SUMMARY OF PhD THESIS

The development and evaluation of a 3D printed laparoscopic simulator in veterinary medicine

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Introduction

The current trend in medicine is to minimize iatrogenic trauma to tissues, which is why minimally invasive surgical procedures (MIS) have become the gold standard in human medicine and are gradually being adopted in veterinary medicine. These techniques, defined as having the purpose of diagnosing and treating pathologies with minimal trauma, have a particular historical feature in the veterinary field: they were transferred from human medicine, unlike most procedures (Fransson & Mayhew, 2015). Their advantages include easier postoperative recovery, reduced pain, and a lower rate of infections, due to fine tissue handling and superior visualization (Sladakovic & Divers, 2016; Tobias & Johnston, 2012).

However, MIS involves considerable investments in equipment and requires intensive training of medical staff. Training focuses on developing hand-eye coordination, spatial orientation, and ambidexterity—skills essential for overcoming challenges such as reduced visual fields and magnification of tissues. Inexperienced teams may cause iatrogenic trauma, which is why professional bodies such as the American and European Colleges of Veterinary Surgeons have included MIS training as a mandatory component of residency programs.

Structure of the thesis

The thesis is structured in two parts. The first part covers the current state of knowledge, including general concepts of minimally invasive surgery, with a special focus on pneumoperitoneum, which was later studied in rabbits, applications of 3D printing in medicine, and training methods in minimally invasive surgery, focusing on existing simulators and their validation process. This part consists of 31 pages.

The second part of the thesis represents the personal contribution, divided into three distinct chapters, following the chronological order of developing a training program using a newly created simulator. The first chapter aimed to identify the knowledge level and training needs of a sample of veterinarians and veterinary medicine students regarding MIS. The second chapter analyzed and evaluated the experience level of faculty members and students at the Faculty of Veterinary Medicine in Cluj-Napoca, using a validated simulator. This study both identified the existing experience levels within the institution and provided baseline results for comparison with those obtained

using the newly created simulator in the following chapter. The last chapter was divided into three stages: a CT-based study of pneumoperitoneum in rabbits, the design and 3D printing of a laparoscopic simulator (ROVHLS) based on these images, and its subjective and objective validation. This part comprises 68 pages.

Research objectives

This PhD thesis aimed to fulfill two complementary sets of objectives. The first set focused on an in-depth analysis of the interest in MIS among the Romanian veterinary medical community. The research began with the creation and distribution of an online questionnaire designed to assess the perceptions and needs of both veterinarians and students at the Faculty of Veterinary Medicine in Cluj-Napoca. Based on the collected data, a structured training program was designed to address the identified needs, taking into account the financial and time constraints reported as major obstacles to participation.

The second set of objectives was centered on a practical and innovative component: the development and validation of a 3D-printed simulator. The simulator, named ROVHLS (Rabbit Ovariohysterectomy Laparoscopic Simulator), was created to allow training in rabbit ovariohysterectomy. The validation process was complex and included several stages:

- Determining the level of experience in MIS among students and faculty to contextualize subsequent performances.
- Comparative validation: directly comparing participants' results obtained on the new simulator with those from a validated simulator, in order to establish objective validity.
- Correlation analysis: investigating whether participants' experience with video games or video-endoscopic surgery had any impact on their performance with the simulator.
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Research results

Chapter 4 assessed the need and feasibility of implementing a training program in MIS at the Faculty of Veterinary Medicine in Cluj-Napoca. The results showed that theoretical and practical knowledge of MIS is currently low among both veterinarians and students, although interest in such techniques is high. The main obstacles identified were the lack of a structured training

program, high equipment costs, and limited time availability. Nevertheless, most respondents expressed willingness to participate in dedicated courses, confirming the feasibility of introducing a standardized training program adapted to local resources and needs.

Chapter 5 focused on determining the level of MIS experience among senior students and faculty members. The evaluations revealed that videoendoscopic experience levels were low and comparable between groups, with similar practical performance. Statistical analysis showed a significant positive correlation between prior MIS practice and performance in experimental tests, highlighting the importance of direct, repeated training. In contrast, non-medical experiences such as video gaming had no relevant impact on surgical performance. These results confirm the need for early integration of standardized training modules into the veterinary curriculum.

Chapter 6 involved the development, construction, and validation of an innovative laparoscopic simulator for veterinary medicine—ROVHLS (Figure 1, Figure 2). The imaging study performed on rabbits, with CO_2-induced pneumoperitoneum, demonstrated significant changes in abdominal cavity dimensions without postoperative complications, data that served as the basis for simulator design. The simulator was 3D-printed using accessible materials and modular, replaceable components. Users rated it as realistic and useful for teaching purposes (subjective validity), and comparative tests with students and veterinarians confirmed construct and concurrent validity. The results demonstrated that ROVHLS is a feasible and effective preoperative training tool, comparable to established simulators.

Fig. 1. 3D printed genital tract

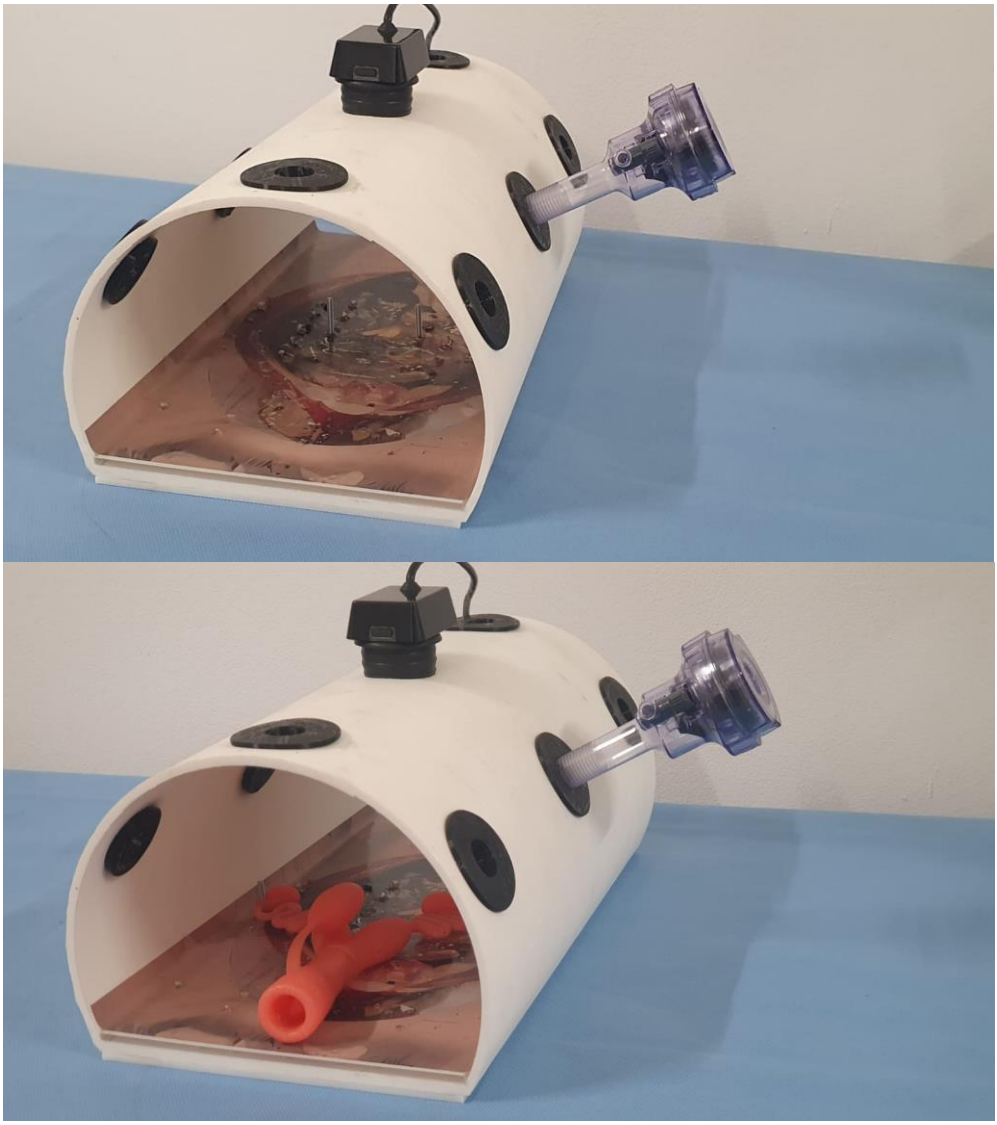

Fig. 2. The ROVHLS simulator assembled without (top) and with the genital tract fixed (bottom). A webcam and a commercial 10 mm trocar placed in the simulator openings. The trocar was inserted only to demonstrate its possible use and was not employed during the simulator validation process.

Final conclusions and recommendations

The general conclusions of the thesis highlight that interest in MIS in veterinary medicine is high, but the current level of training is insufficient, limiting the clinical application of these techniques. Direct practical experience is a key determinant of surgical performance, and standardized training based on simulators represents an optimal and ethical solution. The simulator developed in this thesis—ROVHLS—demonstrated both technical feasibility and didactic value, being a realistic, accessible, and objectively validated tool for laparoscopic training.

The recommendations derived from this research include the integration of a standardized MIS curriculum at the Faculty of Veterinary Medicine, with early introduction of practical modules in the educational pathway. Further studies should be conducted on larger cohorts, including comparisons between novice and expert surgeons, and should assess the correlation between simulator performance and real surgical outcomes to strengthen external validity. Additionally, the ROVHLS simulator should be optimized by introducing progressively more challenging exercises (suturing, haemostasis) and by using materials with biomechanical properties closer to biological tissues. Overall, this research supports the development of a modern, technology-based educational model that facilitates the transition toward safer, more ethical, and more effective veterinary practice.

Originality and innovative contributions

This thesis makes significant contributions to the field of veterinary minimally invasive surgery education, as follows:

Identification of local educational needs: The study identified the barriers to adopting minimally invasive surgery in Romania, such as lack of training, costs, and limited time. Based on a questionnaire administered to veterinarians and students in Cluj-Napoca, the thesis proposed a course program tailored to local needs and realities.

Development and validation of an innovative 3D simulator: An innovative 3D simulator, ROVHLS, for ovariohysterectomy in rabbits was created and validated. Made with 3D printing technology, this simulator is reusable and low-cost. The thesis demonstrates that the simulator is an effective and realistic teaching tool that provides a valid measure of essential technical skills.