialized instruments to control bleeding result in much less blood loss. This is especially beneficial in different animal species that are prone to blood clotting disorders or have lower blood volume relative to their size. By minimizing blood loss, laparoscopic surgery improves the safety of the procedure and reduces the risk of post-operative complications.

4.2. Disadvantages

Despite its many advantages, laparoscopic surgery in veterinary abdominal procedures has certain disadvantages and challenges that must be considered[65]. One of the primary challenges is the cost and availability of specialized equipment. Performing laparoscopic surgery requires the use of advanced instruments such as laparoscopes, high-definition cameras, and electrocautery devices. These instruments can be expensive to purchase, maintain, and sterilize, which can be a significant financial barrier for smaller veterinary clinics. The higher costs of laparoscopic surgery may make it less accessible, particularly in resource-limited veterinary practices or rural areas where specialized equipment may not be readily available. Another limitation of laparoscopic surgery is its restricted access to certain parts of the abdominal cavity. While laparoscopy is effective for many abdominal procedures, such as spaying, biopsy collection, and some types of internal organ surgery, it may not be suitable for more complex or advanced conditions[68]. Large tumors, severe adhesions, or emergency surgeries involving significant bleeding may require traditional open surgery for better visibility and access[69]. In these cases, the small incisions used in laparoscopy may not provide enough room to adequately manipulate instruments or visualize the affected area, making open surgery a more appropriate option. In addition, laparoscopic surgery in veterinary medicine requires skilled surgeons who are trained in using the specialized tools and interpreting the images provided by the laparoscope. Veterinarians must have a high level of expertise in both the technical aspects of the procedure and in managing the challenges posed by performing surgery on animals under anesthesia[70]. Unlike traditional open surgery, which provides direct tactile feedback through palpation, laparoscopy relies on visual images displayed on a monitor, which can be more challenging to interpret. This requires specialized training and experience, and less experienced veterinarians may struggle with laparoscopic procedures, increasing the potential for complications. Furthermore, while laparoscopy offers better precision and smaller incisions, there is still a risk of accidental organ injury. The inability to physically touch the tissues during surgery increases the possibility of inadvertent damage to surrounding organs, such as blood vessels, the intestines, or the bladder. Although the risk is lower compared to open surgery, it remains a concern, especially when performing laparoscopic procedures in unfamiliar or difficult anatomical areas. As such, it is crucial for the veterinarian to have a thorough understanding of the animal's anatomy and to be experienced in laparoscopic techniques to minimize this risk. Finally, laparoscopic surgery may not be suitable for all types of animals or conditions[71,72]. For example, certain large animals or those with obesity may not be good candidates for laparoscopic procedures due to difficulty accessing certain parts of the abdominal cavity. Additionally, emergency cases requiring immediate and extensive surgical intervention may require the more direct approach provided by open surgery. In such cases, open surgery may offer better visibility and control over the surgical site, ensuring a safer and more effective procedure[73].

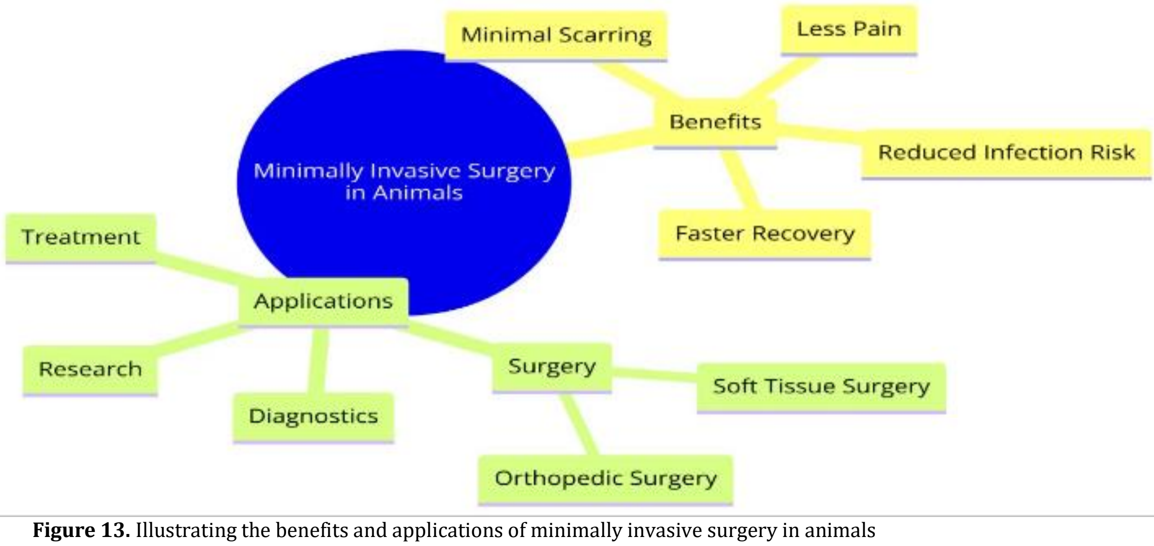

Figure 13. Illustrating the benefits and applications of minimally invasive surgery in animals

5. Challenges and future of laparoscopy in veterinary medicine

While laparoscopy has revolutionized veterinary surgery by offering minimally invasive techniques that improve recovery times and reduce postoperative pain for animals, it is not without its challenges. The integration of laparoscopy into veterinary practice faces a range of hurdles that impact its widespread adoption, particularly in certain regions or smaller veterinary practices. These challenges must be addressed in order to fully realize the potential of laparoscopic surgery in veterinary medicine.

One of the primary challenges is the cost of specialized equipment[73]. Laparoscopic surgeries require specific instruments such as laparoscopes, high-definition cameras, electrosurgical devices, and advanced imaging systems.

These pieces of equipment are often expensive to acquire and maintain, which can be a significant financial burden for many veterinary clinics, particularly in resource-limited areas or smaller practices. For many veterinary professionals, the high initial investment and ongoing maintenance costs of laparoscopic tools may deter them from adopting this technology, despite its benefits in terms of patient outcomes. Moreover, the cost of training veterinary staff to properly use this equipment adds another layer of financial consideration. As a result, many clinics may opt for traditional open surgeries, which require fewer specialized tools.

In addition to equipment costs, training and education represent another key challenge[73]. While laparoscopic surgery has become a standard procedure in human medicine, its application in veterinary practice is still relatively new. Veterinarians must undergo specific training to become proficient in laparoscopic techniques, which often involves both theoretical education and hands-on practice. However, the availability of formal training programs for veterinary surgeons in laparoscopy can be limited. Veterinarians must seek specialized courses or work with experienced mentors, which can take time and resources. This gap in education and training has slowed the adoption of laparoscopic techniques in some veterinary practices. Furthermore, the complexity of interpreting real-time imaging data, managing specialized instruments, and understanding anatomy through a laparoscope presents a steep learning curve for new practitioners. The lack of readily available and standardized training programs can hinder the effectiveness and safety of laparoscopic procedures, especially in practices with limited access to experienced instructors.

The future of laparoscopy in veterinary medicine holds great promise, driven by technological advancements that could overcome some of the current challenges. One of the most exciting areas of progress is the integration of robotic-assisted surgery into veterinary laparoscopy. Robotic systems allow for even greater precision, control, and stability during surgery. By using robotic arms that can move with more accuracy than human hands, veterinarians can perform delicate surgeries with enhanced dexterity and minimal invasiveness. This technology, which has already been utilized in human medicine for some time, is becoming increasingly accessible to veterinary practices. As robotic systems become more affordable and user-friendly, their use in veterinary laparoscopy is expected to increase, potentially revolutionizing surgical procedures for small and large animals alike. Robotic laparoscopy could reduce human error, increase the speed of surgeries, and further decrease the risks of complications during surgery[74].

In addition to robotics, the development of advanced imaging systems is another exciting frontier for the future of veterinary laparoscopy[75]. Modern imaging technologies, such as 3D imaging, high-definition cameras, and intraoperative ultrasound, can significantly improve the visualization of the abdominal cavity during laparoscopic procedures. These technologies allow for greater clarity, accuracy, and a more detailed view of the internal organs, which is especially useful in complex surgeries or when dealing with smaller or more difficult-to-reach anatomical structures. By improving the accuracy of visualization, advanced imaging techniques can lead to better surgical outcomes and a reduction in complications. Furthermore, real-time imaging can provide immediate feedback to the surgeon, allowing for more effective decision-making during the procedure. As these technologies continue to advance, they will likely become more integrated into veterinary laparoscopic surgery, leading to enhanced precision and improved patient safety[75].

The evolution of instrumentation also plays a crucial role in the future of veterinary laparoscopy. Newer, more advanced surgical tools are being developed that can perform complex tasks with even greater efficiency. For instance, energy-based devices that combine cutting and coagulation in one instrument are making surgeries faster, safer, and less traumatic. These devices, which are commonly used in human surgeries, are beginning to be adapted for veterinary use and could become more common in the future. Additionally, miniaturization of laparoscopic instruments is helping to make laparoscopy more accessible to a wider range of animals. Smaller, lighter tools are being designed specifically for use in smaller pets, exotic animals, and even large animals, ensuring that laparoscopic techniques can be applied across different species. Moreover, the integration of artificial intelligence (AI) and machine learning into laparoscopic systems is another exciting possibility[76-79]. AI could assist veterinary surgeons by analyzing real-time data from imaging systems and providing automated guidance during procedures. For example, AI algorithms could help identify abnormalities in organs or tissues, suggest optimal surgical paths, or even predict potential complications based on previous surgical data. Machine learning could also assist in improving the precision of robotic-assisted surgeries by learning from previous cases and continually improving its performance. As these technologies mature, AI and machine learning could become indispensable tools in veterinary laparoscopy, enhancing the capabilities of surgeons and improving overall surgical outcomes. However, for these advancements to be fully realized, ongoing research and collaborative efforts between veterinary professionals, technologists, and engineers are essential. Continued investment in the development of cost-effective equipment, as well as the establishment of more accessible and standardized training programs, will be crucial to overcoming current barriers. The future of veterinary laparoscopy will depend on the willingness of the veterinary community to adopt and integrate these emerging technologies into practice, ensuring that more animals benefit from the improved outcomes associated with minimally invasive surgery.

Therefore, while challenges such as equipment costs, training limitations, and access to technology currently restrict the widespread adoption of laparoscopy in veterinary medicine, the future looks bright. With advancements in robotic surgery, imaging systems, and instrumentation, laparoscopic procedures are expected to become more accessible, precise, and cost-effective. These innovations will not only enhance the quality of care for animal patients but will also provide veterinary professionals with the tools they need to perform complex surgeries with greater confidence and safety. As technology continues to evolve, veterinary laparoscopy will likely become an integral part of routine surgical practice, improving the overall outcomes and well-being of animals worldwide.

6. Conclusion

Laparoscopy offers significant advantages in veterinary abdominal surgery, including reduced postoperative pain, faster recovery times, and smaller incisions that reduce the risk of infection and complications. However, challenges such as the high cost of equipment, the need for specialized training, and limitations in accessing certain anatomical areas remain. The future of laparoscopy in veterinary medicine looks promising, with advancements in robotic surgery, advanced imaging, and more affordable instruments likely to increase accessibility and precision. These innovations will improve surgical outcomes and expand the range of procedures that can be performed. Practical recommendations include developing cost-effective equipment to make laparoscopy more accessible and creating standardized training programs to ensure veterinarians acquire the necessary skills. Additionally, investing in research to explore the use of laparoscopy for various species and conditions, along with advancing robotic technology to enhance surgical precision, is crucial. In summary, while challenges exist, continued innovation and education will help maximize the potential of laparoscopy in veterinary practice, leading to better outcomes for animal patients.

Declarations

Competing interests

The authors have no conflict of interest to declare.

Authors' contributions

Sama Yaghobian and Pouria Ahmadi Simab prepared the initial draft of the manuscript. Nayere Parhizkar revised the draft, addressing language errors and ensuring clarity. All authors critically reviewed the manuscript, approved the final version, and consented to its publication in the current journal.

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This study was conducted in accordance with the ethical standards of the relevant national and institutional guidelines for research and publication. All procedures performed were in compliance with ethical principles, and the authors confirm that they have followed the guidelines for ethical publication as outlined by the journal.

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