UNIVERSIDAD AUTÓNOMA DE BARCELONA
FACULTAD DE VETERINARIA

Departamento de Medicina y Cirugía Animal

TESIS DOCTORAL

VALIDITY OF THE LAPAROSCOPIC SIMULATOR SIMULVET® AND ITS APPLICATION IN TRAINING ON VETERINARY LAPAROSCOPIC SURGERY

VALIDACIÓN DEL SIMULADOR LAPAROSCÓPICO SIMULVET® Y SU APLICACIÓN EN LA FORMACIÓN EN CIRUGIA LAPAROSCÓPICA VETERINARIA

Memoria presentada por

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IV. Published Studies

1. **Development and Evaluation of a Canine Laparoscopic Simulator for Veterinary Clinical Training.** *Journal of Veterinary Medical Education* (JVME).

ADVANCE ONLINE ARTICLE

Development and Evaluation of a Canine Laparoscopic Simulator for Veterinary Clinical Training

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ABSTRACT

Human laparoscopic simulators have been used in medical education for minimally invasive surgery (MIS) in the past years. Simulator-based laparoscopic training has attracted much interest because unique skills have to be learned not only by surgeons in training but also by surgeons in practice. MIS forces the surgeon to adapt to monocular vision and decreased tactile sensation and entails training and improving hand-eye and hand-hand coordination. Those skills require a learning curve that could be overcome gradually with use of simulators. The Canine Laparoscopic Simulator (CLS) for laparoscopic training was developed based on the working and optical space obtained from computed tomography (CT) scan images of three Beagle dogs. Thirty veterinarians (expert group, $n = 7$; novice group, $n = 23$) performed basic laparoscopic exercises in one training session on the CLS. During the performance of the exercises, an experienced laparoscopic veterinarian assessed all the tasks. Afterwards, participants were asked to complete an anonymous survey describing their experience. Most participants expressed positive opinions about the design and usability of the CLS. There were no significant differences between the two groups' opinions. The CLS showed good preliminary acceptance in the basic laparoscopy tasks by veterinarians. They perceived it to be a good training tool, and these results suggest that CLS is an engaging tool for education but still has some limitations inherent in training boxes. Further studies would be needed to establish the validity of training programs performed in the CLS.

Key words: medical simulation, simulator, training, laparoscopy, minimally invasive surgery, canine

INTRODUCTION

Minimally invasive surgery (MIS), especially laparoscopy, has become very popular in veterinary medicine, mainly due to its multiple benefits: less surgical trauma, better recovery, and shorter hospital stays, among others.[1,2] Currently, in human medicine, laparoscopy constitutes a well-established surgical approach, and the same tendency will be progressively integrated in veterinary surgery.[3]

The number of publications regarding veterinary MIS is increasing notably, especially those related to laparoscopy. Nevertheless, the main focus is generally on laparoscopy and thoracoscopy procedures in small animals,[4,5] and only minimal references exist regarding specific training programs or the role that simulation plays in veterinary medicine.[6] In the past, surgery teaching was based on the principle of "See one, Do one, Teach one," a model where the learning of complex techniques is accomplished by observing and assisting in surgeries, followed by the performance of learned procedures on patients. Pursuing the objective of a structured world-wide-applicable training program, in 1998 the Congress of the American Society of Gastroenterologists and Endoscopic Surgeons developed the Fundamentals of Laparoscopic Surgery (FLS), complementing the traditional on-patient training with controlled and structured inanimate learning strategies and modalities.[7,8]

The skills required for laparoscopic surgery are very different from those required for conventional surgery. Laparoscopic surgery forces the surgeon to use both hands in a complementary manner, thus interacting with the non-dominant hand, which works on an altered visual-spatial perception.[9] Therefore, the surgeon should adapt to monocular vision and decreased tactile sensation through a long learning curve of training hand-eye and hand-hand coordination. A considerable investment in time and financial resources is required for appropriate training.[10] There are different available strategies for learning and acquisition of the necessary skills. One such strategy is experimental animal models, commonly used in laparoscopic training in human medicine, which entails a significant cost and demands special facility requirements, in addition to the pertinent ethical issues.[11] For these reasons, animal models constitute a limited, expensive, and difficult resource. Another alternative is virtual reality simulators, but they are more expensive and lack haptic sensation.[12,13] Above all, the most popular strategy is using physical simulators. Although it requires an

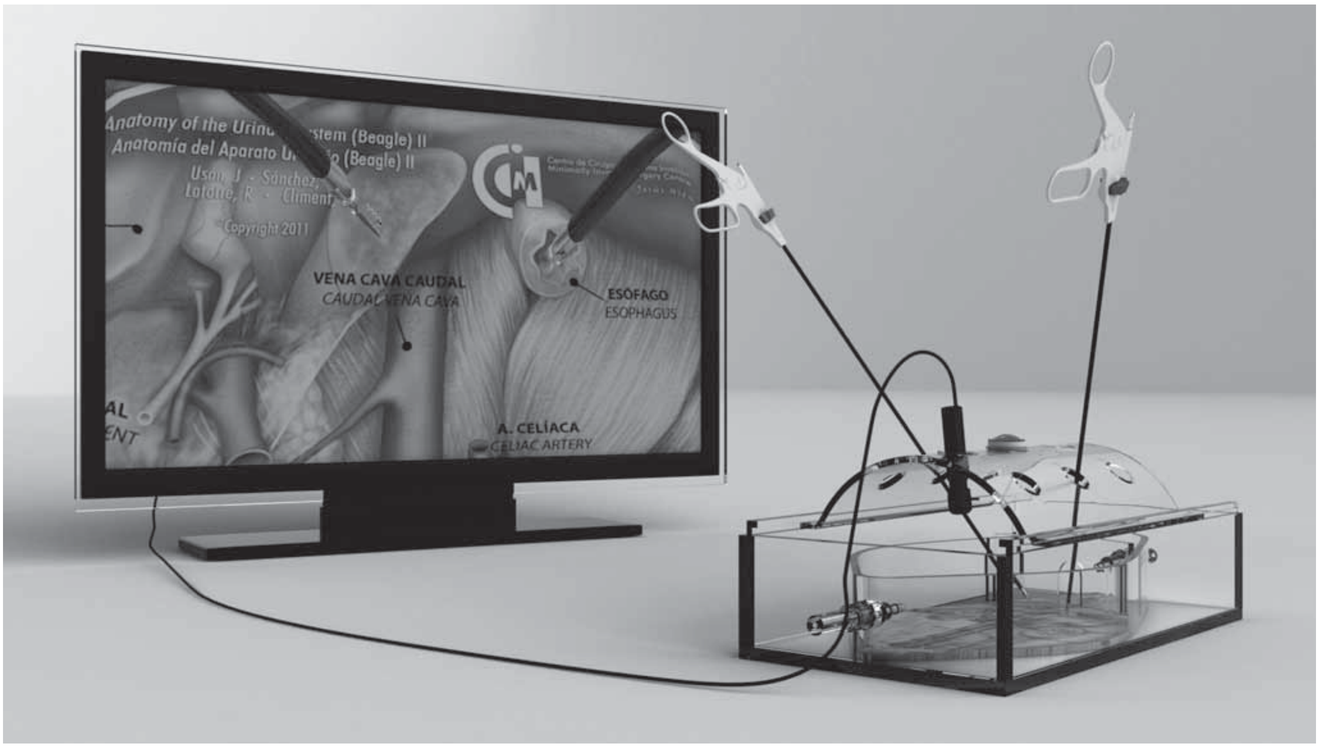

Figure 1: The CLS for practicing laparoscopy directly connected to the television monitor
CLS = Canine Laparoscopic Simulator

expert surgeon to assess the correct performance of the tasks, they are easily available, especially the affordable and basic "training box" model.[14,15]

Laparoscopic simulators are designed to allow the trainee to practice working with the challenges of laparoscopic surgery, which include magnified monocular vision, loss of tactile sensation, tremor amplification, fixed access ports, the fulcrum effect, and reduction in degrees of freedom.[16] The most complete simulators offer the opportunity to repeatedly practice various laparoscopic skills without any risk for the patient and are of extreme usefulness for surgeon–assistant team training.[17] Currently, there is no widely accepted veterinary laparoscopic simulator. In addition, an accurate veterinary simulator should overcome the problem of size variability in patients.

The goal of this study was to describe the Canine Laparoscopic Simulator (CLS) for veterinary training and to evaluate its perceived effectiveness during training performed with this device.

MATERIAL AND METHODS

This research complied with regulations regarding animal care as published by the Spanish Institute of Health's Guide for the Care and Use of Laboratory Animals.

Simulator Development

For the creation and development of the CLS[a] (Figure 1) at the Jesús Usón Minimally Invasive Surgery Centre (JUMISC), one male and two female Beagle dogs were used. All of them were anesthetized, placed in a dorsoventral position, and underwent a computed tomography (CT) scan.[b] Before performing the CT scan, it was necessary to recreate the standards of an abdominal laparoscopic procedure: In aseptic conditions, a Veress needle was introduced in the periumbilical area, and CO_2 was insufflated until an intra-abdominal pressure of 12 mmHg was reached, establishing pneumoperitoneum. After the procedure, the animals recovered from the anesthesia successfully.

The Digital Imaging and Communications in Medicine image sequences collected from the CT scans were processed to define the working and optical space of the CLS. Data regarding the exact area, height, and volume of the abdominal and thoracic cavities were processed by AutoCAD[c] for the preparation of the CLS construction plans.

According to the data obtained in the CT scans, the CLS was developed with the following characteristics: It consists of a transparent methacrylate training box, and its dimensions are 40 cm long, 20 cm wide, and 15 cm deep, creating a cavity of approximately 9,000 cm^3. The inner work space is oval shaped and divided into two sections by a curved sheet of methacrylate as a diaphragm, defining the thoracic and abdominal cavities. The background is covered by a picture of the abdominal and thoracic organs. It has two holes, front and rear, simulating the anatomic oral and anal orifices of the dog, allowing

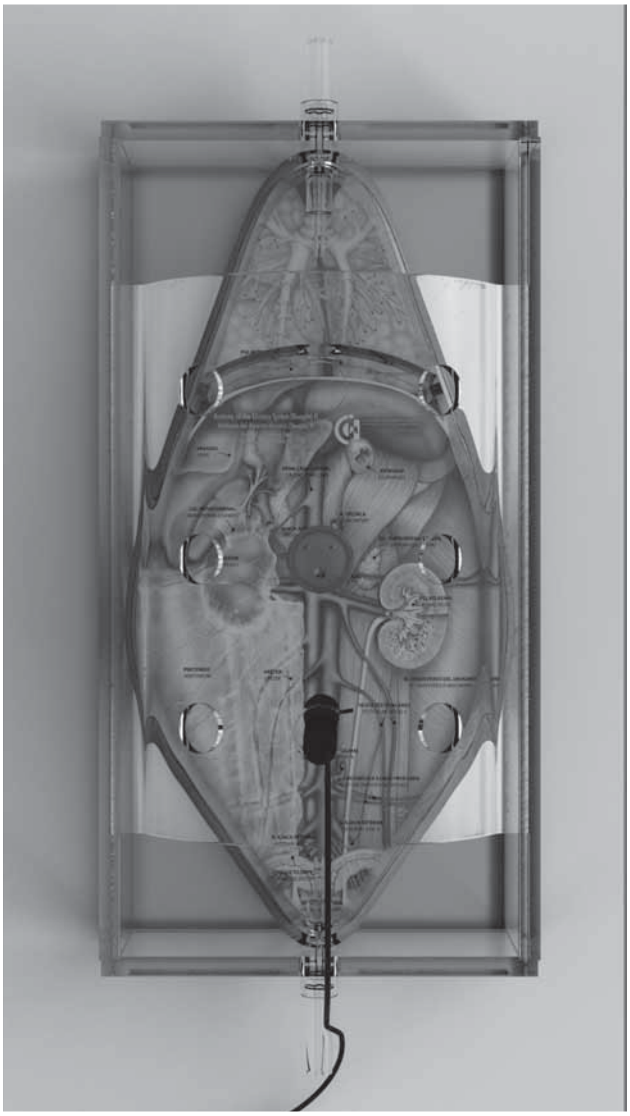

Figure 2: The CLS' background picture of the abdominal and thoracic organs
CLS = Canine Laparoscopic Simulator

for the practice of endoscopy. It also has nine access ports on its curved cover for the introduction of laparoscopic instruments and the integrated camera (Figure 2). The integrated camera can be moved from one port to another and be directly connected to a television monitor, but the simulator also allows for the placement of an optical telescope, thus enabling team training.

The CLS could be used placed on a training cart,[d] which incorporates a tray holder and a television monitor that are adjustable in height.

Evaluation of the CLS

A total of 30 veterinarians participated in the study. According to the number of procedures and years of experience in laparoscopy, they were classified into two groups: experts, with surgical experience in at least 30 laparoscopic procedures and more than 3 years' experience in performing laparoscopic surgery, and novices.

To obtain additional information about the participants, they were asked demographic questions regarding their age, sex, and dominant hand. Afterwards, they completed a survey concerning previous laparoscopic experience, experience with physical and virtual simulation, and experience with video games (response options: low, medium, or high).

Before the performance of each task, the written instructions were read. All participants completed four tasks on the CLS: peg transfer, coordination, precision cutting, and one suturing exercise. The exercises were developed by JUMISC after years of work and were modified from what is used in laparoscopic training in human medicine FLS. In this preliminary assessment, the maximum allowed time was 60 minutes.

Peg transfer—Holding grasping forceps in both hands, participants have to pick up smooth and rough objects and place them on a coordination plate[e] (Figure 3). There are six objects located at the top of the coordination plate. The participants start with the dominant hand to pick up the first object, then the non-dominant hand for the second object, and then successively alternate hands. The objects must be placed in the indicated gaps.

Coordination—At first the participants, holding the dissectors in both hands, have to touch a specific gap at the same time on the coordination plate. Then participants are required to lift one object from the top of the coordination plate with the instrument in the dominant hand, transfer it to the instrument in the non-dominant hand in midair, and then place it in the center gap of the coordination plate. The entire exercise is then reversed.

Precision cutting—Holding the scissors in the dominant hand and the grasping dissector in the non-dominant hand, participants are required to cut two different foam-latex templates of increasing difficulty (Figure 4). These templates allow for straight, curved, and sigmoid cutting paths to be executed with both hands.

Suturing exercise—Holding the needle-holder in the dominant hand and the dissector in the non-dominant hand, a vertical and horizontal intra-corporeal knot suture is required to be done precisely through two marks on an inorganic intestine tissue (Figure 5).

During the performance of the exercises, all the tasks were supervised by an experienced laparoscopic veterinarian. Training sessions were monitored to make sure that tasks were completed correctly and to provide guidance and help, thus ensuring that the training time was not exceeded. The intra-corporeal suturing was proctored in a session instructed by one of the authors (ATA). Afterwards, participants were asked to complete an anonymous survey describing their experience with the CLS. The survey was focused on the design, usability, and other aspects of the CLS. Answers were scored on a 5-point Likert scale. In addition, subjects were asked to rate their opinion of each task and their overall opinion of the CLS on a 10-point scale. The survey questions and tasks are listed in Tables 1 and 2. There were also open-ended questions soliciting comments on specific points of interest.

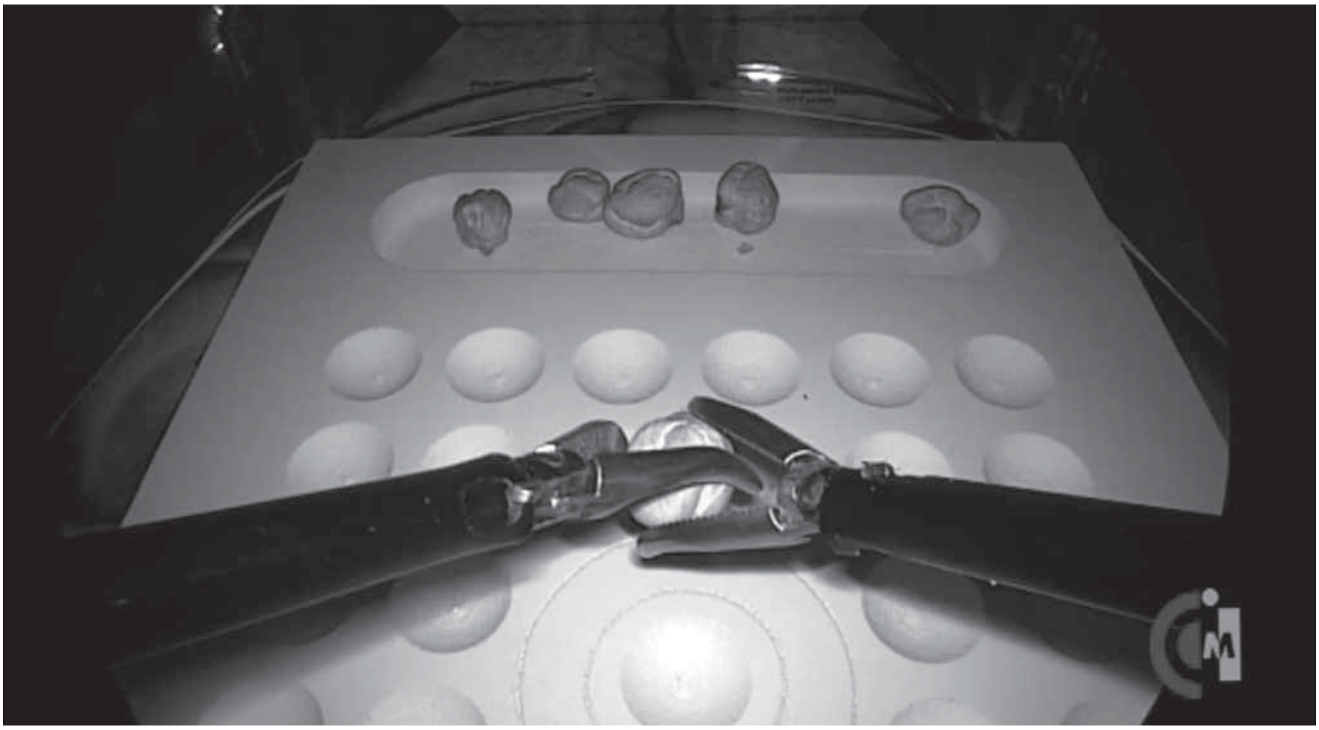

Figure 3: Plate for the training of peg transfer and coordination tasks

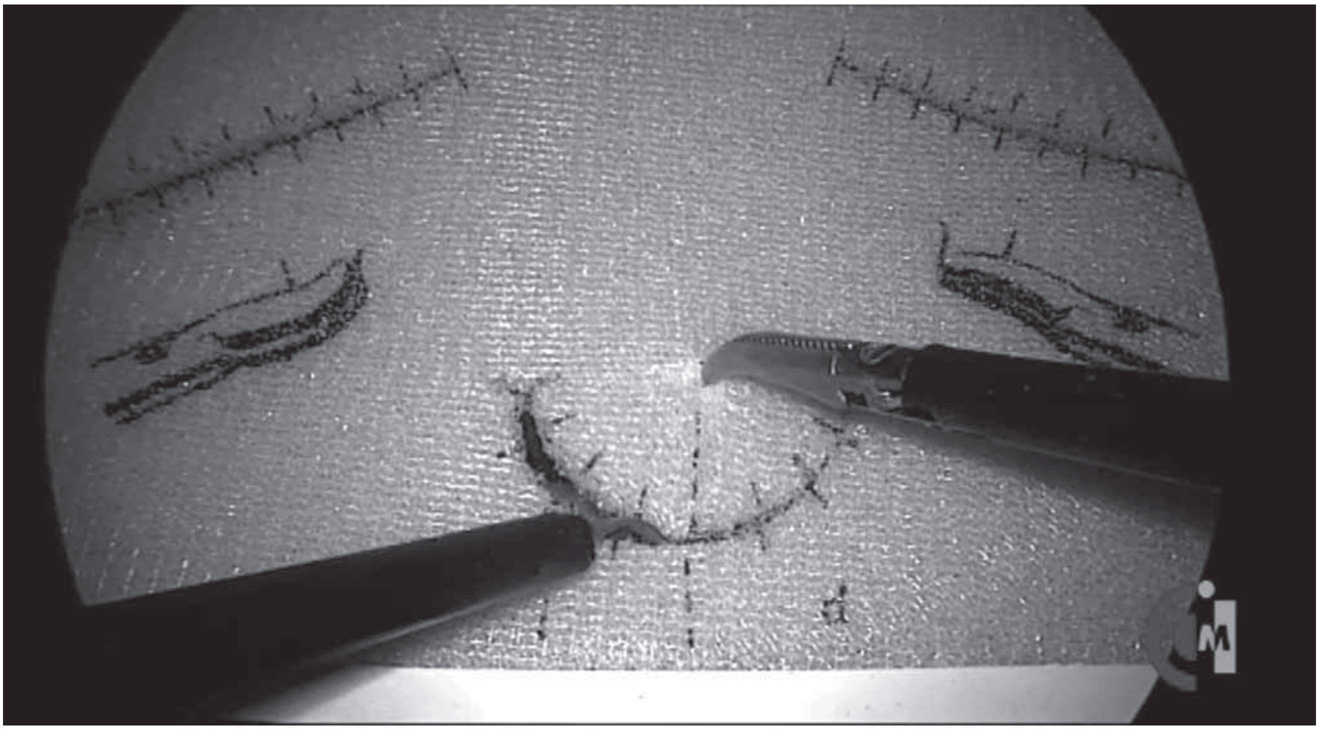

Figure 4: Templates for straight, curved, and sigmoid precision cutting

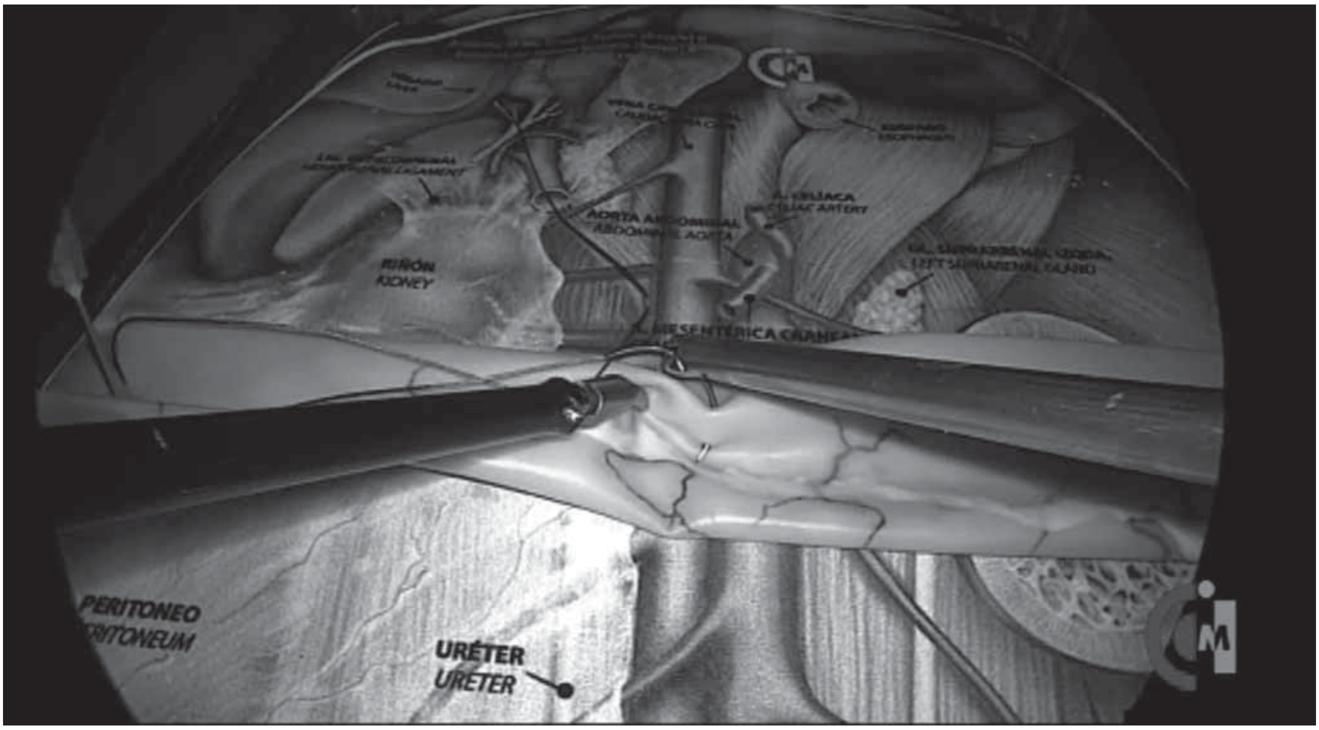

Figure 5: Inorganic intestine tissue for suturing exercise

Table 1: Quantitative responses to the CLS survey (1 = *strongly disagree*; 2 = *disagree*; 3 = *neutral*; 4 = *agree*; 5 = *strongly agree*)

Survey questions	1	2	3	4	5
The CLS is realistic, didactic, and an adequate size for training on basic laparoscopic skills.	0	1 (3.3%)	3 (10.0%)	13 (43.3%)	13 (43.3%)
The CLS has a clear, light, and colorful picture quality.	0	1 (3.3%)	5 (16.7%)	6 (20.0%)	18 (60.0%)
The CLS is useful for training students.	0	0	2 (6.7%)	2 (6.7%)	26 (86.6%)
The CLS is useful for training veterinary surgeons.	0	0	6 (20.0%)	12 (40.0%)	12 (40.0%)
The CLS would help me to improve my laparoscopic skills and also to apply them to my patients.	0	0	3 (10.0%)	9 (30.0%)	18 (60.0%)
Do you consider useful the inclusion of CLS in laparoscopy training programs for vet students before operating room practice?	0	0	1 (3.3%)	8 (26.7%)	21 (70.0%)
If you have already practiced on other simulators, would you prefer using CLS instead?	0	0	1 (8.3%)	8 (66.7%)	3 (25.0%)

CLS = Canine Laparoscopy Simulator

Statistical Methods

The Mann–Whitney *U* test was used to determine existent significant differences between both groups. The significance level was established at $p < .05$.

RESULTS

Population Description

Thirty veterinaries who attended a course in our institution in June 2012 participated in the study. The average age of the participants was 40 years old, and 94% of them were right-handed. In accordance to the number of procedures and years of experience, there were 7 experts and 23 novices. All participants had previously heard about simulators, but only 40% had performed practices on one.

CLS Survey

Regarding the surveys, both groups scored the first seven questions with a median of 3.7 points on the 5-point Likert

Table 2: The scores participants gave to each type of exercise, plus the overall CLS rating

Please rate on a scale from 1 to 10 the tasks performed on the CLS	Median
Peg transfer and coordination	8.4
Precision cutting	8.7
Suturing exercises	8.5
The CLS as a whole	8.7

CLS = Canine Laparoscopy Simulator

scale, which means that they agreed or strongly agreed with the statements. These results are summarized in Table 1. No significant differences were found between groups.

When asked about the global design of the CLS, 87% agreed or strongly agreed that it is realistic, didactic, and an adequate size for training on basic laparoscopic skills. One participant commented, "The fact that the simulator is transparent may help students and less [experienced] veterinarians at first stages of training," whereas another wrote, "I would rather prefer a dark cover to make it more realistic."

Regarding their opinion about picture quality, 80% agreed or strongly agreed that it was clear, light, and colorful. Participant comments included, "Considering that it is a camera and not an optical transmitting the image, I really value the image quality," "Better vision than with other simulators," and "It is a shame that the background image is only two dimensions without relief."

When asked about the usefulness of CLS for training, 93% agreed or strongly agreed that it is very useful for students, and 80% agreed or strongly agreed that it is useful for veterinarians. One participant commented, "It is an excellent tool for learning the first basic laparoscopic skills."

Ninety percent believed that the use of the CLS would help them to improve their laparoscopic skills and apply them to their patients. Someone commented, "I felt very comfortable, I would like to train before every surgery," whereas another wrote, "I think a more complex and longer program is needed to improve my skills."

Almost 100% of experts and novices believed that it would be interesting to include CLS in laparoscopy training programs for veterinary students before practice in operating rooms. Some of them expressed their enthusiasm, such as one participant who commented, "A CLS may be also useful at hospitals in order to explain [to] customers the advantages of laparoscopy."

Regarding their past experience with other simulators, of the 40% of participants who had previously used another simulator, almost 92% would prefer using CLS instead.

Participant Ratings of the CLS Tasks

The scores participants gave to each task plus the overall CLS rating are shown in Table 2. Participants rated the peg transfer and coordination exercises a median score of 8.4, the precision cutting 8.7, and the suturing exercise 8.5. The median score for the CLS as a whole was 8.7 on a 10-point scale. Comments included, "The fact that the exercises [were] presented with an increasing difficulty was a challenge and encouraged the training" and "I felt very comfortable using the CLS at all times."

The expert group did not need much help from the experienced laparoscopic veterinarian, but novices required more help, especially for the suturing exercises, and one novice commented, "I would like to have more time to perform the exercise."

DISCUSSION

The CLS aims to be a complementary learning tool and tries to reproduce the difficulties the veterinarian faces during laparoscopy learning. It also reflects the limitations inherent to small animals, including small structures for various exercises in a smaller space. This influences intraoperative maneuvering, with greater need for precise movement control to cope with available instruments and specific surgical performance carried out on smaller areas of dissection under great magnification. The CLS is based on Beagle breed dimensions, and participants in our study considered this size adequate for their training. However, a veterinarian has to deal daily with much smaller or much bigger dogs, so there is still a need for a simulator capable of creating different and adjustable work spaces.

It has been established in previous studies that early stages of surgery learning should be performed outside the operating room.[18,19] For example, with the Canine Patient Simulator, for learning cardiopulmonary resuscitation, it was evident that this type of simulation is an engaging learning experience for veterinary students.[20] Moreover, in 2011 a quantitative meta-analysis showed that the utility of simulation-based medical education with deliberate practice is superior to traditional clinical medical education in achieving specific clinical skills.[21] In fact, educational games will play a new and increasingly important role in the future veterinary curriculum, providing an attractive and useful way of learning.[22]

We believe that most veterinarians lack the necessary training, and they highly value the possibility of using simulation in laparoscopy. In our view, to introduce laparoscopy to veterinarians, the best choice is to teach basic surgical skills within a structured training program using simulators.[23] We consider that training on a physical simulator is essential not only for learning basic skills but also for more advanced techniques. In fact, at our institution, the training program in veterinary laparoscopic surgery was implemented in 2010, and 35% of laboratory sessions are performed on the CLS before reaching the second level, which consists of completing specific surgical procedures on experimental animal models.

Specifically, in laparoscopy, physical simulators are highly helpful, and their increased use could lead to greater surgical success on patients. However, there is no universally accepted learning model for veterinary laparoscopy as it exists in human medicine with the FLS simulator.[24]

At present, there are few published articles on the use of laparoscopic simulators or their importance in veterinary education.[25,26] In fact, the value of simulation training in veterinary education was demonstrated in the assessment of laparoscopic skills before and after simulation training with a canine abdominal model.[27] In those articles, the need and benefits of using simulation for skills acquisition in veterinary laparoscopic surgery is evident. Previous studies showed that the learning and acquisition of adequate abilities are essential to prevent, or at least reduce, error rate and intraoperative accidents and shorten the learning curve.[28,29]

The validity of the FLS (the simulator and the tasks) and the reliability of the FLS and other simulators have been previously proven, establishing these tools as predictive, constructive, and useful in teaching.[30,31] Furthermore, they can also minimize the use of animals, as stated in several publications.[32,33]

Our training program using the CLS consists of exercises adapted from the guidelines of the FLS and attempts to include all the basic needs following a gradual increase in the exercises' difficulty.[34] This approach was valued positively by veterinarians.

The CLS has many attributes that we think make it a good training tool for veterinarians without laparoscopic experience as they can start with the acquisition of the necessary basic laparoscopic skills before performing a real laparoscopy. The design has all the necessary components for individual use while it can also be adapted for team training. It has a transparent cover, thought to help novices correct their mistakes easily. In addition, the CLS has an integrated camera allowing the veterinarians to work anywhere outside the operative rooms without a laparoscopic tower.

In conclusion, the CLS showed good preliminary acceptance by veterinarians for its use in basic laparoscopy tasks. They perceived it to be a good training tool, and we believe that the CLS represents an important step in the development of simulation-based teaching tools in veterinary laparoscopy. However, limitations in this study included the lack of a clear comparison of the CLS with another simulator; the low number of participants for the evaluation, especially in the expert group; the lack of a student group (those with zero experience in laparoscopy); and the fact that participants were allowed only one training session before assessing the simulator.

To obtain definitive conclusions, more studies are needed on learning programs as well as training and simulation methods in veterinary laparoscopy, including a constructive and predictive validation of the CLS training program.

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CONFLICT OF INTEREST

All of the authors are employees of the Jesús Usón Minimally Invasive Surgery Centre. Two authors (JUG and FSM) are in the patent of Simulvet. A potential conflict of interest may exist.

NOTES

a Simulvet. Cáceres, Spain: JUMISC.
b Brilliance 6 CT Scanner. Eindhoven, Netherlands: Philips.
c AutoCAD. San Rafael, CA: Autodesk, Inc.
d Carro-Lap. Cáceres, Spain: JUMISC.
e Lap-Plate. Cáceres, Spain: JUMISC.

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2. **Assessment of Laparoscopic Skills in Veterinarians Using a Canine Laparoscopic Simulator.** *Journal of Veterinary Medical Education* (JVME).

Assessment of Laparoscopic Skills in Veterinarians Using a Canine Laparoscopic Simulator

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ABSTRACT

The aim of the study was to assess the content and construct validity of the Canine Laparoscopic Simulator (CLS). Forty-two veterinarians were assigned to experienced (n=12), control (n=15) and training (n=15) groups, which were assessed while performing four laparoscopic tasks on the CLS. The initial and final assessments of all tasks were performed blindly by two experienced surgeons using the Global Operative Assessment of Laparoscopic Skills (GOALS) and a task-specific checklist. At the end of the study, the subjects completed an anonymous survey.

The experienced group performed all of the tasks faster, with higher GOALS and checklist scores than the training and control groups (*p≤0.001*). In the second assessment, the training group reduced the time needed to complete all of the tasks and obtained significantly higher GOALS and checklist scores than the control group. The participants perceived the CLS and its training program to be positive or very positive.

The CLS and its training program demonstrated content and construct validity, supporting the suitability of the simulator for training and teaching and its ability to distinguish the degree of experience in laparoscopic surgery among veterinarians. Additionally, face validity showed that the veterinarians fully accepted the CLS´s usefulness for learning basic laparoscopic skills.

Keywords: Canine; Laparoscopy; Minimally Invasive Surgery; Simulator; Validity.

Abbreviations list

CLS: Canine Laparoscopic Simulator

FLS: Fundamentals of Laparoscopic Surgery

GOALS: Global Operative Assessment of Laparoscopic Skills

MISTELS: McGill Inanimate Simulator for Training and Evaluation of Laparoscopic Skills

1. Introduction

Currently, laparoscopy constitutes a well-established surgical approach in human medicine and is becoming established in veterinary surgery[1]. Unfortunately, the skills needed for this approach require a learning curve that should be overcome gradually using non-invasive methods such as simulators[2]. A medical simulator, broadly defined, is a device or set of conditions that aims to imitate real patients, anatomic regions, or clinical tasks and mirrors the real-life situations in which such services are rendered. Simulations can take many forms, ranging from low- to high-fidelity and from devices for the individual user to devices to role play scenarios for groups of trainees[3]. Previous studies have shown that surgeons can improve their skills through the use of simulators[4-6]. In particular, the different types of simulators used for laparoscopic training purposes are traditional box trainers, virtual reality, and augmented reality simulators[7].

Traditional box trainers provide realistic haptic feedback during procedures, and previous studies have shown that realistic haptic feedback is fundamental for appropriate laparoscopic training. Such training results in significantly improved skills transferred to the trainee compared to training without haptic feedback[8-9], but an expert observer must be on hand to assess performance. Virtual reality simulators provide explanations of the task to be practiced and objective assessment of the performance; however, they lack realistic haptic feedback[10]. Augmented reality simulators retain realistic haptic feedback and provide objective assessment of the trainee´s performance. However, this requires a considerable investment in time and financial resources for appropriate training[11-12].

The simulators are simultaneously training and assessment devices. In this way, simulation and its evaluation can be used not only for training purposes but also as a way of crediting a surgical skills exam such as the *"Global Operative Assessment of Laparoscopic Skills"* (GOALS), which is able to correlate surgical abilities on physical simulation with those on real patients[13-17]. In human medicine, a well-established training program, the "*Fundamentals of Laparoscopic Surgery"* (FLS), is a training program teaching the structured basic laparoscopic skills needed for laparoscopy[18]. The FLS simulator uses the "*McGill Inanimate Simulator for Training and Evaluation of Laparoscopic Skills"* (MISTELS) program for the training and assessment of manual skills on a physical laparoscopic training box[19].

In a previous study, the face validity of the Canine Laparoscopic Simulator (CLS) showed good preliminary acceptance by veterinarians for training in basic laparoscopy tasks[20]. They perceived it to be a good training tool, and the results suggested that CLS is an engaging tool for education. However, further studies were needed to establish predictive validity and help determine the moment when the surgeon is ready to clinically perform these techniques with minimal risk to the patient. The aim of this study was to assess the content and construct validity of the CLS for veterinarians performing a set of laparoscopic training tasks before and after two training sessions for the acquisition of psychomotor skills in laparoscopy.

2. Material and methods

2.1. Study subjects

All trials were carried out at the experimental surgical theaters at the Jesús Usón Minimally Invasive Surgery Centre (JUMISC, Cáceres - Spain) and in the surgical area of the Animal Medicine and Surgery Department of the Autonomous University of

Barcelona. The novice subjects were 30 veterinarians with no or minimal experience in laparoscopic surgery. They were divided randomly into a control group (n=15) and a training group (n=15). Additionally, an experienced group was composed of 12 veterinarians with more than three years of experience who had performed at least 30 laparoscopic procedures.

All of the subjects enrolled in the study provided informed consent prior to their participation and completed a questionnaire requesting information on gender, age, dominant hand, laparoscopic surgical experience, and simulator and video game experience.

2.2. CLS and training tasks

The laparoscopic training tasks performed on the CLS[a] were developed at our institution[20] (Figure 1). Access ports were set in the triangulating spatial configuration with the vision system focused on the work area and 2 instrument trocars positioned at approximately 45 degrees with respect to the optics. The CLS was placed on the training cart[b] with a monitor. The height of the support for the box trainer of the cart was adjusted according to the height of the subject, and the monitor was placed on an adjustable stand so that it could be positioned at eye level according to the most up-to-date recommendations[21].

Before the performance of each task, the written instructions were read. All subjects received a previously recorded video with a demonstration of all of the tasks in the first and second assessment. Subsequently, they completed the laparoscopic training tasks on the CLS in the following order: coordination, peg transfer, cutting and suturing (Figure 2).

Coordination: First, the subjects, holding the laparoscopic dissectors[c] (5 mm x 36 cm long, Kelly/Maryland) in both hands, were asked to touch specific wells at the same time on the coordination plate[d]. Then, the subjects were required to lift one object from the top of the coordination plate with the instrument in the dominant hand, transfer it to the instrument in the non-dominant hand in mid-air and place it in the center well of the coordination plate. The entire exercise was then reversed to start with the non-dominant hand.

Peg Transfer: Holding the laparoscopic dissectors in both hands, the subjects were asked to pick up smooth and rough objects and place them on a coordination plate. Six objects were located at the top of the coordination plate. The subjects picked up the first object with the dominant hand and then picked up the second object with the non-dominant hand, successively alternating hands. The objects were then placed in the indicated wells.

Cutting: Holding the laparoscopic scissors[e] (5 mm x 35 cm long) with the dominant hand and the grasping dissector in the non-dominant hand, the subjects were required to cut two different foam-latex templates with an increasing degree of difficulty; straight, curved and sigmoid cutting paths were executed with both hands.

Suturing exercise: Holding the laparoscopic needle holder[f] (5 mm x 33 cm long) in the dominant hand and the dissector in the non-dominant hand, a vertical and horizontal intra-corporeal knot suture was precisely created through two marks[g].

2.3. Skills assessment protocol

The experienced and novice subjects (including the control and training groups) underwent a skills assessment protocol at the beginning of the study. Next, the training group carried out two simulation training sessions, and 2 weeks later, both the control and training groups repeated the skills assessment protocol.

All tasks were performed by the conventional laparoscopic approach, and a time limit of 10 minutes was established for each task. The exercises were modified and adapted from those used in laparoscopic training in human medicine (FLS)[*]. This training program for veterinarians focuses on the learning and assessment of laparoscopic surgical skills and has been implemented at our institution. In all groups, the initial and final assessments of all tasks were video recorded for later blind analysis by two experienced surgeons using GOALS and a task-specific checklist. Both experienced surgeons had performed more than 100 laparoscopic procedures and had more than 10 years of experience in minimally invasive approaches.

GOALS: consists of a 6-item global rating scale. The items on GOALS are scored using a 1-5 point Likert scale with anchors at 1, 3, and 5 where “1” represents the lowest level of performance, and “5” is considered the ideal performance (Appendix A).

Task-specific checklist: This 10-item checklist consists of completed and not-completed items pertaining specifically to the four tasks of the training program on the CLS. The items are awarded 1 point if they are done properly and no point if they are not done (Appendix B).

Finally, all of the subjects were asked to complete an anonymous survey describing their experience with the CLS. The answers were scored on a 1-5 point Likert scale.

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[*] Fundamentals of Laparoscopic Surgery (FLS). FLS manual skills written instructions and performance guidelines [Internet]. Los Angeles: Society of American Gastrointestinal and Endoscopic Surgeons; 2012 [cited 2012 Feb 15] Available from: http://www.flsprogram.org.

2.4. Simulation training sessions

The subjects in the training group underwent 2 simulation sessions after the first assessment. Simulation training consisted of the same four tasks performed twice with the CLS and standard operating-grade laparoscopic instruments. Participants used both hands for instrument manipulation, and the maximum time allowed for each training session was 50 minutes. A training time was scheduled for the training group to ensure that all individuals had the opportunity to train. This group received in-suite technical assistance, and the training sessions were monitored to ensure that the training time was not exceeded. The intra-corporeal suturing was proctored in a session instructed by one of the authors (ATA). The completions of the 2 training sessions were separated by a minimum interval of 48 hours with a maximum interval of 7 days between sessions.

2.5. Statistical analysis

All statistical analyses were performed using the statistics software SPSS 15.0 for Windows (SPSS Inc., Chicago, IL). Descriptive statistics for the time and leak test variables were obtained by the calculation of characteristic parameters: mean, standard deviation, and maximum and minimum values. In every case, a Kolmogorov-Smirnov test was performed to determine the normal distribution of the samples. As this condition was verified in all cases, a factorial ANOVA test with Bonferroni post hoc was performed to compare groups. SPSS was used to calculate t-tests for each comparison with statistical significance set at $p<0.05$. Additionally, a Pearson correlation coefficient was determined between the results of both evaluators.

3. Results

3.1. Experienced group- A total of 12 experienced laparoscopic veterinarians (six men and six women) were enrolled and completed the study; they had an average age of 33.0

± 5.1 years. Eleven veterinarians were right-handed, and one was left-handed. Six participants had a PhD in minimally invasive surgery, whereas the other six were pre-doctorate veterinary surgeons in laparoscopy at our institution. All of them had much experience with laparoscopic simulators and had performed previous extensive practices on one. Nine of them had previous experience with video games.

3.2. Control and training groups- A total of 30 veterinarian volunteers (18 men and 12 women) were enrolled in the novice group, of which 15 were randomly assigned to the control group and 15 were assigned to the training group. Twenty-six veterinarians were right-handed, and four were left-handed. They had an average age of 29.0 ± 9.1 years. None of them had any previous experience with laparoscopic surgery and simulators. Twenty-two of veterinarians in the novice group had previous experience with video games. No significant differences or associations were found among the three groups for age, dominant hand and video game experience.

3.3. Performance timings- The mean time used by the experienced group was shorter than the novice control and training groups in all tasks in the first assessment ($p \leq 0.001$). No significant differences were found between the control and training groups (Table 1). In the second assessment, the training group reduced times significantly for all tasks ($p \leq 0.001$). In addition, task completion time was significantly lower in the training group than in the control group except for that of the cutting task (Table 2).

3.4. GOALS and task-specific checklist- The GOALS and task-specific checklist scores were higher for the expert group than for the control and training groups in all tasks in the first assessment ($p \leq 0.001$). No significant differences were found between the control and training group (Table 3 and Figure 3). In the second assessment, the GOALS and task-specific checklist scores were significantly higher for the training group than the control group ($p \leq 0.005$) (Table 4 and Figure 4). The correlation between raters was strong and positive (r=0.91, $p \leq 0.01$).

3.5. Survey question- All groups scored the seven questions with a median of 4.4 points on the 1-5 point Likert scale, and no significant differences were found among the groups. This means that they agreed or strongly agreed with the statements. These results are summarized in Table 5. All participants believed that the use of the CLS would help them improve their laparoscopic skills and apply these skills to their patients. All experts and novices believed that it would be interesting to include CLS in laparoscopy training programs for veterinary students before practicing in operating rooms.

4. Discussion

Early stages of learning in laparoscopic surgery should be performed outside the operating room, as established in previous studies[22-23]. The present study suggests that the CLS and its training program tasks could be used to assess basic laparoscopic skills in veterinarians, and basic laparoscopic skills could be improved with simulation training. In fact, the use of laparoscopic simulators and education about their importance in veterinary training is needed. The benefits of simulators include not only the evident skills acquisition and accreditation in laparoscopic surgery but also the ability to minimize or completely prevent the use of animals during laparoscopic training, as stated in several publications[3, 24].

We believe that veterinarians should focus on their own technical preparation and simulator training as an essential step in their learning[5]. However, there is no universally accepted model for learning veterinary laparoscopic surgery today. In fact, some differences from MISTELS are encountered in laparoscopic training in the veterinary field. Laparoscopic surgery is an important field in veterinary care because veterinarians work in a space that is more confined than the FLS training box due to the different size of veterinary patients. In fact, the main challenge in veterinary laparoscopic surgery is the patients' variability in size. This influences intraoperative maneuvering of the instruments, with a greater need for precise movement control of the optics and available instruments, and requires that specific surgical performance be carried out on smaller areas of dissection under great magnification[25].

The CLS aims to be a complementary learning tool in laparoscopy for veterinarians. Our objective was to assess the content and construct validity of the CLS. We consider that the evaluation or assessment of the CLS must address issues of reliability and validity. Reliability is the reproducibility and precision of the test or testing device. Validity indicates that the simulator is able to teach what it is intended to evaluate or measure[26-27].

Face validity relates to the realism of the simulator. In our previous study, it was determined that the CLS received good acceptance by veterinarians[20]. In fact, participants expressed positive opinions regarding the size and general aspect of the CLS. Our surveys revealed that most veterinary surgeons lack necessary training and highly valued the possibility of using a simulation to learn laparoscopy. The participants believed that CLS is useful for training students and veterinarians and that it is necessary to have an expert observer to assess the first stages of performance.

Content validity is a judgment of the appropriateness of the simulator as a teaching modality. Taking into account the improvement in the different tasks with our training program, the simulator would be very useful for students and veterinarians before operating room practice. In fact, the training group significantly improved their scores in all laparoscopic tasks after practice on the CLS.

Construct validity indicates whether the simulator is able to distinguish the knowledge of the novice from that of the experienced surgeon. Our assessment methods identified a significant difference between the groups. Our results, using both GOALS and task-specific checklists, found significant differences between the novice and experienced groups. Therefore, the CLS represents an important step in the development of simulation in veterinary laparoscopy.

The CLS and its training program assessment can be used for training purposes but also as a way to structure credited surgical skills exams such as GOALS[17, 28]. Different validated assessment tools are required based on quantitative data, such as time, error determination, number and range of movements, or based on task-specific checklists with the appropriate rating scale[13, 26, 29-30]. In our study we used three assessment methods: GOALS, a task-specific checklist and the time to evaluate veterinarians during a set training program on the CLS. These methods are objective evaluations that were blindly performed by two experienced surgeons. These experienced observers were also suited to the type of assessment that we chose to use. It is interesting to note the high level of correlation found between the two experienced surgeons, which gives more strength to the results. It was demonstrated in a previous study[31] that global rating scales, when completed by experts, are superior to checklists for the evaluation of technical skills.

We believe that an objective measure of laparoscopic performance is useful not only in training but also in evaluation. Such a measure has the potential to examine the impact of training curricula using various simulators to determine whether the simulator practice improves operating room performance[32]. As technical skills are only a part of a surgeon's competence, the assessment of technical skills needs to be integrated with cognitive and behavioral characteristics such as team skills and decision making to develop methods that assess surgical competence[16].

This study was affected by several limitations. The number of participants included in this study, especially in the experienced group, was low. Thus, we believe that further studies must be performed with subjects from multiple institutions. This should include a larger number of subjects with different levels of experience in laparoscopy to obtain more representative data about different tasks and how they could affect laparoscopic skills performance.

Another limitation was that the novice subjects from the training group performed only two training sessions. Therefore, more in-depth studies should be carried out during a longer training program to analyze how the length of the training program may affect the learning curve. It could be interesting to set up a longer training program with different tasks on all study groups. In addition, a comparison of the performance on the CLS with another type of simulator should be assessed.

The task-specific checklists used here were developed for this study. The checklist consisted of a combination of previously described task-specific checklists[14, 17, 33]. These results were used as complementary information to GOALS to assess and validate the training program of the CLS. The laparoscopic performance GOALS and task-specific checklists were, for ethical and other reasons, not performed on live animals. In fact, this makes evaluation of the participant´s tissue handling harder because bleeding and bruising are indicators of rough tissue handling only in the live animal. However, all participants believed that simulator training is essential for the acquisition of adequate basic surgical skills prior to the use of animal models. More studies are needed on training programs as well as on training and simulation methods in veterinary laparoscopy, including a predictive validation of the CLS.

5. Conclusions and clinical relevance

Finally, we conclude that laparoscopic skills require a learning curve that should be overcome gradually with non-invasive methods such as simulators. The CLS and its training program demonstrated content and construct validity, indicating the suitability of the simulator for training and teaching and its ability to distinguish the degree of experience in laparoscopic surgery among veterinarians. Additionally, the face validity of the CLS´s usefulness for learning basic laparoscopic skills was fully accepted by the veterinarians.

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Conflict of interest statement

Some of the authors are employees of JUMISC. J.U.G and F.M.S.M are included in the patent of SIMULVET®. A potential conflict of interest may exist.

Footnotes

a) SIMULVET® JUMISC, Cáceres - Spain.

b) CARROLAP® JUMISC, Cáceres - Spain.

c) Click Line® #33310 MC, Karl Storz, Germany.

d) LAP-PLATE® JUMISC, Cáceres - Spain.

e) Click Line® #34310 MC, Karl Storz, Germany.

f) Macro Needle Holder® #26173 KAT, Karl Storz, Germany.

g) Inorganic Intestine Tissue JUMISC, Cáceres - Spain.

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FIGURE AND TABLE LEGENDS

Figure 1. A. CLS with different devices placed on the training cart. B. Detail of the subject performing the peg transfer and coordination task.

Figure 2. Laparoscopic training tasks: a) Plate for the training of peg transfer and coordination tasks, b) Templates for straight, curved, and sigmoid lines for the precision cutting task, c) Inorganic intestine tissue for the suturing task.

Figure 3. Task-specific checklist scores in the first assessment by the different groups during the training program on the CLS (* $p \leq 0.001$).

Figure 4. Task-specific checklist scores in the second assessment by the control and training groups during the training program on the CLS (* $p \leq 0.005$).

Table 1. The mean time (seconds) of the different groups in the first assessment during the training program on the CLS.

Table 2. The mean time (seconds) of the control and training groups in the second assessment during the training program on the CLS.

Table 3. GOALS scores in the first assessment of the different groups during the training program on the CLS.

Table 4. GOALS scores in the second assessment of the control and training groups during the training program on the CLS.

Table 5. Quantitative responses to the CLS survey (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree).

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Figure 1. A. CLS with different devices placed on the training cart.

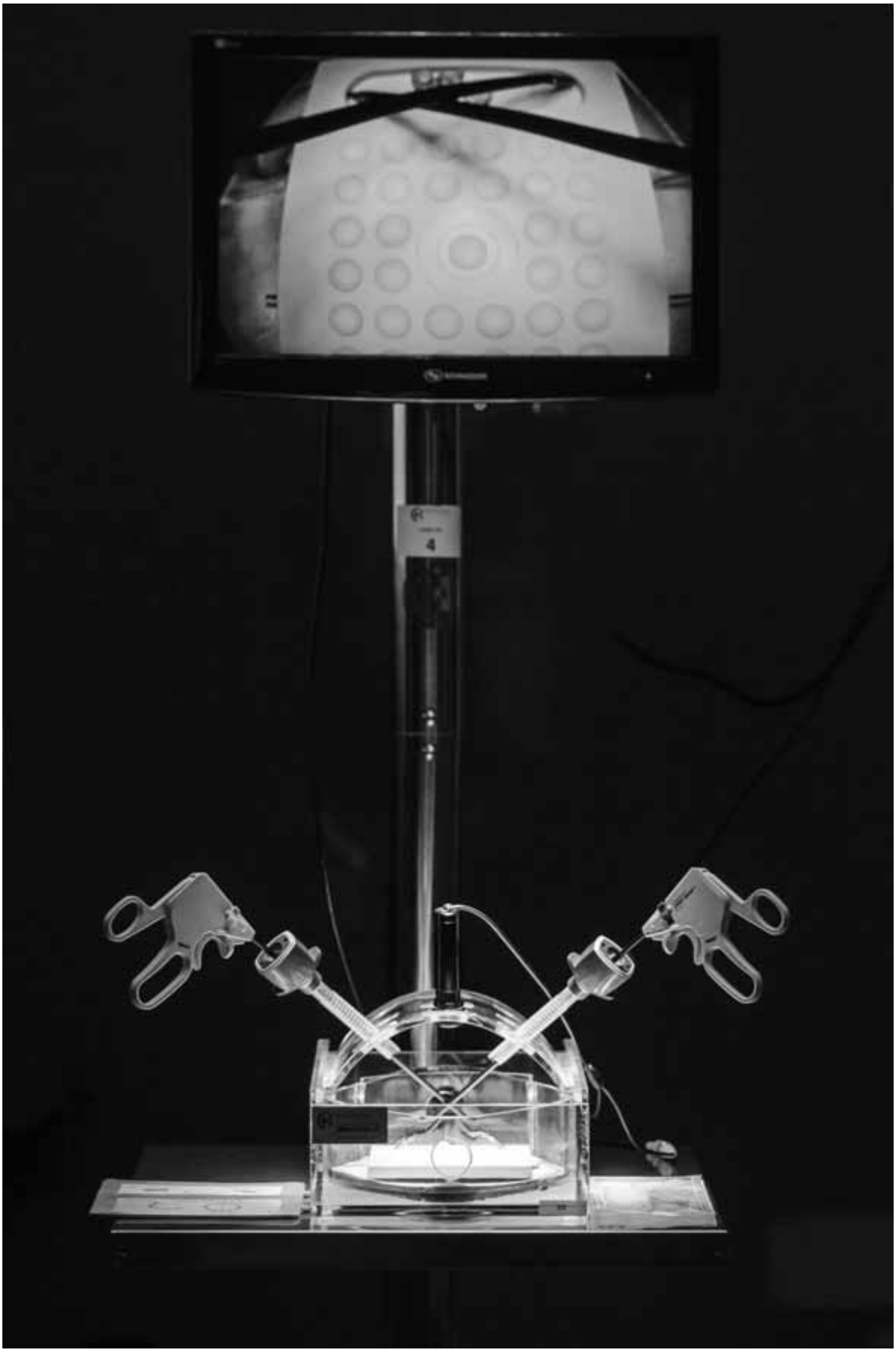

Figure 1. B. Detail of the subject performing the peg transfer and coordination task.

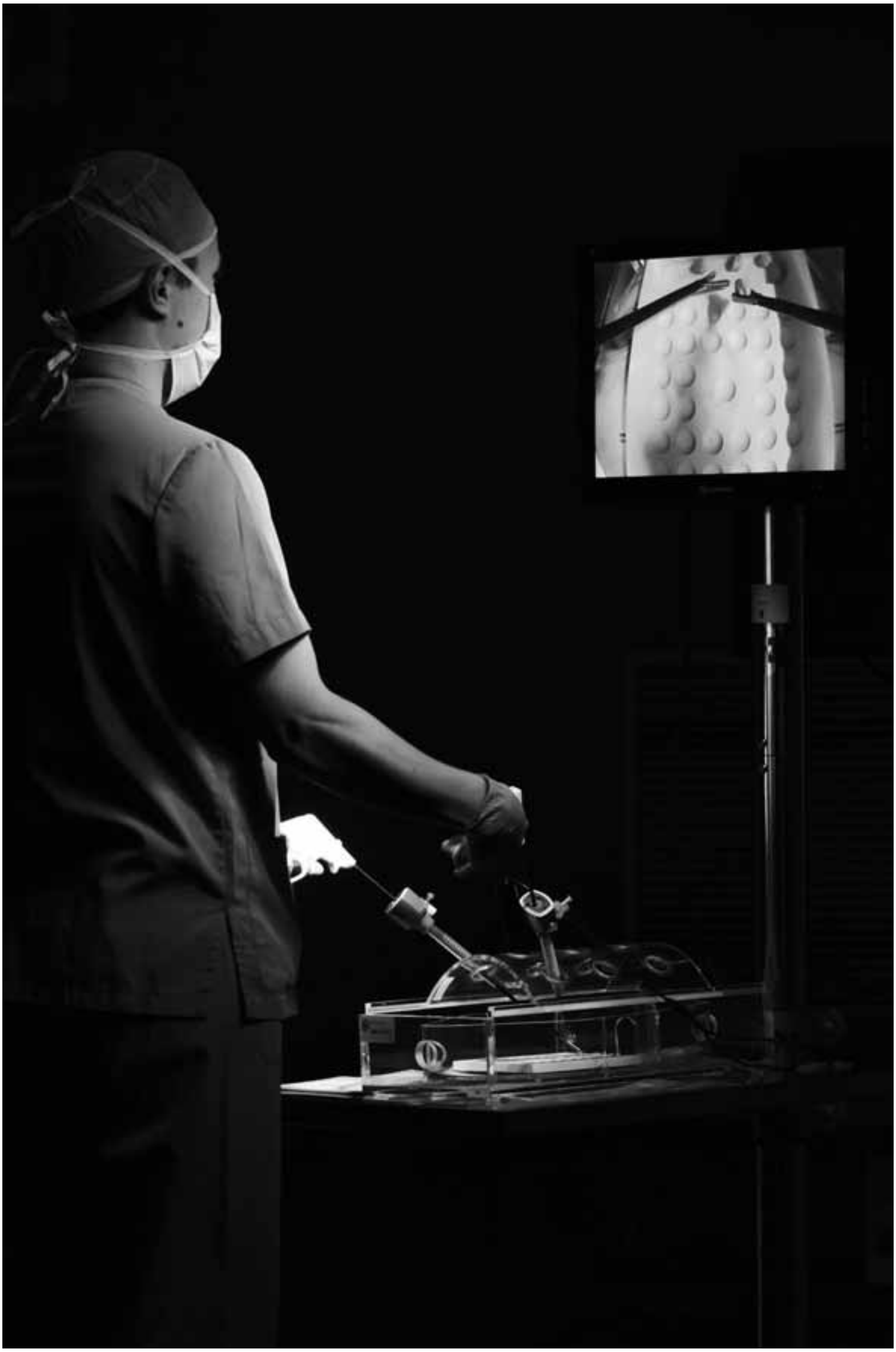

Figure 2. Laparoscopic training tasks: a) Plate for the training of peg transfer and coordination tasks, b) Templates for straight, curved, and sigmoid lines for the precision cutting task, c) Inorganic intestine tissue for the suturing task.

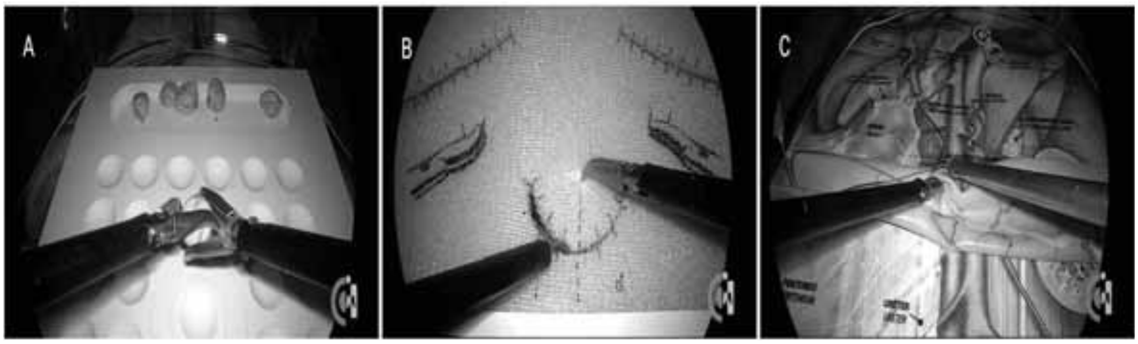

Figure 3. Task-specific checklist scores in the first assessment by the different groups during the training program on the CLS (* $p \le 0.001$).

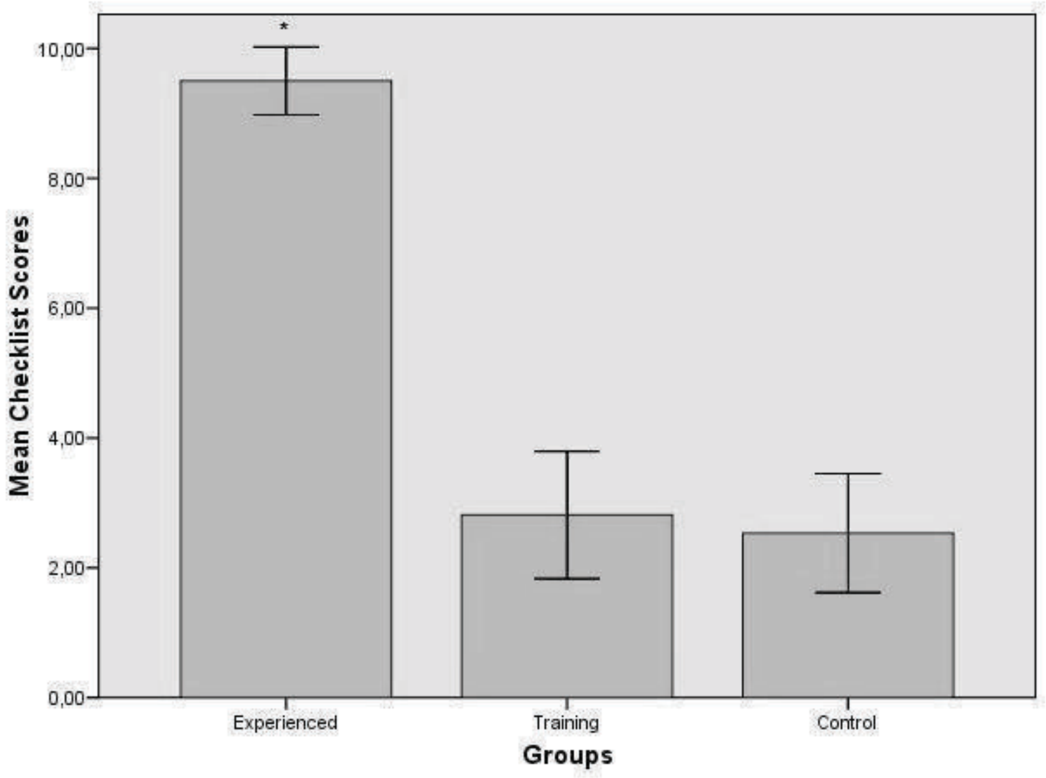

Figure 4. Task-specific checklist scores in the second assessment by the control and training groups during the training program on the CLS (* *p≤0.005*).

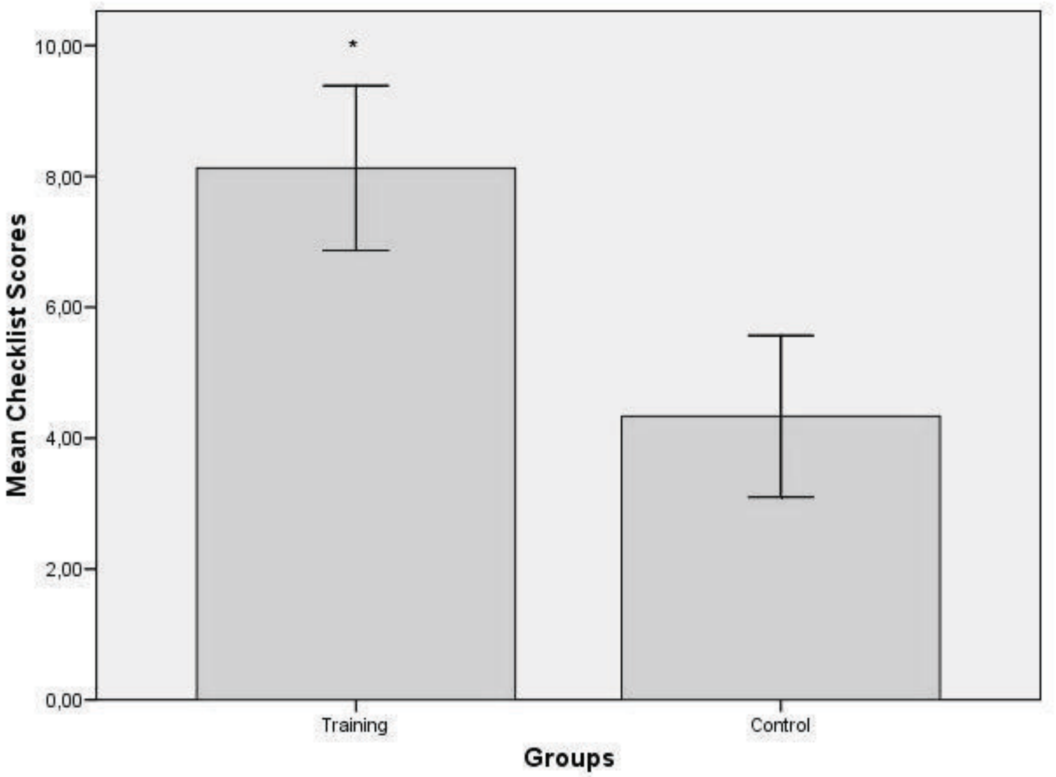

Table 1. The mean time (seconds) during the first assessment of the different groups during the training program on the CLS.

Groups / Tasks	**Experienced** **(Mean ± SD)**	**Control** **(Mean ± SD)**	**Training** **(Mean ± SD)**	**Sig.**
Coordination	$91.92^{a} \pm 15.44$	$209.75^{b} \pm 55.00$	$201.93^{b} \pm 54.10$	≤ 0.001
Peg transfer	$150.08^{a} \pm 96.59$	$508.13^{b} \pm 194.30$	$435.13^{b} \pm 205.80$	≤ 0.001
Precision Cutting	$645.92^{a} \pm 143.08$	$1049.13^{b} \pm 276.00$	$1076.67^{b} \pm 341.00$	≤ 0.001
Suturing	$296.65^{a} \pm 76.43$	$1158.94^{b} \pm 123.40$	$1142^{b} \pm 123.40$	≤ 0.001

P values from the ANOVA test are indicated in the last column (Sig.)

Different letters denote significantly different means (Bonferroni *post hoc* test) between tasks for each group: a - b.

Table 2. The mean time (seconds) in the second assessment of the control and training groups during the training program on the CLS.

Groups **Tasks**	**Control** **(Mean ± SD)**	**Training** **(Mean ± SD)**	**Sig.**
Coordination	167.44 ± 37.90	125.93 ± 27.76	0.002
Peg transfer	458.03 ± 182.22	207.53 ± 104.36	≤ 0.001
Precision Cutting	727.81± 240.96	737.6 ± 285.82	0.561
Suturing	1054.00 ± 181.70	635.53 ± 163.70	≤ 0.001

P values from the T-test are indicated in the last column (Sig.)

Table 3. GOALS scores in the first assessment of the different groups during the training program on the CLS.

Groups **Tasks**	**Experienced (Mean ± SD)**	**Control (Mean ± SD)**	**Training (Mean ± SD)**	**Sig.**
Coordination	51.20^a ± 3.03	32.26^b ± 2.57	32.81^b ± 1.81	≤ 0.001
Peg transfer	26.25^a ± 1.01	16.43^b ± 1.33	16.12^b ± 0.82	≤ 0.001
Precision Cutting	26.12^a ± 0.82	16.43^b ± 1.85	16.09^b ± 1.03	≤ 0.001
Suturing	27.50^a ± 1.17	13.36^b ± 1.35	13.43^b ± 1.04	≤ 0.001

P values from the ANOVA test are indicated in the last column (Sig.)

Different letters denote significantly different means (Bonferroni *post hoc* test) between tasks for each group: a - b.

Table 4. GOALS scores in the second assessment of the control and training groups during the training program on the CLS.

Groups **Tasks**	**Control** **(Mean ± SD)**	**Training** **(Mean ± SD)**	**Sig.**
Coordination	36.50 ± 3.57	44.28 ± 3.98	≤ 0.001
Peg transfer	19.56 ± 2.60	23.62 ± 1.29	≤ 0.001
Precision Cutting	19.66 ± 2.08	22.34 ± 2.72	≤ 0.005
Suturing	16.96 ± 2.58	22.50 ± 2.67	≤ 0.001

P values from the T-test are indicated in the last column (Sig.)

Table 5. Quantitative responses to the CLS survey*

Survey question	**1**	**2**	**3**	**4**	**5**
The CLS is realistic, didactic, and an adequate size for training on basic laparoscopic skills.	0	0	12 (28.5%)	22 (52.4%)	8 (19.1%)
The CLS has a clear, light, and colorful picture quality.	0	0	10 (23.8%)	22 (52.4%)	10 (23.8%)
The CLS is useful for training students.	0	0	3 (7.1%)	15 (35.8%)	24 (57.1%)
The CLS is useful for training veterinary surgeons.	0	0	5 (11.9%)	12 (59.5%)	25 (28.6%)
The CLS would help me improve my laparoscopic skills and apply them to my patients.	0	0	0	10 (23.8%)	32 (76.2%)
Do you consider useful the inclusion of the CLS in laparoscopy training programs for vet students before operating room practice?	0	0	0	10 (23.8%)	32 (76.2%)
Do you consider an expert observer necessary during performance assessment?	0	0	5 (11.9%)	12 (59.8%)	25 (28.6%)

CLS = Canine Laparoscopy Simulator

*** 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree**

3. Ergonomics in Veterinary Laparoscopy: Analysis of Surface Electromyography and Hand Motion.

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Ergonomics in Veterinary Laparoscopy: Analysis of Surface Electromyography and Hand Motion

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Conflicts of Interest Statement

None of the authors have any financial or personal relationships that could inappropriately influence or bias the content of this paper.

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ABSTRACT

Objective: To evaluate veterinarians´ ergonomics while performing a set of laparoscopic training tasks through the analysis of muscular activity and hand motion.

Procedure: 12 experienced laparoscopic attending veterinarians performed the following four tasks on box trainer: peg transfer, coordination, cutting and suturing. Muscular activity of right biceps brachii, triceps brachii, forearm flexors and extensors, and trapezius muscles was analyzed using surface electromyography. Right hand movements and wrist angle data were registered through a data glove, which was followed by the establishment of risk levels for the wrist joint according to a modified Rapid Upper Limb Assessment (RULA) method. One-way repeated measures ANOVA with Bonferroni's post hoc test was performed to make comparisons between each task.

Results: The muscular activity for the coordination task was the lowest in all muscles ($p \leq 0.05$), except for the biceps brachii. Precision cutting had the highest muscular activity for the forearm extensor and flexor muscles compared to the coordination task ($p \leq 0.05$). The suturing task had the highest muscular activity for the trapezius compared to all tasks ($p \leq 0.001$). The RULA score was unacceptable (score=3) for coordination, peg transfer and precision cutting tasks, whereas an acceptable score of 2 was obtained for the suturing exercise ($p \leq 0.001$).

Conclusions and Clinical Relevance: The tasks performed and instrument´s design affect veterinarians' ergonomy during laparoscopic training. The laparoscopic cutting and suturing tasks have the highest levels of muscular activity. The acceptable wrist position, according to the RULA method, was found for the suturing exercise, which was performed with an axial handled instrument.

ABBREVIATIONS

Electromyography (EMG)

Maximal Voluntary Contraction (MVC)

Rapid Upper Limb Assessment (RULA)

INTRODUCTION

Ergonomics can be defined as the science of adapting the work environment to the worker[1]. It is a multidisciplinary field that studies people's characteristics, needs, abilities and skills, and focuses on those aspects that affect product design or work processes. Ergonomics tries to adapt the products, tasks, tools, spaces and overall environment to the ability and needs of people, improving the efficiency, safety and welfare of consumers, users or workers. The ergonomic approach consists of designing the products and tasks so that they are adapted to people and not *vice versa*[2-3].

In surgery, ergonomics aims to guarantee the availability of adequate equipment for the reduction of muscle fatigue and associated disorders in surgeons[4]. Previous studies were performed to gain a better understanding of ergonomics in minimally invasive surgery. These include video analysis to describe variations in the relative orientation of the surgeon´s body and the range of joint movements; electromyography with surface electrodes to determine muscular participation and the presence of local muscular fatigue; and epidemiological surveys to obtain information about the conditions and habits of surgeons in their working environment[5-7]. With acquired knowledge, risk levels and injury influencing factors associated with body postures and muscular tension were defined.

However, fulfilling ergonomic criteria is challenging during laparoscopic training, which may lead to high levels of musculoskeletal stress. This stress in turn increases the risks for the surgeon and causes ergonomic deficiencies during the laparoscopic practice, related to the reduced freedom of movement and forced postures, leading to greater muscle fatigue than the one observed during conventional surgery[8-9].

A basic ergonomic problem associated with laparoscopy is the surgeon's non-neutral posture during laparoscopic procedures[10]. Due to this disadvantage, the surgeon's performance and precision decrease, while physical fatigue and musculoskeletal pain increase[5]. The following are five main issues in laparoscopic surgery that influence the surgeon's posture: the (hand-held) instrument design, the position of the monitor, the use of foot pedals to control diathermy, the poorly adjusted height of the operating table, and the static body posture[11]. Based on the scientific literature, some recommendations for a correct body posture during laparoscopic surgical performance are: no corporal segment should be in a forced posture; the screen should be placed facing the surgeon and at his/her eye's level or a bit lower; to avoid bending or twisting excessively the cervical vertebrae; the elbow's flexion-extension angle should be between 90° and 120º; regarding the position of the hands, the hyperflexion of the wrist should be avoided[1,7,12].

The use of simulation technology for teaching and training has increased in laparoscopy in both the human and veterinary health care industries[13-14]. In addition to various technical limitations associated with laparoscopic box trainers, there are a number of disadvantages for the surgeon, including magnified monocular vision, loss of tactile sensation, tremor amplification, fixed access ports, fulcrum effect, and reduction in the degrees of freedom, resulting in poor ergonomic postures usually maintained for relatively long periods of time[15].

Some studies have reported that veterinarians have significantly greater problems with musculoskeletal pain than dentists and nurses, who have already been identified as having a higher risk than the general population[16-17]. The understanding of their causes, especially work-related causes, remains critical to primary prevention[18-19].

Moreover, and despite the numerous advantages demonstrated in other disciplines, there are only a few studies on the application of ergonomic criteria in laparoscopic training programs, which could, if correctly applied, greatly benefit both surgeons and patients[20]. Additionally, there is no clear consensus about the systems for laparoscopic skills assessment and certification in veterinary medicine.

To the best our knowledge, there are no published studies on the body posture and muscle activity in veterinary surgeons during laparoscopy. Therefore, further ergonomic studies in laparoscopic training and tools design are needed in this field. The aim of this study is to detect and evaluate ergonomic problems in veterinarians, by analyzing muscular activity and hand motion during the completion of laparoscopic training tasks using a box trainer.

MATERIALS AND METHODS

Subjects

All of the trials were carried out at the experimental surgical theaters at the Jesús Usón Minimally Invasive Surgery Centre (JUMISC, Cáceres - Spain). Veterinarians who had performed at least 30 laparoscopic procedures over more than three years were included in this study, after voluntarily accepting to participate in the trials and signing a consent form. Additionally, all participants had experience in laparoscopic simulation training.

Instruments

The laparoscopic training tasks were performed in a box trainer[a] that was developed at our institution[21]. Access ports were set in triangulating spatial configuration with the optic system focused on the work area and 2 instrument trocars positioned at approximately 45 degrees with respect to the optics (Figure 1). During the peg transfer and coordination tasks, all subjects used a ringed-handled laparoscopic dissector[b] (5 mm x 36 cm long, Kelly/Maryland) on each hand. For the precision cutting task on specific templates, subjects used ringed-handled laparoscopic scissors[c] (5 mm x 35 cm long) on the dominant hand and a laparoscopic dissector on the non-dominant hand. Finally, for the suturing task, subjects used an axial-handled laparoscopic needle holder[d] (5 mm x 33 cm long) on the dominant hand and a laparoscopic dissector on the non-dominant hand (Figure 2). The box trainer was placed on the training cart[e] equipped with a monitor. The height of the platform for the box trainer was adjusted according to the height of the subject, and the monitor was placed on an adjustable stand so that it could be positioned at eye level according to current recommendations[1].

Skills assessment protocol

Before the performance of each task, written instructions were read. All subjects watched a previously recorded video with a demonstration of the tasks. Subsequently, they completed the laparoscopic training tasks on the box trainer in the following order: peg transfer, eye-hand and hand-hand coordination, cutting and suturing[21] (Figure 3). All tasks were performed by the conventional laparoscopic approach and a time limit of 10 minutes was established for each task. The exercises were modified and adapted from those used in laparoscopic training in human medicine (Fundamentals of Laparoscopic Surgery program)[22]. A training program for veterinarians, focused on learning and assessment of laparoscopic basic and advanced surgical skills, has been implemented at our institution. In previous studies, assessment methods for laparoscopic skills showed that it could distinguish different levels of experience in laparoscopic surgery in human and veterinary medicine.[23-24]

Peg transfer: Holding the dissectors in both hands, the subjects were asked to pick smooth and rough objects and place them on a coordination plate. There were six objects located at the top of the coordination plate. The subjects picked up the first object with the dominant hand and then picked up the second object with the non-dominant hand, successively alternating hands. The objects were then placed in the indicated wells.

Coordination: First, the subjects, holding the dissectors in both hands, were asked to touch specific wells at the same time on the coordination plate[f]. Then, the subjects were required to lift one object from the top of the coordination plate with the instrument on the dominant hand, transfer it to the instrument on the non-dominant hand in mid-air, and place it in the center well of the coordination plate. The entire exercise was then repeated in reverse order of steps.

Cutting: Holding the scissors on the dominant hand and the dissector on the non-dominant hand, the subjects were required to cut two different foam-latex templates with an increasing degree of difficulty; straight, curved and sigmoid cutting paths were executed with both hands.

Suturing exercise: Holding the needle-holder on the dominant hand and the dissector on the non-dominant hand, a vertical and horizontal intracorporeal knot suture was precisely created through two marks[g].

Electromyography (EMG) protocol

For the electromyography study, a previously validated protocol was used[25-26]. Data recording was completed by means of a MP 150 System[h] connected to a laptop[i] equipped with the acquisition software AcqKnowledge v3.7[j] was used, allowing for simultaneous data acquisition from up to 16 analogical and digital channels, with a maximum sampling speed of 400 KHz. EMG signals were obtained from the right biceps brachii, right triceps brachii, right forearm flexors and extensors, and right trapezius muscles (Figure 4). All registered data were acquired through triple-surface electrodes that were placed on the medial area of each muscle group. Once the electrodes were adequately positioned, a Maximal Voluntary Contraction (MVC) test was performed to subsequently normalize the EMG data. The EMG signals that were acquired during the performance of laparoscopic tasks were then amplified and transferred to the laptop at an acquisition frequency of 1000 Hz for later storage in a hard drive. Before processing, the acquired data were visually inspected for detection of any artifacts that could interfere with the analysis. The signals were then full-wave rectified, and low-pass and smoothing filters were applied. The mean amplitude value of the EMG data was calculated for each muscle, and the final results were expressed as a percentage of the MVC, allowing us to analyze the muscular activity of all subjects.

Data glove protocol

To record the hand and wrist positions, a motion capture data glove[k] was used. This device consists of a group of 16 conductive sensors with resistance flows that are sensitive to flexion variations. The sensors register the metacarpophalangeal and interphalangeal deviation as well as the finger´s extension and flexion, separation between the torsion of the thumb and little finger in relation to the palm, radiocubital flexion-extension and deviation of the wrist. Before starting data acquisition, a calibration process was performed to record the morphologic features of each surgeon's hand. For this study, we considered the thumb, index and middle fingers as the most relevant fingers for holding laparoscopic instruments. Therefore, and considering the scheme presented in Figure 5, the mean angle of the sensors corresponding to these three fingers was analyzed, thumb (sensors 1-3), index finger (sensors 4 and 5), middle finger (sensors 11 and 7) and the distance between fingers (sensors 0 and 8). Additionally, risk analysis of the postures regarding the wrist joint (sensor 16) was performed according to a modified version of the Rapid Upper Limb Assessment (RULA) method[27-29]. The traditional RULA method divides its evaluation into two groups, A (arms, forearms and wrists) and B (legs, torso and neck). In this study, we focused exclusively on the flexion and extension angles of the wrist, which were included in group A. During the performance of each task, signals obtained from the data glove's sensors were registered by a specific software[l] with a frequency of 100 samples per second. Then, all data were analyzed using an adapted software[m] developed at our institution[29]. This software converts sample data into angle values, facilitating its interpretation. The data glove's angle range lies between 0 degrees in wrist flexion, and 120 degrees in extension, although these may vary from one subject to another depending on their biometric characteristics. The typical score of the

RULA method applicable to the flexion-extension degrees of the wrist joint[27] has been adapted to a range of positive angles generated by the motion capture data glove[25], as shown in Table 1. Levels 1 (neutral) and 2, regarding the flexion-extension of the wrist, indicate a posture that is acceptable for the joint. However, level 3 is considered an excessive flexion-extension of the wrist joint, which is classified as unacceptable or hazardous[29].

Statistical analysis

All statistical analyses were performed with statistics software SPSS 15.0 for Windows[n]. Descriptive statistics for each variable were obtained by calculating the following characteristic parameters: mean value, standard deviation, and maximum and minimum values. In every case, a Shapiro-Wilk normality test was performed to determine the normal distribution of the samples. Because this condition was verified in all cases, one-way repeated measures ANOVA with Bonferroni's post hoc test was performed to make comparisons between each task. Statistical significance was set at $p<0.05$.

RESULTS

A total of twelve veterinarians were recruited and completed the study (six men and six women) with an average age of 33 ± 5.1 years. Eleven veterinarians were right-handed and one was left-handed. Six participants had a PhD in minimally invasive surgery, while the other six were pre-doctorate students in laparoscopic surgery at our institution, who had previous extensive experience in laparoscopic surgery.

EMG

Table 2 shows the normalized values obtained by EMG during the different tasks. The lowest muscular activity was registered in all muscles during the coordination task ($p \leq 0.05$), except for the biceps muscle. Muscular activity during peg transfer was not statistically significant compared to the coordination task. The precision cutting task showed the highest muscular activity in the forearm extensors and flexors muscles, with statistical significance compared to the coordination task ($p \leq 0.05$). The suturing exercise showed the highest muscular activity in the trapezius muscle with significant differences ($p \leq 0.001$) compared to all of the remaining tasks.

DATA GLOVE

Values obtained from the different data glove's sensors are shown in Table 3. Statistically significant differences were found in all analyzed sensors ($p \leq 0.05$), except in the case of sensors 0, 1 and 8. There were no significant differences between sensors during the completion of coordination or peg transfer tasks. However, the precision cutting task showed significant differences for two sensors (sensors 4 and 7) compared to the coordination task ($p \leq 0.05$). During the suturing exercise, there were significant differences for five sensors (sensors 2, 3, 5, 11, and 16) compared with the rest of the tasks ($p \leq 0.05$).

Figure 6 represents the mean angle values (flexion-extension) obtained for the wrist joint during the performance of the different laparoscopic tasks, as well as their corresponding scores obtained with the modified RULA method. The risk value attributed by this method for the coordination, peg transfer and cutting tasks was 3 (hazardous), while it was 2 (acceptable) for the suturing exercise, with significant differences between the analyzed tasks ($p \leq 0.001$).

DISCUSSION

Minimally invasive surgery, especially laparoscopy, has been established firmly within the veterinary field, mainly due to its multiple benefits for the patient, which include but are not limited to, less surgical trauma, better recovery and a shorter hospital stay[30-32]. However, at the same time, surgeons encounter some disadvantages, such as the adoption of incorrect postures or the increased physical effort required for these procedures compared to conventional surgery[1, 33]. In this study, we aimed to detect and evaluate ergonomic problems in veterinarians while they were performing a set of laparoscopic training tasks on a box trainer, focusing on the forearm muscular activity and hand motion. The results derived from this work will be used to elaborate a series of ergonomics guidelines that could be used in specific laparoscopic training programs for veterinarians in order to prevent ergonomic problems during laparoscopy.

The results showed a higher demand of muscle activity during the cutting and suturing tasks, especially in the forearm extensor and flexor and trapezius, respectively. Additionally, in a previous study we found that laparoscopic suturing involves a higher degree of muscle effort[26]. Moreover, an acceptable wrist position according to the RULA method was observed in the suturing exercise with an axial handled instrument. In fact, the results of this study show that the motion capture data glove with the RULA method is a useful tool for ergonomic assessment of hand movements because it can detect the forced positions of the surgeon’s wrist[25,28-29].

One of the most important ergonomic problems in laparoscopic surgery is the cramped position that the surgeon sometimes has to adopt during these procedures[34]. Additionally, the design of surgical instruments and the equipment in laparoscopic surgery are often not compatible with ergonomic criteria, and laparoscopic surgeons can suffer repetitive strain injuries[35]. Consequently, laparoscopic surgery has a higher physical requirement than conventional surgery. Therefore, we hypothesize that redesigning the operating rooms and equipment the physical and mental fatigue in surgeons will be reduced. When the surgeon uses a training cart, the table height could be adjusted to the subjects' needs, and the monitor could be positioned according to visual height, which might reduce fatigue during training[36]. In fact, one of the first studies that focused on determining the optimal height of the table for laparoscopic surgery concluded that it should be between 64 and 77 cm[37] depending on the individual's physical characteristics, which is lower than the limit of most available surgical tables in clinical operating rooms.

We have used surface EMG and motion capture data glove recordings as objective evaluation techniques for the ergonomic assessment of veterinary surgeons during laparoscopic training. Surface EMG constitutes a widely used tool for ergonomic studies in laparoscopic surgery allowing for the analysis of muscle activity during surgery[38-39]. We chose surface electrodes to register the electromyographic signals because they are non-invasive and more reliable than depth electrodes[40]. The analysis of the electromyographic signal's amplitude is the most frequently employed method for similar studies[6,41]; therefore, we decided to employ it in our study. EMG signals were normalized, according to the MVC of each muscle in each participant, to compare the results obtained for different subjects. Concerning the muscles included in this study, we chose the most relevant in the leading role of the arm during laparoscopic surgery. For forearm flexors and extensors muscles, we could not analyze each muscle individually because of the difficulty in detecting a single muscle signal without interference from adjacent muscles[42]. The lowest muscle activity for any of the analyzed muscles was found during the coordination and peg transfer tasks. There was higher muscle activity in the precision cutting task for the forearm flexors and extensors muscles. The highest muscle activity during the cutting task could be derived from the constant opening and closing movements of the scissors during cutting on the specific templates. It should be noted that the laparoscopic scissors used during these tasks were equipped with a ringed-handle. Additionally, the highest muscle activity during the suturing exercise was recorded in the trapezius muscle. This exercise was carried out with the axial-handled needle holder, which could explain the increased trapezius muscle activity as well as its difference from the other tasks. We have observed that the height of the table can influence the activity of the trapezius muscle in changing the angle of the elbow with an axial handle; therefore, the increased height of the table causes augmented muscle activity in trapezius. In our study, the table height of the training cart was adjusted according to surgeon's height for all tasks[26].

To register and catalogue hand and wrist movements, we used the motion capture data glove. Motion data gloves have been used in other fields of study different from surgery, such as ergonomics analysis of some tools as well as for assessing hand precision and coordination while gripping objects[43-44]. In addition, several studies have presented the use of the RULA method for analyzing the ergonomic conditions in different working environments such an office, children's computing posture, and factories[45-47]. This is the first time that a motion data glove is used in conjunction with the RULA method for ergonomic assessment during laparoscopic veterinary practice. In laparoscopic surgery, the use of this device has only been reported by our institution[25,28-29]. The results obtained in the present study agree with previous studies, which indicate that both the type of task and the instrument design affect ergonomics. For basic tasks (coordination, peg transfer and precision cutting), we found only two differences in the results, corresponding to sensors 4 and 7 for precision cutting. In these tasks, the subjects used ringed-handled instruments. However, in the suturing exercise where the subjects used an axial-handle instrument we found statistically significant differences in 5 sensors. Therefore, for this exercise the current evaluation method was also able to differentiate between the task types performed with different instrument handles.

The data generated by the motion capture data glove allowed us to establish the postural risk levels for the wrist joint through employing a modified version of the RULA method.

Conventional RULA divides the subjects in two groups for evaluation, A (arm, forearm and wrist) and B (legs, torso and neck). In our case, we focused exclusively in the flexion-extension of the wrist joint inside group A and assigned risk values according to the articulation angle. In laparoscopic practice the flexion-extension of the wrist could be greatly affected by movement restrictions imposed by the surgical ports, the type of laparoscopic instrument used and the task to be performed. We found that, during training, there were high-risk levels in the first three tasks (coordination, peg transfer and cutting tasks), which may correspond to less comfortable and realistic postures, compared to the suturing task. Moreover, we observed evidences of acceptable wrist positioning during the suturing task, which appears more realistic and involves a higher level of dexterity during training than the more basic tasks.

Some limitations of this exploratory study included the low number of subjects for the evaluation and the fact that all subjects were associated with the same institution, as well as the reduced training session and the set of instruments assessed. Thus, we believe that further studies have to be done with subjects from multiples institutions. This should include a larger number of subjects with different levels of experience in laparoscopy in order to obtain more representative data about how instruments design and tasks could affect laparoscopic skills performance. In addition, subjects performed a single training session. Therefore, deeper studies should be carried out to detect ergonomic problems during a longer training program and to analyze how it may affect the learning curve.

The last limitation of the study was that a reduced set of laparoscopic instruments was used for different tasks. This could lead to familiarity with the used laparoscopic instruments, which may bias the results. In order to extend the scope of this study, in future works we pretend to compare each task with different types of instruments. It is necessary to be careful to conclude that our results can be applied to the clinical setting, especially considering that only specific models of grasper, scissors and needle holder were used. Therefore, these results should not be generalized to other instruments produced by the same manufactures. Thus, we believe it is imperative to perform studies that objectively evaluate the ergonomic adequacy of the laparoscopic training in veterinarians. These studies are needed to obtain more information about the ergonomics of the different laparoscopic instruments. Also the performance on a box trainer with another type of simulator should be assessed.

Once the feasibility of using this ergonomic assessment method in a box trainer has been proved, the next step should be to carry out an ergonomic study in an actual clinical scenario with an animal model. Thus, we can have real clinical conditions such as patient´s tilting, use of different type of instruments and real surgical procedures.

Regarding the muscles analyzed in this study we have focused on the surgeon’s upper limbs. However, it will be interesting to include also lower limbs muscles in order to complete the study, taking into consideration the recommendations of the ideal positions for the hands and surgeons.

Finally, we conclude that the type of training task and instrument design affect ergonomics during veterinary laparoscopic training. The laparoscopic training task performed on a box trainer that had the highest levels of muscle activity was precision cutting task, namely for forearm extensors and flexors muscles. This was observed during the suturing exercise for the trapezius muscle. Additionally, a more acceptable wrist position was observed during the suturing task with an axial-handled instrument than for the coordination, peg transfer and cutting tasks, the latter performed with a ringed-handled instrument.

FOOTNOTES

a) SIMULVET® JUMISC, Cáceres - Spain.

b) Click Line® #33310 MC, Karl Storz, Germany.

c) Click Line® #34310 MC, Karl Storz, Germany.

d) Macro Needle Holder® #26173 KAT, Karl Storz, Germany.

e) CARROLAP® JUMISC, Cáceres - Spain.

f) LAP-PLATE® JUMISC, Cáceres - Spain.

g) Inorganic Intestine Tissue JUMISC, Cáceres - Spain.

h) Biopac Systems, Inc.®

i) Sony VAIO® Sony, UK.

j) Biopac Systems, Inc., CA, USA.

k) CyberGlove®; CiberGlove Systems LLC; San Jóse, CA, USA.

l) ErgoRec® JUMISC, Cáceres - Spain.

m) ErgoStatistics® JUMISC, Cáceres - Spain.

n) SPSS Inc., Chicago, IL.

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FIGURE AND TABLE LEGENDS

Figure 1: Details during the laparoscopic training tasks in a box trainer.

Figure 2: Instrument set. The set consisted of: a) 5 mm x 36 cm long Kelly/Maryland dissecting, b) 5 mm x 35 cm long scissors, and c) 5 mm x 33 cm long needle holder.

Figure 3: Laparoscopic training tasks. a) Plate for the training of peg transfer and coordination tasks. b) Templates for straight, curved, and sigmoid for the precision cutting task. c) Inorganic intestine tissue for the suturing task.

Figure 4: Electrode attachment sites.

Figure 5: Position of each sensor on the surgeon's hand and wrist.

Figure 6: Wrist angles obtained during the performance of four tasks, and their equivalence to the RULA method values (* $p \leq 0.001$).

Table 1: Score regarding the wrist angle following the RULA method adapted to a data glove.

Table 2: Average electromyography registries during different tasks as a percentage of the MVC (%).

Table 3: Average of the sensors' registries during different tasks as degrees of wrist angles (°).

Table 1: Score regarding the wrist angle following RULA method adapted to data glove.*

Score	Position
1	If the flexion-extension angle is 60° ± 3°
2	If the wrist is flexed or extended between 45° and 75°, except for the score 1 case
3	If the flexion-extension degree is higher than 75° or lower than 45°

* Sánchez-Margallo FM, Sánchez-Margallo JA, Pagador JB, et al. Ergonomic Assessment of Hand Movements in Laparoscopic Surgery Using the CyberGlove®. *Computational Biomechanics for Medicine* 2010:121-128

Table 2: Average electromyography registries during different tasks as a percentage of the MVC (%).

	COORDINATION	PEG TRANSFER	CUTTING	SUTURING	*Sig.*
BICEPS	8.45 ± 4.92	8.06 ± 5.10	7.40 ± 3.76	8.85 ± 4.49	0.897
TRICEPS	3.98 ± 2.56^{a}	5.42 ± 2.20^{ab}	7.89 ± 3.60^{b}	8.86 ± 4.11^{b}	0.003 **
FLEXOR	11.43 ± 10.46^{a}	17.37 ± 6.67^{ab}	25.70 ± 14.22^{b}	19.03 ± 13.19^{ab}	0.040 *
EXTENSOR	16.66 ± 13.80^{a}	20.08 ± 15.88^{ab}	36.64 ± 21.36^{b}	27.18 ± 19.12^{ab}	0.027 *
TRAPEZIUS	16.37 ± 8.54^{a}	15.05 ± 7.47^{a}	19.42 ± 13.88^{a}	39.50 ± 18.87^{b}	0.001 ***

One-way repeated-measures ANOVA followed by the Bonferroni *post hoc* test

P values from ANOVA test are indicated in the last column (Sig.)

Different letters denote significantly different means (Bonferroni *post hoc* test) between tasks for each muscular group: a - b.

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 3: Average of the sensors' registries during different tasks as degrees of wrist angles (°).

	COORDINATION	**PEG TRANSFER**	**CUTTING**	**SUTURING**	***Sig.***
Sensor 1	54.41 ± 31.47	53.68 ± 39.06	59.11 ± 37.46	62.22 ± 25.19	0.82
Sensor 2	67.19 ± 32.65^{a}	67.56 ± 29.88^{a}	72.26 ± 30.30^{a}	41.23 ± 29.88^{b}	0.027*
Sensor 3	76.88 ± 23.04^{a}	78.02 ± 15.55^{a}	71.72 ± 20.37^{a}	50.52 ± 22.50^{b}	0.001***
Sensor 4	67.91 ± 15.44^{a}	71.02 ± 16.11^{a}	91.53 ± 11.99^{b}	66.72 ± 9.96^{a}	0.001***
Sensor 5	78.70 ± 13.22^{a}	79.23 ± 10.79^{a}	78.03 ± 11.93^{a}	68.79 ± 11.92^{b}	0.020*
Sensor 11	36.91 ± 15.67^{a}	38.14 ± 15.38^{a}	44.15 ± 16.33^{a}	76.88 ± 25.19^{b}	0.001***
Sensor 7	33.09 ± 11.25^{a}	29.40 ± 9.83^{ab}	21.11 ± 15.68^{b}	27.86 ± 7.20^{ab}	0.006**
Sensor 0	44.44 ± 30.75	31.51 ± 30.50	42.53 ± 31.44	51.61 ± 22.67	0.342
Sensor 8	27.08 ± 25.83	43.87 ± 28.52	40.08 ± 24.30	28.61 ± 17.42	0.068
Sensor 16	22.79 ± 10.33^{a}	21.73 ± 10.25^{a}	23.57 ± 14.96^{a}	45.43 ± 4.91^{b}	0.001***
RULA Test	**3**	**3**	**3**	**2**	

One-way repeated-measures ANOVA followed by the Bonferroni *post hoc* test

P values from ANOVA test are indicated in the last column (Sig.)

Different letters denote significantly different means (Bonferroni *post hoc* test) between tasks for each sensor: a - b.

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

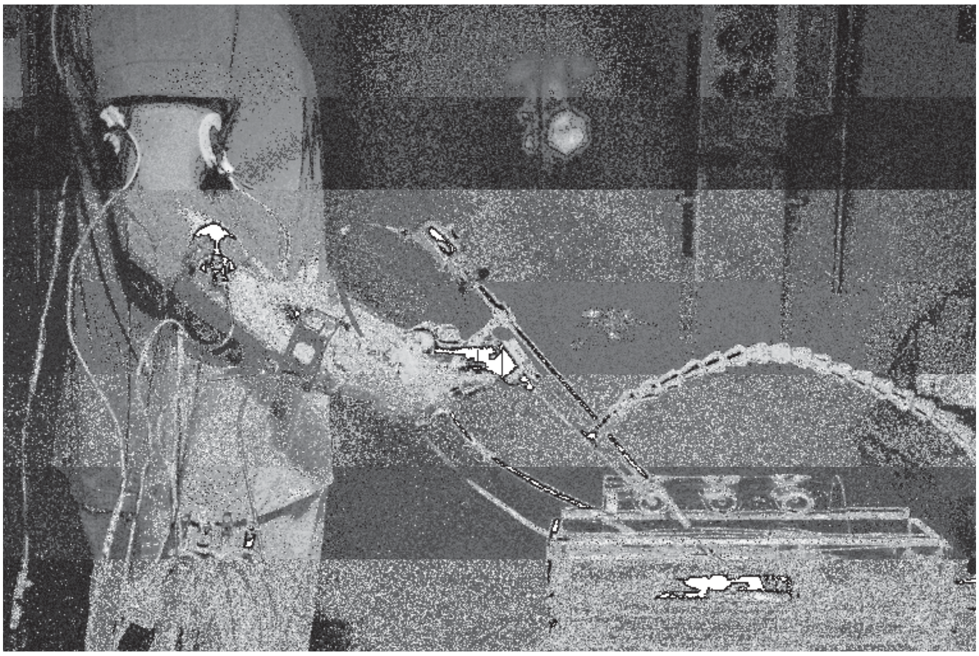

Figure 1. Details during the laparoscopic training tasks in a box trainer.
363x241mm (300 x 300 DPI)

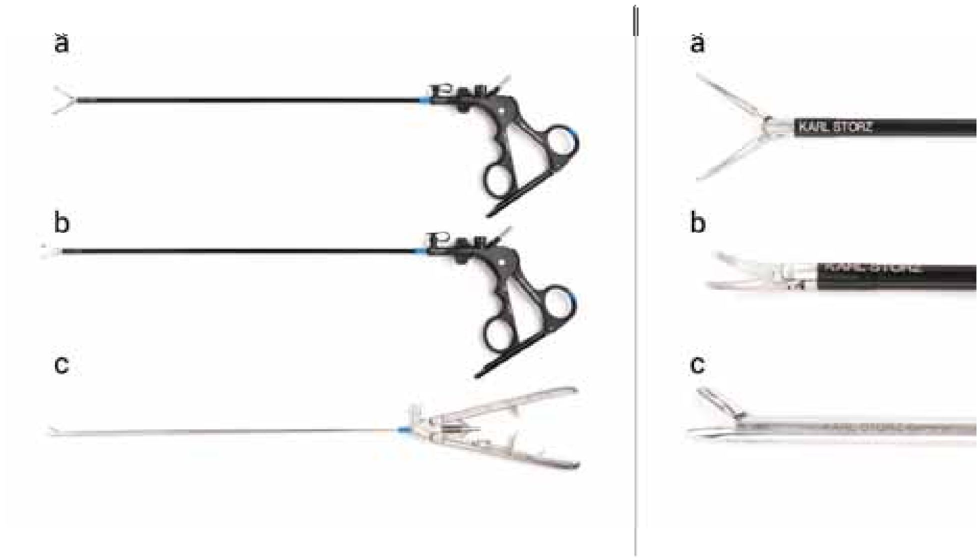

Figure 2. Instrument set. The set consisted of: a) 5 mm x 36 cm long Kelly/Maryland dissecting, b) 5 mm x 35 cm long scissors, and c) 5 mm x 33 cm long needle holder.
209x148mm (300 x 300 DPI)

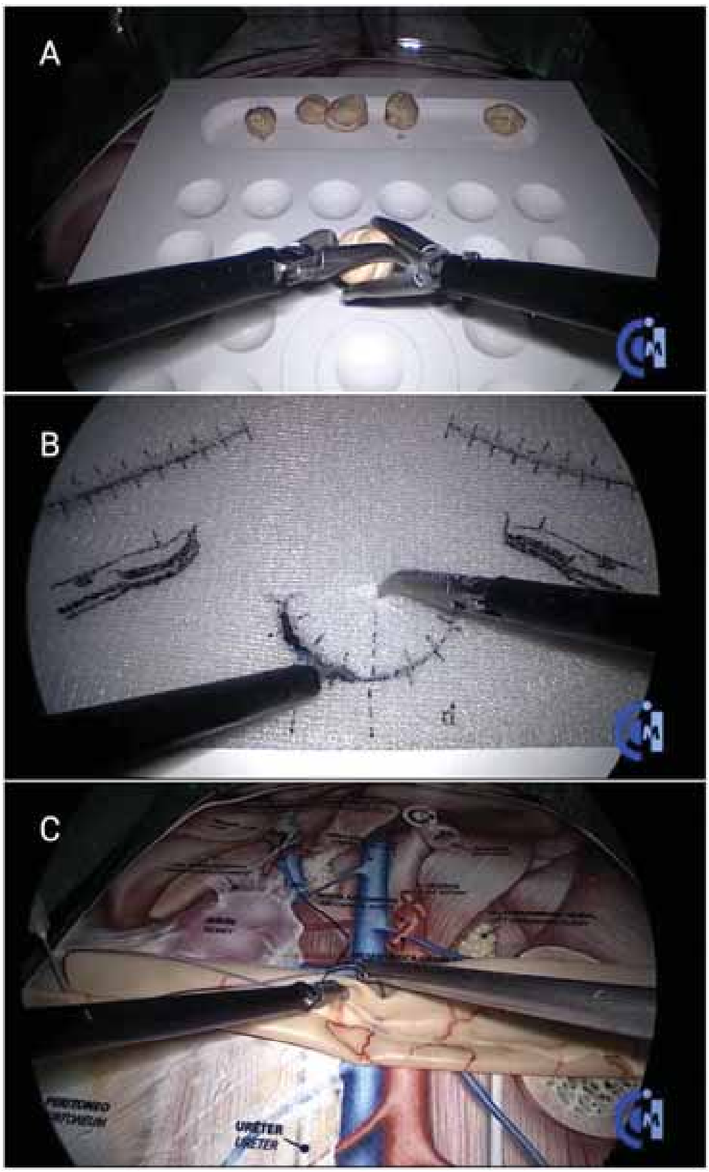

Figure 3. Laparoscopic training tasks. a) Plate for the training of peg transfer and coordination tasks. b) Templates for straight, curved, and sigmoid for the precision cutting task. c) Inorganic intestine tissue for the suturing task.
373x617mm (72 x 72 DPI)

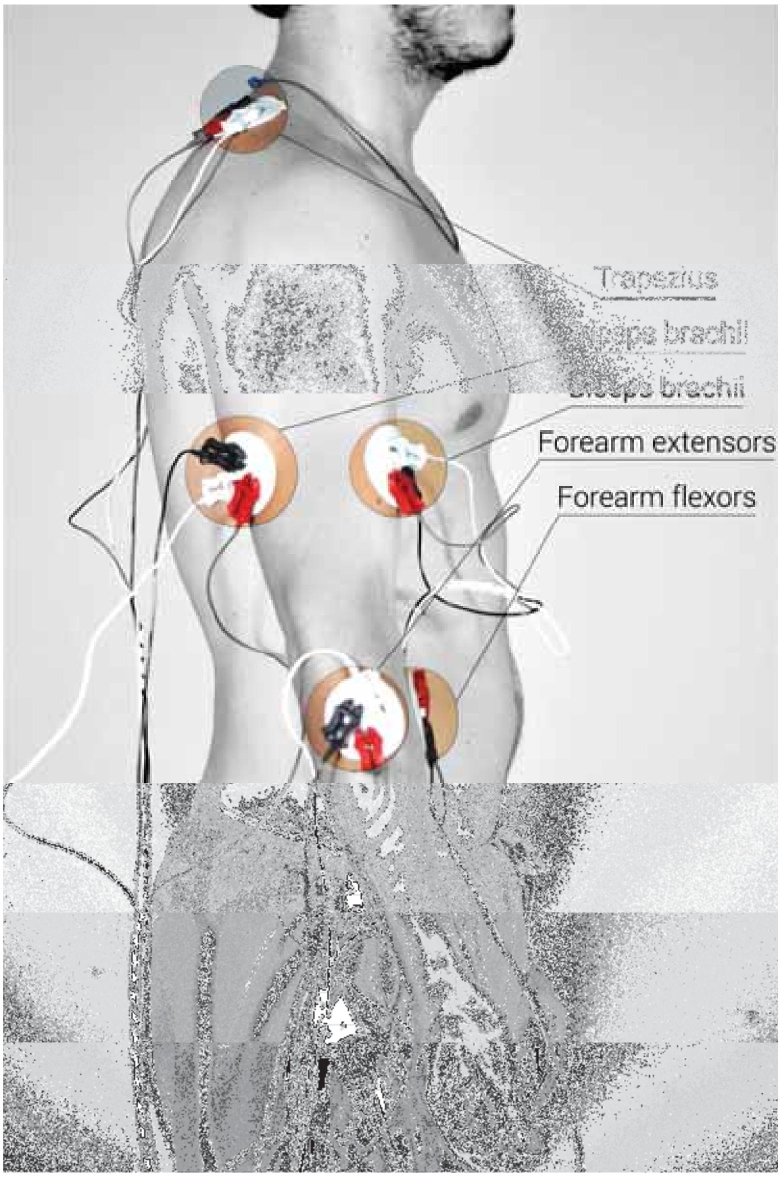

Figure 4. Electrode attachment sites.
241x363mm (300 x 300 DPI)

Figure 5. Position of each sensor on the surgeon's hand and wrist.
264x213mm (300 x 300 DPI)

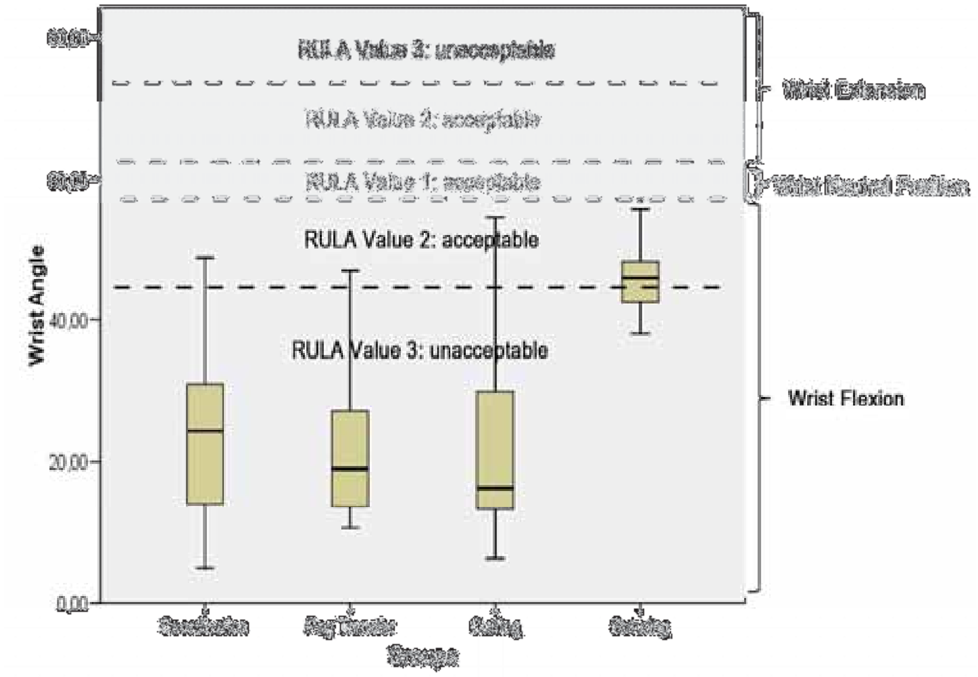

Figure 6: Wrist angles obtained during the performance of four tasks, and their equivalence to the RULA method values (* p≤0.001).
165x120mm (300 x 300 DPI)

V. Discussion

This study describes and evaluates the CLS as a training tool in laparoscopic surgery for veterinarians, designed at the JUMISC. The CLS aims to be a complementary learning tool and tries to reproduce the difficulties that the veterinarian faces during the laparoscopy learning[35].

Laparoscopic surgery is displacing conventional surgery because it offers greater benefits to the patient[117]. However, this approach requires certain technical skills that surgeons must develop; hence, the learning curve is longer than for conventional surgery. In this way, in order to reduce surgical errors the relevance given to develop proper training method for reducing the learning curve and certification of acquired laparoscopic skills is increasing[122].

Traditional training is based in gaining operative experience through supervised trial and error on real patients, which is called the Halsted method. This approach is questionable by ethical and practical reasons: it is opportunistic, stressful, and limited regarding available time, fears, costs and trainees' concerns about not obtaining the degree. Although there is a discussion about how operative skills should be taught, nowadays there is a spread consensus that there is a clear necessity of acquiring technical surgical skills outside the operating room. In addition, there is a lack of standards to train and accredit surgeons. There is no standardized curriculum of training or accepted consensus of how skills and knowledge have to be transferred.

The training on simulators is an essential tool for learning minimally invasive surgery. Although they can be combined with practices in experimental animal or cadavers for upgrading advanced procedures, simulator exercises are essential in the learning stages of laparoscopic surgery[39, 51-52].

However, the number of existing simulators specifically designed for veterinary education is a key factor. A research of the literature using MEDLINE (Simulators AND Veterinary) provided seventeen reports on simulation devices used in veterinary training. A few additional articles reported the use of more general simulation techniques (e.g., simulated clients or computer-based simulations) for veterinary medical education. The Ohio State University College of Veterinary Medicine did some of the earliest work with simulators for teaching surgical skills[123-124].

More recently, a group from the University of Glasgow (UK) has described their work with virtual reality animal simulators. They have created systems based on the force feedback device, a haptic interface that provides users with tactile responses to simulate palpation of virtual objects. Using this technology, they have devised simulations for teaching horse ovary palpation and bovine rectal palpation[125-126].

Development of this type of simulation devices is one remedy to the identified shortcomings in veterinary training of technical, especially invasive, procedural skills[127]. Other simulation methods offer alternatives for teaching the professional communication and interpersonal skills deemed inadequate in current veterinary curricula. For instance, one ‘‘virtual veterinary clinic’’ used online, small-animal case simulations as clinical problem-solving exercises[128]. In another example, whose students and graduates reported deficiencies in communication skills training, have created an innovative learning laboratory, where students practice their interpersonal skills[129]. Modeled on the experience with simulated or standardized patients in human medical education, they implemented a program using simulated clients and patients in the first-year curriculum[130].

Another study about simulation and training, concluded that video game performance in veterinary students could predict laparoscopic skills although not traditional surgical skills, suggesting that laparoscopic performance may be improved with video gaming experience[131]. Furthermore, regarding the relationship between gaming experience and the level of laparoscopic surgery skills, it was found that playing video games improved psychomotor skills, although not spatial orientation or perception skills[132]. However, other studies barely showed significant differences between groups with expertise in video games and groups without such experience[133-134], leading to a need for stronger results regarding this association. In this thesis, the results showed no significant differences or associations among participants with video game experience.

In fact, educational games will be a new and increasingly important point in the future veterinary curriculum, providing an attractive and useful way of learning[135]. Moreover, in 2011 a quantitative meta-analysis showed that the utility of simulation-based medical education with deliberate practice is more effective than traditional clinical medical education to achieve specific clinical skills[136].

Multiple factors have contributed to the increasing use of simulation technology in medical education. These include technological progress in diagnosis and treatment, such as newer imaging modalities and endoscopic procedures. In fact, health professions education, particularly veterinary medical education today, faces many challenges in achieving the goal of producing competent practitioners. Multiple factors limit the opportunities for learners to practice the necessary professional and clinical skills with real patients. The CLS offers a safe, ethical alternative for training and provide opportunities for the deliberate practice essential to master professional performance.

Currently, as described before, there are few animal simulators specifically designed for veterinary education. However, like in human medicine, new testing and accreditation requirements may encourage the further development of such technologies. At present, there are few published articles on the use of laparoscopic simulators or its importance in veterinary education[4, 81]. In fact, the value of simulation training in veterinary was verified in assessment of laparoscopic skills before and after simulation training with a canine abdominal model[3]. In those articles the need and benefits of using simulation for skills acquisition in veterinary laparoscopic surgery is evident. Previous studies showed that the learning and acquisition of adequate abilities are essential to prevent or, at least, reduce error rate, intraoperative accidents and shorten the learning curve[122, 137]. More specifically, the use of CLS in veterinary education actually leads to desired and demonstrable learning outcomes. Undoubtedly, the recognition and use of laparoscopic simulators in veterinary education is needed. In fact, benefits of simulators are not only the evident acquisition of skills and accreditation in laparoscopic surgery, but also the minimization or complete prevention of the use of animals during laparoscopic training, as stated in several publications[135, 138]. In addition, a growing concern for animal welfare and greater awareness of the need to train veterinarians without use of animals, may lead to increased funding for the development and implementation of simulation-based educational programs.

Training programs on simulators, and in particular on the CLS must meet a number of requirements including precision studies, verification/calibration and validation of different types. Adapting a simulator to fidelity criteria in its design phase is essential and must be defined prior to the development of any simulator. Simulators can reproduce reality more or less genuinely, depending on the clinical situations that want to be represented. At early stages, for learning the most basic tasks, it would not be necessary to recreate environments that are too elaborated. On the contrary, high-realism simulators are recommended for training more advanced tasks and for specific surgical procedures[17].

The CLS is based on Beagle breed dimensions and participants in our studies considered this size adequate for their training. However, a veterinarian has to deal daily with much smaller or much bigger dogs and consequently a simulator capable of creating different and adjustable work spaces would be needed.

Once fidelity is accomplished, a simulator may be suitable to be used as a tool for training and/or assessment of surgical skills. Attractive aesthetics, usefulness, appropriate exercises and easy interpretation of results are some of the essential features in order to know the users' opinion about it.

To grant a simulator the condition of validated, the objective part should not be the only target considered but the subjective assessment of the simulator by the users. In this thesis, validation criteria (subjective and objective) of the CLS have been assessed.

Face validity relates to the appearance of the simulator. In our study, it has been determined that the CLS had a good acceptance among veterinarians in the survey. In fact, participants showed positive opinions regarding the size and overall aspect of the CLS. Our surveys revealed that most veterinary surgeons lack the necessary training and appreciate the possibility of using simulation in laparoscopy.

The content validity is a judgment of the appropriateness of the simulator for teaching. Taking into account the improvement on the different tasks performed with our training program, veterinarians on this study proved to be very useful for students and other veterinarians before operating room practice.

The construct validity indicates whether the simulator is able to distinguish the knowledge ability of the novice and experienced surgeons. Our assessment methods identified a significant difference between experienced and novice groups. Therefore, the CLS represents an important step in the development of simulation-based teaching in veterinary laparoscopy.

In our studies, we consider that the development of an evaluation system of psychomotor skills in veterinary laparoscopic surgery is necessary, to determine the ability of a veterinarian to safely operate a patient. However, given the wide range and variety of assessment methods, obtaining universal parameters for determining psychomotor and surgical skills on a reliable manner can be a complex task. This evaluation should take into account parameters both quantitative and qualitative to distinguish different levels of skills. An ideal tool would assess the quality of the intervention more automatically and in real time, avoiding the inconvenient associated with current observational assessment tools: the high consumption of time and the need for skilled surgeons.

Different validated assessment tools are required based on quantitative data (such as time, error, determination, number and range of movements), or on task-specific checklists with the appropriate rating scale[2, 8, 51, 139]. In our study we used three validated assessment methods: GOALS, a task-specific checklist and the duration of training programs on CLS.

Veterinarians are increasingly demanding training programs with objective metrics of surgical skills and alternatives that might be used at any time. The CLS and its training program assessment can be used for training purposes, but also as a way to structure credited surgical skills exams such as the GOALS, which is able to correlate the surgical abilities on the simulation with those on the actual patient. In this sense, predictive validity could be established by the use of simulation, and could help determining the moment when the surgeon is ready to perform these techniques with minimal risk to the patient[70, 140].

The usefulness of the assessment method is reflected in the results on the evaluation of time and observational tools employed (GOALS and list of specific tasks). The total time and scores of the participants in the training group improved significantly in all exercises. Therefore, as the differences between novice and expert surgeons are more evident when exercises involve a higher degree of surgical skill and learning, the skills development is also more evident with this type of exercises[141].

The CLS for training and evaluation of medical and surgical skills should also try to provide an individualized learning in which the tasks are graded to suit the user's level and allow to store the records individually, depending on who uses it. Additionally, physical simulators as CLS are often associated with assessment methods that require external evaluation. That is why the register of laparoscopic surgical skills is often by experts who, relying on different types of charts and reports, deliver a score.

Traditionally, measurements of the skills of a surgeon on physical simulators, or during real-time operations in human or animal models where there are not computer-based systems available to record the performances, are usually made with evaluation tables or checklists. In all cases, there must be an agreement (correlation) between the performance of the assessments of the different observers and, if possible, carried out on different days to avoid biases of subjectivity or personal mood. In our studies, the high level of correlation found between both experienced surgeons strengthens the results, demonstrating that the CLS is a good tool to improve surgical skills in veterinarians.

The CLS should provide feedback information to the user to detect the aspects that must be improved. Such information processing should be fast clear and easy for the user to interpret if performances are improving or not. It is also recommended that it is not a purely informative feedback, but the device must set goals to achieve to be able to progress to more advanced levels. The CLS has proven to be valid for learning and improving skills of veterinary surgical techniques in this discipline. Participants also showed a high degree of satisfaction with the program during training exercises.

Furthermore, supervision and tutoring during the development of the training course is a factor that seems to have directly influenced the improvement of technical skills. In several studies it has been observed that participants receiving an assessment or guidance during training procedures performed better than those unsupervised[142-143]. In addition, there has been a strong demand from the students themselves in order to have adequate support and be supervised and advised during their practice sessions with animals[144]. On this basis, despite the requirements of staff, we believe that this is crucial for increased performance and provide high quality training. Participants believed that CLS is useful for training students and veterinarians, and that it is necessary to have an expert observer to assess the first stages of performance.

It has been shown that training programs that include mentoring of novice surgeons in hospitals improve surgical outcomes during the learning curve and reduce significantly the rate of complications in the first cases[145]. In this sense, some authors believe that surgeons should not operate patients without supervision unless they have demonstrated competence by passing at least one exam about technical skills[146].

Our research has demonstrated the effectiveness of such instructional methods; simulation designers, veterinary school administrators, and educators should draw upon the best available evidence to match the features and uses of simulation technology to their training objectives. Consequently, veterinary medical education could achieve its principal goal of graduating competent doctors with the skills needed to serve their profession, their patients, and the wider community. The CLS has many attributes that make it a good training tool for veterinarians without laparoscopic experience, as they can start with the acquisition of the basic laparoscopic skills necessary before performing real laparoscopy. In fact, after practice in CLS the participants on the training group improved significantly their scores in all laparoscopic tasks.

However, surgeons encounter some disadvantages in laparoscopy and training on the CLS, such as the adoption of incorrect postures or the increased physical effort required for these procedures compared to conventional surgery[97, 101]. In this sense, it is essential that, during the first stages of laparoscopic training, veterinarians become aware of the importance of ergonomics in laparoscopic surgery.

One of the most important ergonomic problems in laparoscopic surgery is the cramped position that the surgeon eventually adopts during these procedures[147]. Additionally, the design of surgical instruments and the equipment in laparoscopic surgery are not often compatible with ergonomic criteria, and laparoscopic surgeons can suffer repetitive strain injuries[148]. Consequently, laparoscopic surgery has a higher physical requirement than conventional surgery. Therefore, we hypothesize that by redesigning the operating rooms and equipment, the physical and mental fatigue in surgeons will be reduced. When the surgeon uses a training cart, the table height can be adjusted to the subjects' needs, and the monitor can be positioned according to visual height, which could reduce fatigue during training[95]. In fact, one of the first studies that focused on determining the optimal height of the table for laparoscopic surgery concluded that it should be between

64 and 77 cm depending on the individual's physical characteristics, which is lower than the limit of most available surgical tables in clinical operating rooms[99, 149].

We have used surface EMG and motion capture data glove recordings as objective evaluation techniques for the ergonomic assessment of veterinary surgeons during laparoscopic training in the CLS. Surface EMG constitutes a widely used tool for ergonomic studies in laparoscopic surgery allowing the analysis of muscle activity during surgery[150-151]. We chose surface electrodes to register the electromyographic signals because they are non-invasive and more reliable than depth electrodes. The analysis of the electromyographic signal's amplitude is the most frequently employed method for similar studies[152-153].

We have observed that the height of the table can influence the activity of the muscles in changing the angle of the elbow with an axial handle; therefore, the increased height of the table causes augmented muscle activity in the trapezius. In our study, the table height of the training cart was adjusted according to surgeon's height for all tasks. To register the hand and wrist movements, we used the motion capture data glove. Motion data gloves have been used in other fields of study different from surgery, such as ergonomics analysis of some tools as well as for assessing hand precision and coordination while gripping objects[154-155].

This is the first time that a motion data glove is used in conjunction with the RULA method for ergonomics assessment during laparoscopic veterinary practice. In laparoscopic surgery, the use of this device has only been reported by our institution[156-157]. The results obtained in the present study agree with previous studies, which indicate that both the type of task and the instrument design affect ergonomics. Therefore, for this exercise the current evaluation method was also able to differentiate between the tasks types performed with different instrument handles.

The data generated by the motion capture data glove allowed us to establish the postural risk levels for the wrist joint employing a modified version of the RULA method. Conventional RULA divides the subjects in two groups for evaluation: A (arm, forearm and wrist) and B (legs, torso and neck). In our case, we focused exclusively in the flexion-extension of the wrist joint inside group A and assigned risk values according to the articulation angle. In laparoscopic practice the flexion-extension of the wrist could be greatly affected by movement restrictions imposed by the surgical ports, the type of laparoscopic instruments used and the task to be performed[107, 149]. We found that, during training, there were high-risk levels in the first three tasks (coordination, peg transfer and cutting tasks), which may correspond to less comfortable and realistic postures, compared to the suturing task. Moreover, we observed evidences of acceptable wrist positioning during the suturing task, which appears more realistic and involves a higher level of dexterity during training than the more basic tasks.

VI. Conclusions

- The Canine Laparoscopic Simulator (CLS) showed good preliminary acceptance by veterinarians for its use in basic laparoscopy tasks. They perceived it as an excellent training tool.

Jesús Usón-Gargallo, ***Angelo E. Tapia-Araya,*** *Idoia Díaz-Güemes Martin-Portugués, Francisco M. Sánchez-Margallo. Development and Evaluation of a Canine Laparoscopic Simulator for Veterinary Clinical Training. Journal of Veterinary Medical Education (JVME) (2014), Vol. 41(3), pp. 218-224.*

- The CLS demonstrated content and construct validity -meaning the suitability of the simulator for training and teaching-, and its ability to distinguish the degree of experience in laparoscopic surgery among veterinarians.

Angelo E. Tapia-Araya*, Jesús Usón-Gargallo, Silvia Enciso-Sanz, Francisco J. Pérez-Duarte, Idoia Díaz-Güemes Martin-Portugués, Laura Fresno Bermejo, Francisco M. Sánchez-Margallo Assessment of Laparoscopic Skills in Veterinarians Using a Canine Laparoscopic Simulator. Sent to the Journal of Veterinary Medical Education (JVME), In second review 20th May 2015.*

- Tasks performed and the instruments design affect veterinarians' ergonomics during laparoscopic training on the CLS. Laparoscopic cutting and suturing tasks have the highest levels of muscular activity. The acceptable wrist position was found for the suturing exercise, which was performed with an axial handled instrument.

Angelo E. Tapia-Araya*, Jesús Usón-Gargallo, Francisco J. Pérez-Duarte, Juan A. Sánchez-Margallo, Idoia Díaz-Güemes Martin-Portugués, Francisco M. Sánchez-Margallo. Ergonomics in Veterinary Laparoscopic: Analysis of Surface Electromyography and Hand Motion. Sent to Journal American Journal of Veterinary Research (AJVR), Accepted May 2015.*

VII. Summary

Minimally invasive surgery, including laparoscopy has become a reference option in many procedures. This is due to its proven benefits for the patient. However, to perform these techniques it is required to go through a learning period in which simulators play an important role in the acquisition of new surgical skills. The objectives of this work are to describe the development of a Canine Laparoscopic Simulator (CLS) for veterinarians, to validate the training program and determine its usefulness in the acquisition of new surgical skills and to assess ergonomic problems while performing laparoscopic training tasks using the CLS.

A total of 84 veterinarians with different levels of experience in laparoscopic surgery were included in different studies of this work. The training program consisted of four tasks performed on the CLS: coordination, peg transfer, cutting and suturing. To build the CLS various informatics programs were used, as well as images of computer tomography. As objective measures of evaluation, we used time, GOALS (Global Operative Assessment of Laparoscopic Skills) scale and task-specific checklist to evaluate laparoscopic training tasks. To study the ergonomics, muscular activity was analyzed by surface electromyography, and hand movements were recorded using a virtual glove.

The CLS had a good preliminary acceptance in basic laparoscopic tasks. The results of the validation tests showed that the CLS is suitable for training and educating in laparoscopic basic tasks, and is able to distinguish the degree of laparoscopic experience among veterinarians. The tasks of cutting and suturing showed greater muscular activity. On the other hand, the axial handle showed better ergonomic positions compared with ring handle during the different tasks of the training program in the CLS.

In conclusion, the CLS is a good tool for the veterinarians' training in laparoscopic surgery, although it has some limitations inherent to all simulators. In addition, the CLS has proven its content and constructive validity in its program of laparoscopic training for veterinarians. Finally, laparoscopic ergonomics in veterinary is affected by the type of task, as well as by the instrument used during training in the CLS.

VIII. Resumen

La cirugía de mínima invasión, en particular la cirugía laparoscópica, se ha convertido en una opción de referencia en muchos procedimientos. Esto es debido a sus ya demostrados beneficios para el paciente. Sin embargo, para poder realizar estas técnicas se requiere pasar por un periodo de aprendizaje, en el cual los simuladores juegan un papel muy importante en la adquisición de nuevas destrezas quirúrgicas. Los objetivos de este trabajo son describir el desarrollo de un Simulador Laparoscópico Canino (CLS) para veterinarios, validar su programa de entrenamiento y determinar su utilidad en la adquisición de nuevas habilidades quirúrgicas, así como evaluar los problemas ergonómicos durante la realización de tareas de entrenamiento laparoscópico utilizando el CLS.

En los diferentes estudios de este trabajo se incluyeron un total de 84 veterinarios con diferente grado de experiencia en cirugía laparoscópica. El programa de entrenamiento consistió en cuatro tareas realizadas sobre el CLS: coordinación, transferencia de objetos, corte y sutura. Para la realización del CLS se utilizaron diversos programas informáticos, así como imágenes de tomografía computarizada. Como medidas objetivas de valoración, se ha utilizado el tiempo de ejecución, la escala GOALS (Global Operative Assessment of Laparoscopic Skills) y una lista de tareas específicas para evaluar el programa de entrenamiento laparoscópico. En cuanto al estudio de ergonomía, se analizó la actividad muscular mediante electromiografía de superficie y se registraron los movimientos de la mano mediante un guante virtual.

El CLS tuvo una buena aceptación preliminar en las tareas básicas de laparoscopia. Los resultados de las pruebas de validación mostraron que el CLS es adecuado para el entrenamiento y la enseñanza en las tareas básicas laparoscópicas, siendo capaz de distinguir el grado de experiencia laparoscópica entre los veterinarios. Las tareas de corte y sutura mostraron mayor grado de actividad muscular. Por otro lado, el mango axial mostró mejores posturas ergonómicas en comparación con el mango anillado durante las diferentes tareas del programa de entrenamiento en el CLS.

En conclusión, el CLS es una buena herramienta de formación en cirugía laparoscópica para veterinarios, aunque tiene algunas limitaciones inherentes a todos los simuladores. Además, el CLS ha demostrado su validez de contenidos y constructiva en su programa de formación laparoscópica en veterinarios. Finalmente, la ergonomía laparoscópica en veterinarios se ve afectada por el tipo de tarea, así como por el instrumental utilizado durante el entrenamiento en el CLS.

IX. Resum

La cirurgia de mínima invasió, en particular la cirurgia laparoscòpica, s'ha convertit en una opció de referència en molts procediments. Això és degut al seus beneficis ja provats en el pacient. No obstant això, per poder realitzar aquestes tècniques és obligat passar per un període d'aprenentatge, on els simuladors juguen un paper molt important en l'adquisició de noves habilitats quirúrgiques. Els objectius d'aquest estudi són descriure el desenvolupament d'un Simulador Laparoscòpic Caní (CLS) per veterinaris, validar el seu programa de formació i determinar la seva utilitat en l'adquisició de noves habilitats quirúrgiques, així com avaluar els problemes ergonòmics durant la realització de tasques de formació laparoscòpica utilitzant el CLS.

Els diferents estudis d'aquest treball inclouen un total de 84 veterinaris amb diferent graus d' experiència en cirurgia laparoscòpica. El programa d'entrenament consistia en quatre tasques realitzades sobre el CLS: coordinació, trasllat d'objectes, tall i sutura. Diversos programes informàtics, així com imatges de tomografia d'ordinadors van ser utilitzats per a la realització del CLS. Com a mesures objectives de valoració, s'ha utilitzat el temps d'execució, l'escala GOALS (Global Operative Assessment of Laparoscopic Skills) i una llista de tasques específiques per avaluar el programa d'entrenament laparoscòpic. Quant a l'estudi d' ergonomia, es va analitzar l'activitat muscular mitjançant electromiografia de superfície i es van enregistrar els moviments de la mà mitjançant un guant virtual.

El CLS ha tingut una bona acceptació preliminar en les tasques bàsiques de la laparoscòpia. Els resultats de les proves de validació mostraven que el CLS és adequat per l'entrenament i ensenyament de tasques bàsiques laparoscòpiques. És capaç de distingir el grau d'experiència laparoscòpica entre els veterinaris. Les tasques de tall i sutura mostraven un major grau d'activitat muscular. D'altra banda, el mànec axial mostrava millors postures ergonòmiques en comparació amb el mànec anellat durant les diferents tasques del programa de formació en el CLS.

En conclusió, el CLS és una bona eina per a la formació en cirurgia laparoscòpica per a veterinaris, encara que té algunes limitacions inherents a tots els simuladors. A més a més, el CLS ha demostrat la seva validesa de continguts i constructiva amb el seu programa de formació laparoscòpica en veterinaris. Finalment, l'ergonomia laparoscòpica en veterinaris es veu afectada pel tipus de tasca, així com pels instruments utilitzats durant l'entrenament amb el CLS.

X. References

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XI. Annexes

1. Veterinary Laparoscopy and Minimally Invasive Surgery. *Companion Animal* (CA).

Veterinary laparoscopy and minimally invasive surgery

Laparoscopic surgery has benefited from many technical advances over recent years, achieving better results and reducing surgical complications. The wide range of equipment and instruments available allow for the performance of surgical procedures without the large incisions that characterise conventional surgery. Laparoscopic surgery constitutes a growing area of expertise in clinical practice, where the main beneficiaries are the patients. The most common procedures such as organ biopsy or ovariectomy, and other more complex surgeries such as adrenalectomy and pericardiectomy are described.

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Key words: Minimally invasive surgery | Laparoscopy | Thoracoscopy | Dog | Cat

The modern age of minimally invasive surgery (MIS) in human medicine boomed in the late 1980s. In contrast, in veterinary medicine, the same paradigm shift to a minimally invasive approach has yet to occur. Some evidence exists in veterinary patients supporting the hypothesis that MIS approaches, such as laparoscopy, decrease the severity or incidence of certain surgical morbidities compared to open surgery (Davidson et al, 2004; Devitt et al, 2005; Hancock et al, 2005; Culp et al, 2009). However, in veterinary medicine, the field of MIS is still very much in its infancy and further evidence-based randomised studies are required (Mayhew, 2011a).

Laparoscopic surgery has been one of the fastest growing areas in modern surgery. In the last five to ten years, it has awakened great interest amongst veterinarians due to reported advantages for the patients, which include less surgical trauma, real therapeutic safety and faster recovery. Laparoscopy and thoracoscopy provide minimally invasive access to the abdominal and thoracic cavities respectively, allowing for the completion of diagnostic and therapeutic procedures (Lansdowne et al, 2012a; 2012b). The purpose of this review is to define MIS laparoscopic and thoracoscopic approaches as real surgical alternatives in veterinary medicine.

Basic principles

Laparoscopic surgery has become well established in human and veterinary medicine, but it involves a number of disadvantages for the surgeon: loss of depth perception; loss of tactile sensation; tremor amplification; reduction in degrees of movement for instrumentation; and the adoption of positions that are not always ergonomic during relatively long periods of time. In laparoscopic surgery, the applications of ergonomics criteria in the surgical field could have great benefits, both for surgeons and patients. Regarding tower positioning, the surgeon ideally places himself directly across from the main monitor (*Figure 1*); the table height should be lower than in conventional surgery to take account of the length of the instruments (Usón et al, 2010).

Laparoscopy and its associated skills require a learning curve that should be overcome gradually in a dry lab environment using simulators, thus safeguarding the patient from morbidities. Moreover, to perform laparoscopy it is necessary to acquire a new set of technical skills, as it forces the surgeon to adapt to monocular vision and decreased tactile sensation. These can be acquired by improving hand-eye and hand-hand coordination through training on a simulator (Fransson et al, 2010; 2012). Laparoscopic physical simulators (*Figure 2*) permit the surgeon to acquire enough skills to handle new surgical instruments before applying them in experimental programs, or in clinical situations (Dunkin et al, 2007; Schout et al, 2010; Usón-Gargallo et al, 2014).

Laparoscopic equipment and surgical instruments

A basic laparoscopic tower is composed of the following elements: (*Figure 3*):

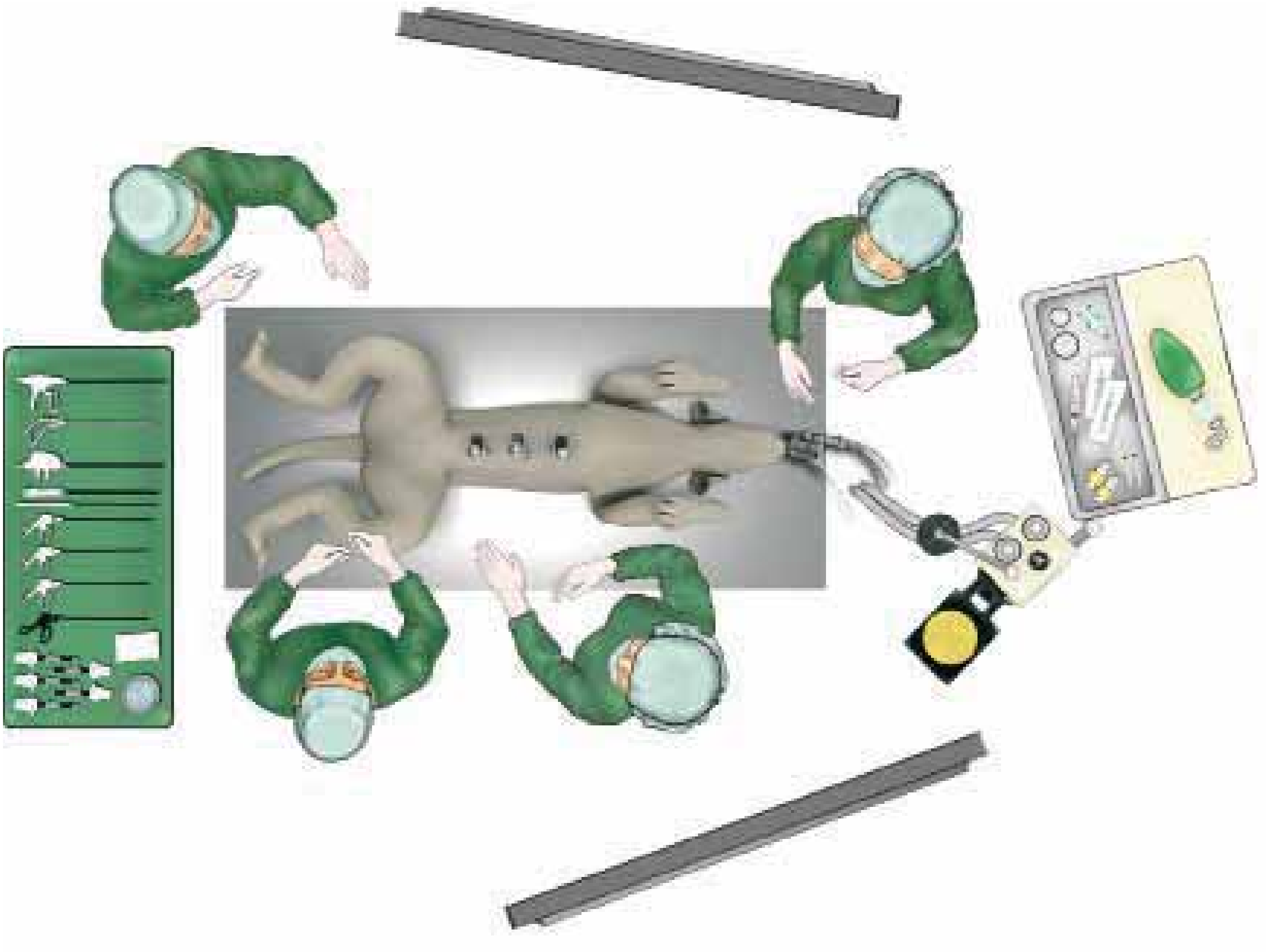

Figure 1. Position of the surgical team and placement of the trocars.

- CO_2 insufflation unit: laparoscopic surgical access is achieved by insufflating the peritoneal cavity with CO_2 to create a pneumoperitoneum. The insufflation unit should provide, at least, fast and precise readings of the patient's intra-abdominal pressure, pre-programmed pressure, predetermined gas inlet flow and the amount of the CO_2 used during the intervention
- Laparoscopic camera: current laparoscopic cameras are light and compact, and they transmit the image from the optics to the video capture unit. The essential components in the image are electronically transferred to a microelectronic video camera (charge couple device, CCD) with high-resolution chips. This results in a superior image of the operating field, particularly if three-chip cameras are used
- Rigid optics or laparoscopes: these provide the means of obtaining images from the inside of the surgical site. The eye-piece is attached to the camera via a universal adaptor, and the fibre-optic light guide cable is connected to light guide post of the laparoscope. The image is transmitted through optical fibres surrounding the lens from the tip of the rigid optics to the eye-piece and is then captured by the camera

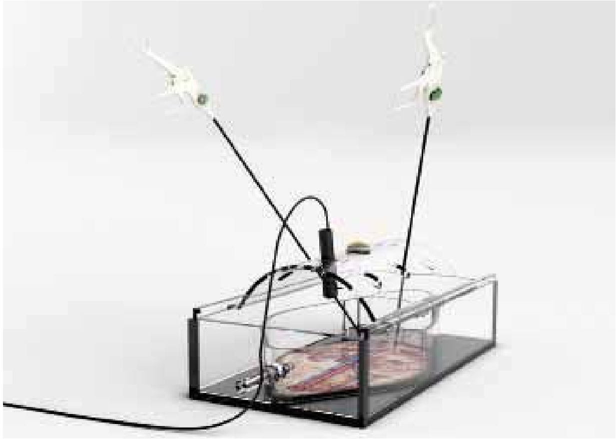

Figure 2. View of a laparoscopic training physical simulator (SIMUL-VET®). The top cover is transparent and made of a plastic which allows for instruments and camera introduction.

- Light source unit: a high-intensity light source emits the necessary illumination, through a bundle of fibre optics, towards the tip of the laparoscope. Whilst xenon is considered the gold standard, many units now use metal halide light sources and LED light sources are also becoming available

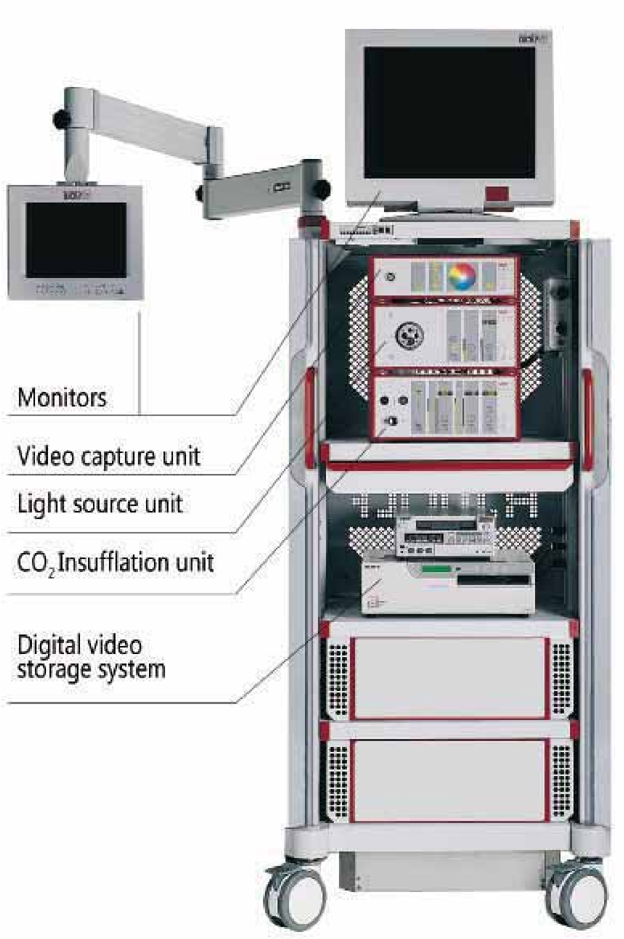

Figure 3. A standard tower for laparoscopic surgery.

- Digital image capture unit: this is part of the image acquisition system. It records both video and still images from the camera, processes it and sends it to the monitor for immediate visualisation and to the recording system to store acquired visual information if the surgeon deems necessary. Recording video during the performance of surgical procedures should be considered essential, even in low-quality digital formats, as it can help on learning process and when problems arise during the post operative period. Modern digital reproduction and recording systems (DVD, DV, DVCAM, etc.) have recently been incorporated in the laparoscopic tower. Additionally, most of the video capture units and monitors have output connections for exporting images directly to computers
- Monitors: one or two placed opposite the surgeon and another opposite the assistant. The size of the monitor is closely related to the working distance of the surgeon and his/her assistants with optimum image quality and resolution
- There is some additional equipment, which could be included as part of the laparoscopic tower and constitute useful tools during the performance of laparoscopic procedures. Among the different available alternatives, we highlight:
    - Electrocoagulation: standard monopolar or bipolar energy sources can be used for tissue section and haemostasis. In highly vascularised tissues it is somewhat more convenient to use alternative energy sources, such as modified bipolar, ultrasonic energy sources, radiofrequency or even laser coagulation
    - Aspirator and irrigator: this device can be connected to a central or portable system, and increases procedural safety by maintaining a clear surgical field through removal of blood clots, ascites or exudates
    - Considering available hand instruments, there are multiple alternatives and variants of each tool, which can vary in design, materials, manufacturers and cost. Laparoscopy and thoracoscopy instruments can be classified into three groups according to their function and specific use during the performance of surgical procedures (*Figure 4*)
    - The first group includes access instruments such as trocar-cannula units and the pneumoperitoneum needle. Trocar-cannula units diameter and length, as well as valve characteristics, can vary according to the procedure, animal size and reusability
    - The second group includes dissection and cutting, gripping and retractor instruments, forceps, scissors and retractors
    - The last group comprises instruments used for additional manoeuvres, and should be acquired according to the procedure intended. These include: aspiration-irrigation device; extraction bags for surgical specimens; laparoscopic vascular clamping or gripping instruments; needle holder and surgical stapler for laparoscopic intracorporeal suturing; bipolar coagulation forceps; and metal and plastic haemostatic clip applicators, among others.

Patients, anaesthetic and surgical considerations

Major advantages in laparoscopy include shorter post-operative convalescence and improved patient recovery times, especially when managing debilitated patients. Before determining patient suitability and choosing an anaesthetic protocol, each case should be thoroughly examined and all the laboratory results carefully considered (Quandt, 1999). For abdominal laparoscopy, veterinary surgeons must be aware of the main haemodynamic and respiratory consequences of laparoscopic procedures on the patient: increased intra-abdominal pressure created by the establishment of the pneumoperitoneum, the type of gas used (CO_2) and the position in which to place the patient on the operating table for easy manoeuvring of the surgeon (Dorfelt et al, 2012). For some procedures, tilting of the table increases visualisation. However, excessive tilting towards the head of the patient should be avoided, because it could interfere with diaphragmatic excursion.

Insufflation

In laparoscopy, the surgical working space is created by introducing CO_2 into the abdominal cavity. There are two possible techniques to achieve pneumoperitoneum: a closed technique with the use of a Veress needle, and the open or Hasson technique performed through a full wall incision with a blunt trocar-cannula (Doerner et al, 2012). In both cases it is recommended to catheterise the urinary bladder, or at least to manually empty the bladder through expression. Note that once the pneumoperitoneum has been established, the abdomen becomes tympanic to palpation.

Intra abdominal pressure is usually set at 10 mmHg. However, it can be decreased to 6–9 mmHg in small animals, or when the patient's physiological condition demands.

Considering thoracoscopy, a surgical space can be obtained by decreased tidal volume under ventilation, avoiding the need for CO_2 insufflation. However, in cases where the anaesthetist cannot carry out this manoeuvre, a low-pressure pneumothorax can be created. In fact, for many simple procedures, open chest, decreased ventilation volume methods are often more practical than one-lung ventilation methods.

- Veress needle technique: this is the most common method for insufflating the abdominal cavity. A skin puncture incision is performed in the selected abdominal area, and the abdominal wall is lifted and tensed upwards. The Veress needle is then inserted and directed caudally at a 50° angle from the skin, ideally towards the right caudal quadrant and away from the spleen. This insertion should be preferably carried out in the same site intended for the introduction of a trocar-cannula; the site is often caudal or cranial to the umbilicus. Usually the Veress needle insertion site corresponds to the second trocar-cannula (*Figure* 5)
- Hasson technique: this method requires a small (0.5–1 cm) surgical incision though the skin. Stay sutures are then placed at each end of the incision through the linea alba and a small incision (slightly smaller than the trocar-cannula diameter) is made through into the abdominal cavity, through which a blunt trocar and cannula are placed. The abdomen is then insufflated through this cannula. This technique avoids blind insertion of a sharp needle into the peritoneal space, and allows for safer access to the abdominal cavity before the introduction of the vision system (*Figure* 6).

Laparoscopy procedures

Laparoscopic procedures performed entirely within the peritoneal cavity include exploration of the abdominal cavity, biopsies of abdominal organs and ovariectomy. Some procedures can be performed entirely by laparoscopy, or may be laparoscopically-assisted, such as ovariohysterectomy and prophylactic gastropexy. There are also procedures using laparoscopic manipulation of organs for extraperitoneal surgery, such as cystotomy and intestinal surgery.

Laparoscopically-assisted biopsy

There are many available modalities for tissue sample collection, and both laparoscopic and laparoscopically-assisted techniques offer a minimally invasive alternative for biopsy of multiple abdominal and thoracic organs.

Figure 4. Proposed model for placement of the frequently used instruments in laparoscopic surgery. (A) Trocar/cannula units and pneumoperitoneum needle; (B) dissection and cutting instruments; (C) grasping forceps; and (D) retractor instruments; (E) laparoscopic instruments used for aspiration, extraction and clamping; (F) laparoscopic intracorporeal suturing (needle holder and surgical stapler); (G) bipolar coagulation forceps; and (H) metal and plastic haemostatic clip applicators.

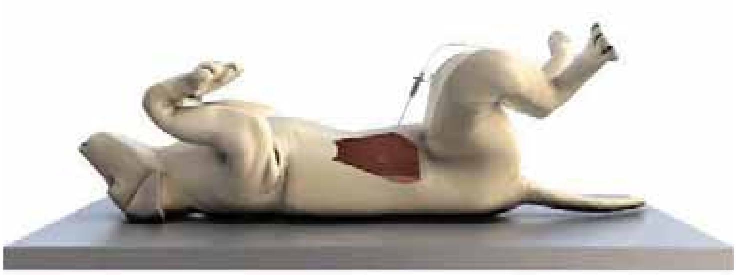

Figure 5. 3D dog pneumoperitoneum model with Veress needle technique.

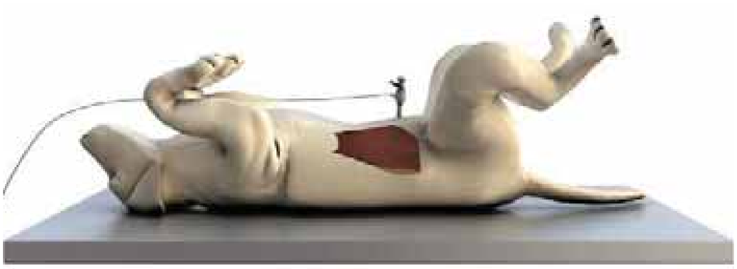

Figure 6. 3D dog pneumoperitoneum model with Hasson technique.

- Liver and spleen biopsy: these are common uses of diagnostic laparoscopy in small animal practice, especially in cases of hepatic nodules, diffuse conditions and splenomegaly. Advantages over blind techniques include the ability to observe the surface texture and colour, the ability to choose a specific puncture site and improved control of any possible haemorrhage. Moreover, larger diagnostic biopsy samples can be collected than those obtained by ultrasound guided spring loaded biopsy needles (*Figure* 7) (Petre et al, 2012; Radhakrishnan and Mayhew, 2013)
- Pancreatic biopsy: laparoscopic procedures in pancreatic disease are not only helpful for tissue sample collection, but also allow the surgeon to explore the pancreas in relation to surrounding organs. Laparoscopic explorations will also indicate the best puncture site, thus reducing the risks of damaging the pancreatic duct (*Figure* 8) (Webb and Trott, 2008)
- Renal biopsy: this constitutes a useful diagnostic tool in primary renal disease, also for the assessment of the nature and severity of renal involvement in other systemic disorders. The use of laparoscopy to obtain renal biopsy specimens has several advantages over the blind technique, for example direct visualisation of the kidney after biopsy and the possibility of haemorrhage evaluation and control (*Figure* 9) (Vaden, 2005; Nowicki et al, 2010).

Laparoscopic ovariectomy

In human gynaecology, ovariectomy was one of the first surgical fields where laparoscopy was widely accepted as a therapeutic approach. In dogs, ovariectomy is one of the most frequent clinical applications within laparoscopic surgery. Different genital laparoscopy techniques have been reported in dogs since 1985 (Wildt and Lawler, 1985), including laparoscopic ovariectomy, laparoscopic ovariohysterectomy and laparoscopically-assisted ovariohysterectomy and, more recently, laparoscopically-assisted ovariohysterectomy for treatment of canine pyometra (Austin et al, 2003; Gower and Mayhew, 2008; Adamovich-Rippe et al, 2013).

The laparoscopic approach to spaying follows essentially the same steps performed by conventional surgery, but with the added advantage of being a minimally invasive procedure. In the past few years, different strategies have been performed and documented as successful, such as variations in the number of access trocar-cannula units. For instance some authors use a three trocar-cannula access, other two trocar-cannulas or one single port access (*Figure 10*) (Dupre et al, 2009; Case et al, 2011).

Laparoscopically-assisted cystotomy and urethrocystoscopy

The numbers of both diagnostic and therapeutic urologic procedures involving laparoscopy are many and increasing. It is important to highlight that it is contraindicated to perform laparoscopically-assisted cystotomy in any cases of suspected transitional cell carcinoma, due to the likely resultant aggressive abdominal metastasis that will result if the bladder is breached. The most common indication for cystotomy in dogs is vesicular calculus. Other conditions such as chronic cystitis unresponsive to medical therapy, and extraction of mineral plaques or ulcerated areas, could also benefit from the laparoscopic approach. Also, urethrocystoscopy may be employed for investigation of a wide range of conditions affecting the lower urinary and reproductive tracts (*Figure 11*) (Dupre et al, 2009; Defarges et al, 2013).

Laparoscopically-assisted enterotomy

In general practice, a laparoscopically-assisted approach is performed by grasping the bowel laparoscopically and exteriorising a loop of bowel before incising it to remove the foreign body (*Figure 12*). This technique involves opening the intestinal wall to explore the mucosa in order to retrieve foreign bodies obstructing the intestinal lumen, or to perform full thickness biopsies, followed by suture of the enterotomy site (Freeman, 2009). As the procedure exposes the content of the bowels, the surgeon must be very careful to prevent peritonitis, and should be equipped with an adequate set of advanced skills (Sánchez-Margallo et al, 2007b).

Laparoscopic cryptorchidectomy

Laparoscopic examination of the peritoneal cavity can aid in both the diagnosis and treatment of abdominal cryptorchidism, through either a totally laparoscopic or a laparoscopically-assisted technique (*Figure 13*) (Mayhew, 2009). Laparoscopic surgery provides clear advantages over conventional surgery as it allows for easier location of the abdominal testicle, decreases surgical time and improves the animals' recovery. A retrieval bag should be used to remove the abdominal testicle; this is particularly advisable if there is any suspicion of testicular neoplasia.

Laparoscopic adrenalectomy

Laparoscopic adrenalectomy is feasible in dogs for both right and left adrenal tumours. Nevertheless, detectable vascular invasion is a clear contraindication to laparoscopic approaches. Good

Figure 7. The biopsy forceps are inserted and the liver is grasped.

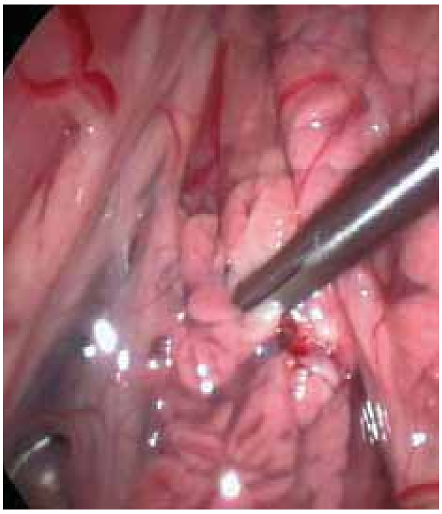

Figure 8. The biopsy forceps are inserted and the pancreas is grasped.

Figure 9. Trucut® biopsy needle is preferred to obtain renal specimens.

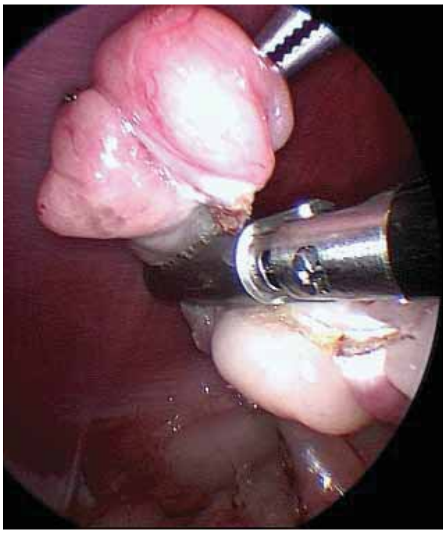

Figure 10. A bipolar vessel sealer/cutter such as the Ligasure® being used for laparoscopic ovariectomy.

Figure 11. Endoscopic appearance of uroliths in an urethrocystoscopy.

Figure 12. Laparoscopically-assisted enterotomy for retrieving foreign bodies.

case selection, experience and availability of high-quality equipment are critical to avoid high levels of procedural complications and high rates of conversion to laparotomy (*Figure 14*) (Jimenez Pelaez et al, 2008).

Laparoscopic gastropexy

Gastropexy has been described as a prophylactic procedure to prevent the occurrence of gastric dilation volvulus (GDV), or at the time of surgical correction of GDV to prevent recurrence. Laparoscopically-assisted gastropexy is an excellent combination of a minimally invasive approach for therapeutic safety and conventional open suturing for operative time reduction (Sánchez-Margallo et al, 2007a). Also, combining prophylactic gastropexy with routine ovariectomy, both performed entirely by laparoscopy, has been shown to have a high success rate and low morbidity for dogs susceptible to GDV (*Figure 15*) (Rivier et al, 2011).

Figure 13. Laparoscopic cryptorchid resolution. Exposure of a testicle in the caudal abdominal cavity.

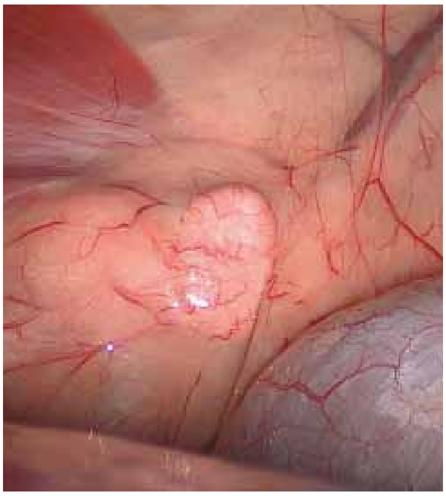

Figure 14. Laparoscopic photograph of the adrenal gland with normal aspect.

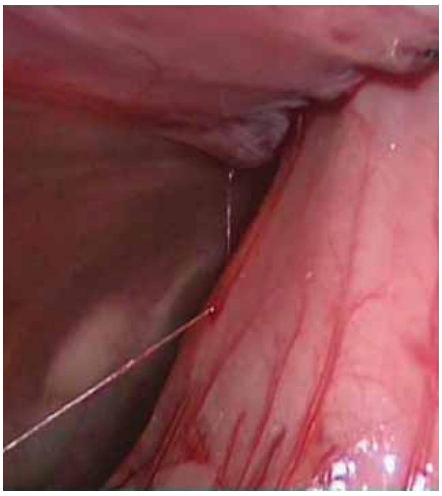

Figure 15. Final laparoscopic photograph showing the suture gastropexy site.

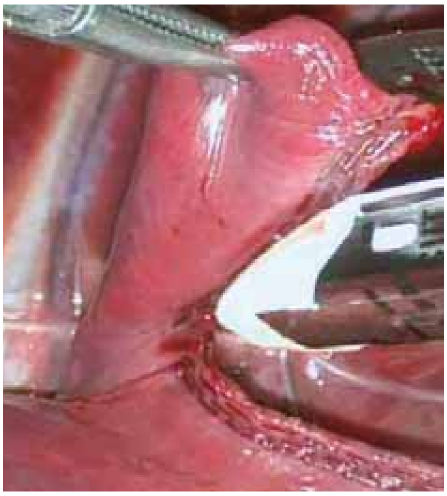

Figure 16. Thoracoscopic partial lobectomy using endoscopic stapling.

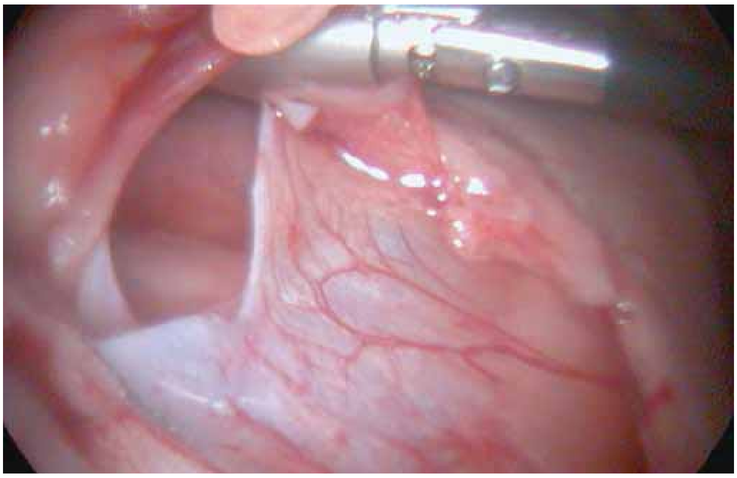

Figure 17. The pericardium is tented during incision in a subtotal pericardiectomy.

Thoracoscopy procedures

This constitutes one of the most advantageous MIS approaches in small veterinary practice, allowing the surgeon to perform similar procedures to those accomplished by open thoracotomy. Furthermore, thoracoscopy is a minimally invasive surgical technique that facilitates direct exploration of the thoracic cavity and pleural space by means of a thoracoscope. Resection of tumours can also be carried out through tiny incisions, instead of open chest surgery that is associated with high morbidity rates and a difficult recovery process. Note that surgeons should not be undertaking thoracoscopy unless they are already familiar and competent with open thoracic surgery techniques.

Lung biopsy

Diagnostic tissue sample size is comparable or superior to that obtained by transthoracic needle puncture or transbronchial biopsy. Therefore, reliable diagnosis can be achieved without the need for more invasive techniques. Morbidity and postoperative time are far lower than with thoracotomy (Mayhew et al, 2012).

Partial and complete lobectomy

A thoracoscopic approach for partial or complete lobectomy has been proved effective. Thoracoscopy can be used for therapeutic pulmonary resection and for treating any lesions covering less than two distal thirds of the pulmonary lobe. Partial or complete lobectomy may be required for lung tumours, abscess, bulla or subpleural blebs (Figure 16) (Lansdowne et al, 2005; Monnet, 2009).

Subtotal or partial pericardiectomy

The use of thoracoscopy considerably reduces surgical trauma and tissue damage caused by thoracotomy, which constitutes one of the main causes of postoperative complications. Subtotal or partial pericardiectomies are well tolerated by animals, and its benefits are clearly increased with the choice of minimally invasive access. Surgical drainage of pericardial effusion is indicated when medical management fails to control the effusion, and can be easily accomplished by thoracoscopy. A partial or pericardial window procedure may be performed in either lateral or dorsal recumbency, while a subtotal (subphrenic) pericardiectomy (*Figure 17*) requires dorsal recumbency. Dorsal recumbency has the further advantage of not requiring single-lung ventilation. It allows examination of both sides of the chest, and allows a subtotal pericardiectomy to be performed. The removed section of pericardium should always be submitted for histopathology, as well microbiology if indicated (Mayhew et al, 2009).

Other laparoscopic or thoracoscopic procedures

Laparoscopy and thoracoscopy have a great variety of applications either for diagnostic or therapeutic procedures. Among the different additional procedures that can be performed by laparoscopy, we highlight: diaphragmatic hernia repair, cholecystectomy, nephrectomy and transperitoneal or retroperitoneal lymphadenectomy for cancer staging. Thoracoscopy also allows for the completion of procedures such as persistent ductus arteriosus ligation, drainage of chylothorax and thoracic duct ligation, among others.

Novel surgical approaches

Laparoendoscopic single-site surgery (LESS) and natural orifice transluminal endoscopic surgery (NOTES) represent novel approaches. LESS-NOTES are new surgical techniques and their future evolution is probably dependant on feasibility (Georgiou et al, 2012).

LESS: The approach for a single-port device presents an evolution in technique, potentially allowing for morbidity reduction and improved postoperative recovery. The larger incision associated with single-port surgery facilitates specimen removal (i.e. splenectomy). Despite the potential benefits to the patient, specific and essential training is needed to acquire the skills necessary for its application. The main drawbacks for the surgeon are the continuous collisions between the instruments, decreased working space and un-ergonomic positions. There is a need for the industry to develop specific tools to solve these technical problems. There are some recent studies proving its feasibility in dogs and cats (Kim et al, 2011; Manassero et al, 2012; Runge et al, 2012).

NOTES: This is a new approach that combines aspects of flexible endoscopy and laparoscopy and whose ultimate goal is the absence of scars on the skin of the patient and reduced incision site pain. NOTES surgery can be hybridised if external laparoscopic assistance is required, or pure if it does not need any accessory trocar-cannula. Limitations of this technique include inefficient tissue grasping, reduction in degrees of movement for instrumentation and possible risk of infection due to incorrect disinfection or organ closure. Within NOTES surgery there are several surgical approaches: transgrastric, transesophageal, transvaginal, transcolonic and transvesical among others. For these approaches, very expensive dedicated equipment is needed and there is no real clinical application in veterinary clinical practice at the moment. Some experimental works exist in veterinary medicine and there are a few reported cases (Alford and Hanson, 2010; Brun et al, 2011; Freeman et al, 2009; Freeman et al, 2010).

General complications

Intra-operative complications of laparoscopic and thoracoscopic surgery described in veterinary medicine range from 2% to 35%, (Monnet and Twedt, 2003; McClaran and Buote, 2009) and are usually a consequence of the introduction of a Veress needle or access trocar-cannula units, or improper instrument and tissue handling. They include perforation or laceration of viscera, haemorrhage and subcutaneous emphysema. Also, in the postoperative period, seroma has been observed at the cannula entry site. However, with careful attention to technique, the occurence of complications is rare. Reported conversion rates to laparotomy are 7–21% (McClaran and Buote, 2009; Buote et al, 2011). Anaesthetic complications related to CO_2 pneumoperitoneum (such as anaemia, hypotension or respiratory compromise with reduced diaphragmatic excursion and lung volume) were also reported in a few series, and a significant increase in the occurrence of complications has been observed in feline, elderly and lightweight patients (Mayhew, 2011b). The latter is related to the increased technical difficulty due to reduced working spaces in these patients. It is noteworthy to comment that most of these inherent MIS complications are closely related to the inexperience of the surgeon and their team, with higher incidence during the earlier phases of the learning curve (Lekawa et al, 1995).

KEY POINTS

- Minimally invasive surgery has multiple benefits: less surgical trauma, better recovery and shorter hospital stays.
- The skills for this approach require a learning curve that should be overcome gradually with non-invasive methods such as simulators.
- There are many different instruments and surgeons need to adapt to the decreased tactile sensation by training and improving their hand-eye and hand-hand coordination.
- Laparoscopic biopsy is an established technique with excellent results.
- Laparoscopic ovariectomy is one of the most commonly performed procedures.
- Thanks to technological advances and increased availability of laparoscopic surgery training, this approach has been introduced in veterinary practice.

Summary

Laparoscopic and thoracoscopic surgery, and the constant search for new low-trauma surgical techniques and instruments, has allowed for an increasing number of procedures to be performed by minimally invasive surgery. Moreover, these new approaches are now consolidating as very attractive techniques in veterinary practice for numerous procedures, mainly due to the reduction in surgical trauma when compared to conventional surgery. As a result of the continued interest in reducing surgical trauma, a series of novel surgical approaches has been described, including LESS and NOTES, constituting an evolution of laparoscopic surgery, with the potential benefits of further reduced morbidity and faster postoperative recovery.

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2. **Laparoscopic Ovariectomy in Dogs: Comparison between Laparoendoscopic Single-Site and Three-Portal Access.** *Journal of Veterinary Science* (JVS).

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Laparoscopic ovariectomy in dogs: Comparison between Laparoendoscopic Single-Site and Three-Portal access

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The aim of this study was to evaluate the feasibility and therapeutic safety of Laparoendoscopic Single-Site Ovariectomy (LESS-OVE) and 3-portal Laparoscopic Ovariectomy (Lap-OVE) in dogs. Ten female mixed breed dogs were included in the study. Dogs were divided into group 1 (LESS-OVE; n=5) and group 2 (Lap-OVE; n=5). All procedures were performed by laparoscopic-skilled surgeons. The anesthetic protocol was the same for all the patients. In both groups, the ovarian vascular pedicle and ligaments were transected using a bipolar vessel sealer/divider device. The mean total surgical time was slightly longer in LESS-OVE (36.6 ± 3.5 min) than Lap-OVE (32.0 ± 3.0 min), however differences were not significant. Perioperative complications were not reported in any group. Both laparoscopic techniques have shown to be equally feasible and safe for the patients. However, surgeons found LESS-OVE more skill-demanded than Lap-OVE. Therefore, deeper studies should be carried out to evaluate this novel approach in clinical veterinary practice, along with a proper laparoscopic training program for veterinary surgeons.

Keywords: Laparoendoscopic Single-Site; Laparoscopy; Ovariectomy; Minimally Invasive Surgery; Dogs.

Introduction

Minimally invasive surgery, especially laparoscopic surgical techniques, are being increasingly used in both human and veterinary surgery due to its reported advantages (less surgical trauma, less postoperative pain, rapid return to normal activity, shorter hospitalization times, among others) compared with open procedures [24]. One of the main disadvantages in laparoscopic surgery is the need of learning new surgical skills. These techniques present a steep learning curve, which has to be reached gradually and ethically by means of simulators and/or by animal models training programs (preserving patient safety) [23]. The latter is time consuming and represents an important financial limitation. Soft tissue surgery in veterinary medicine follows the same shift to minimally invasive surgery as happens in human medicine. Veterinary practitioners are being more aware of its advantages and a slow but steady evolution and refinement of minimally invasive techniques in small animal practice is taking place [18,19].

Single port access is a new laparoscopic technique that has been developed as an alternative to 2 or 3 portal traditional laparoscopic techniques in an effort to potentially reduce morbidity and hospitalization [8,30]. Reducing portal size and number is currently gaining popularity in human medicine. However, it is associated to an increased technical difficulty, which in turn can lengthen surgical times and raise perioperative complications, especially in less trained surgeons [32].

Elective sterilization in dogs and cats is one of the most common procedures performed in veterinary practice. Since 1985 [36], different genital laparoscopic techniques have been evaluated in the bitch, as well as laparoscopic ovariectomy, laparoscopic ovariohysterectomy and laparoscopic-assisted ovariohysterectomy [1,15,34,]. These techniques have gained acceptance because of their demonstrated advantages, including less postoperative pain, less morbidity and a rapid return to normal activity [10]. Ovariohysterectomy has historically been the sterilization technique of choice in small animals [4], however there is no scientific evidence for the preferential use of ovariohysterectomy over ovariectomy [9], and some studies have demonstrated that ovariectomy potentially induces less surgical trauma (smaller incisions, better viewing of the ovarian pedicle, and possibly less risk of complications associated with surgical manipulation of the uterus) and reduces surgical and anesthetic times [27,35].

The aim of this study is to evaluate the feasibility and therapeutic safety of Laparoendoscopic Single-Site Ovariectomy (LESS-OVE) and 3-portal Laparoscopic Ovariectomy (Lap-OVE) in dogs, comparing surgical times, perioperative complications, patient recovery and follow-up, as well as a surgeon’s subjective assessment of both laparoscopic techniques.

Materials and Methods

Ethical considerations

All procedures were approved by the Ethical Commission of Animal and Human Experimentation of the “Jesús Usón” Minimal Invasive Surgery Center (JUMISC). All animals were kept and procedures were performed in accordance to the Spanish Government for Animal Care guidelines (RD 53/2013).

Study design

All procedures were performed by two experienced veterinary surgeons in minimally invasive techniques. Initially, a training period was accomplished using a physical simulator conduct LESS dissection, cutting and suturing maneuvers.

Ten intact female mixed breed dogs were included in the study, which was performed in the JUMISC. Dogs were randomly assigned to group 1 (LESS-OVE; n=5) and group 2 (Lap-OVE; n=5) for laparoscopic ovariectomy. All dogs included in the study were complete physical examination with no previous or current history of illness. Blood count and serum biochemical profile were performed before surgery. Food was withdrawn twelve hours before surgery. The cephalic vein was catheterized in order to administrate the anesthetic agents and fluids during the surgery period.

The anesthetic protocol used was the same for all animals. Dogs were premedicated using dexmedetomidine (Esteve, Spain) 10 mcg/kg IM. After a short period of pre-oxygenation using a hall face mask, anesthesia was induced using propofol (Sandoz, Spain) dosed to effect (1-4 mg/kg IV) and tracheal intubation was performed. Anesthesia was maintained by inhalation of sevofluorane (Abbott Laboratories, UK) at 1.25 minimum alveolar concentration (MAC) (1 MAC = 2.36%) combined with 100% oxygen via a semi-closed anesthetic system. Volume controlled mechanical ventilation was carried out in order to maintain normocapnia ($EtCO_2$ from 35 to 40 cm H_2O), leading to a respiratory rate of 20 rpm. Ketorolac tromethamine (Normon S.A., Spain) (1mg/kg IV) and tramadol (Grünenthal Pharma S.A., Spain) (2 mg/kg IV) and amoxicillin (Ceva, Spain) (15 mg/kg IM) were administered before surgery. During the entire procedure, respiratory and cardiac rate, pulse-oximetry, FiO_2, $EtCO_2$, tidal volume per minute, inhaled and exhaled anesthetic agent and airway peak pressure were monitored with a multi-parametric monitor (Dash 3000, General Electric Healthcare, Milwaukee, Wisconsin, USA).

Before starting surgery, the hair on the abdomen needs to be clipped and aseptically prepared for laparoscopic surgery and the urinary bladder was emptied by catheterization. The animal was positioned in dorsal recumbency.

Group 1 (LESS-OVE): A 3cm vertical skin incision was performed at the peri-umbilical area to expose the linea alba and after blunt dissection of all abdominal layers, a single access device (SILS^{TM} Port, Covidien, MA, USA), previously lubricated (K-Y^{TM}, Johnson & Johnson, New Brunswick, NJ), was placed in the abdominal wall using a Doyen clamp (Figure 1). Then, three laparoscopic 5 mm cannulas were introduced through the access channels of the single access device. Pneumoperitoneum was established with an electronic insufflator to 10 mmHg with a flow rate of 1 L/min using CO_2. Complete exploration of the abdominal cavity was performed with a 5 mm 30° laparoscope 50 cm in length (Laparoscope HOPKINS II, Karl Storz GMBH & Co. Germany), followed by patient placement in right lateral recumbency with slight lumbar elevation to facilitate the exposure of the left ovary and uterine horn. Both surgeons were positioned on the right side of the operating table.

The left ovary was identified and a 5 mm grasping forceps was introduced through the operating channel to pull the ovary up. Using a 5 mm laparoscopic vessel sealer/divider device (LigaSure V, Valleylab, Covidien, Vienna, Austria), the proper ovarian ligament, ovarian pedicle and suspensory ligament were progressively sealed and transected. Once the left ovary was completely transected, one laparoscopic cannula of 5 mm was removed and replaced by one 10 mm laparoscopic cannula, in order to facilitate ovary exteriorization. The dog was then positioned in left lateral recumbency and ovariectomy was repeated on the right side using the same technique. Immediately after removal, the ovaries were checked to ensure complete removal and pneumoperitoneum was released. The abdominal incision was closed in 3 layers using a 3/0 USP braided absorbable material (Polysorb™ 3/0, Covidien, MA, USA) and simple interrupted suture pattern.

Group 2 (Lap-OVE): A skin incision of about 1 cm long was made 1-2cm caudal to the umbilicus. The first 10 mm portal was inserted using an open technique and pneumoperitoneum was established through this portal. Then, two 5 mm portal were inserted in linea alba around 5 and 7 cm cranial and caudal to the first portal, respectively. A 5 mm diameter, 30º angle of vision telescope (Laparoscope HOPKINS II, Karl Storz GMBH & Co. KG) was used and a thorough inspection of the abdominal cavity was performed. In right lateral recumbency, the left ovarian pedicle, proper ligament, and suspensory ligament were sealed and transected as described for LESS-OVE technique (Figure 2). The ovary was pulled through the 10 mm portal under direct visualization. After re-establishing pneumoperitoneum, and with the dog repositioned in left lateral recumbency, right ovariectomy was performed using the same technique as described above. Immediately after removal, the ovaries were checked to ensure complete removal and pneumoperitoneum was released. The three portals were removed and abdominal incisions closed in 3 layers using a 3/0 USP braided absorbable material (Polysorb™ 3/0, Covidien, MA, USA) and simple interrupted suture pattern.

When the surgical procedure was completed in both groups, dogs received a single dose of buprenorphine (Richterpharma AG, Austria) (0.03 mg/kg IV), and meloxicam (Virbac, Irland) (0.1mg/kg SC) every 24h during 3 days. In order to detect postoperative complications, physical examination and wound inspection was daily performed for 10 days.

Recorded data

Total surgical time (defined as the time elapsed from 1st portal placement until skin closure) and surgical wound length measurements were recorded. Information about weight and body condition scores (on a 5-grade scale) was collected. Other data registered were fat scores of the ovarian ligament and perioperative complications like bleeding coming either from the ovarian bursa, from the ovarian pedicle, or from the proper ligament. After each procedure, all surgeons were invited to fill a questionnaire to evaluate the difficulty degree of the surgical approaches. A 1-5 point Likert scale was used being 1 the lowest level of difficulty and 5 the highest one.

Statistical analysis

All analyses were performed with a statistical software package (SPSS version 15.0 for Windows, SPSS Inc., Chicago, IL). Normally distributed variables are reported as mean ± SD (Shapiro-Wilk test). We used an unpaired T-test to compare surgical times and surgical wound length in the 2 study arms. Categorical data was analyzed with a χ^2 test (body score, fat score of the ovarian ligament, ovarian bleeding events). Level of significance was set at $p<0.05$.

Results

A total of ten mixed-breed dogs were included in the study. Mean age for group LESS-OVE and group Lap-OVE was 3.4 ± 1.1 years and 3.2 ± 1.1 years, respectively; and mean weight was 12.0 ± 3.5 kg (range, 6.5-16 kg) for group LESS-OVE and 13.0 ± 2.0 kg (range, 7.5- 15 kg) for group Lap-OVE. Two dogs were classified as underweight (body condition score: 1-2), seven dogs as normal weight (body condition score: 3), and one as overweight (body condition score: 4); the amount of fat in the ovarian pedicle did not influence the operative time in both groups.

Data for total surgical time and surgical wound length measurements are shown in table 1 and 2 for LESS-OVE and Lap-OVE, respectively. There was no significant difference between groups (*p*=0.052) for total surgical time. Mean total surgical time was 36.6 ± 3.5 minutes (range 34-42 min) for group LESS-OVE, and 32.0 ± 3.0 minutes (range 28-35 min) for group Lap-OVE. Surgical time was not correlated neither with the weight (R^2=0.104 for LESS-OVE and R^2=0.073 for Lap-OVE) or age (R^2=0.391 for LES-OVE and R^2=0.432 for Lap-OVE), thus not being apparently related to the amount of fat of the ovarian pedicle. The mean surgical wound length for group LESS-OVE was 3.0 ± 0.1cm (range 2.9-3.1 cm) and 2.2 ± 0.2cm (range 2.0-2.4 cm) for group Lap-OVE ($p \leq 0.001$).

No lesions or hemorrhages were observed during the laparoscopic procedure and ovaries were removed without incidences. No relevant hemodynamic changes were observed as a consequence of pneumoperitoneum or surgery. All dogs recovered from anesthesia uneventfully and within 30 minutes after switching off the sevofluorane vaporizer. No immediate or mid-term postoperative complications, swelling or signs of pain were observed during patient examination.

The same surgeons performed all surgical procedures. Surgeons completed a subjective survey describing their experience with both laparoscopic techniques. Ovariectomies performed by LESS-OVE received a mean score of 2.4 points over 5 in almost all the questions of the survey, which belongs to a medium level of difficulty, except for evaluation of “manoeuvrability and/or instrument collision” which obtained a mean of 3.4 points over 5 ($p \leq 0.001$). Regarding for ovariectomies performed by Lap-OVE, the score obtained was slightly lower with a mean of 1.5 points over 5 (Table 3).

Discussion

This comparative study highlights the feasibility and therapeutic safety of LESS-OVE in dogs by using a commercial single port device, as it has been shown in human and veterinary surgery [3,30]. There were no significant differences in total surgical time, LESS-OVE results in an acceptable surgical time, although slightly increased compared to Lap-OVE.

In this study, laparoscopic ovariectomy has been selected as the technique of choice for female sterilization for being a simple, less invasive and faster technique compared to ovariohysterectomy. It is considered that ovariectomy is the procedure of choice over ovariohysterectomy in healthy bitches without uterine abnormalities (mainly cystic endometrial hyperplasia - pyometra and uterine neoplasia) [16].

Minimal invasive surgery, particularly laparoscopic ovariectomy, has many advantages over traditional open surgery, either using LESS-OVE or Lap-OVE approach: less postoperative pain, low morbidity, smaller incisions, better viewing of the ovarian pedicle, possibly less risk of complications associated with surgical manipulation of abdominal viscera, and faster recovery to normal activity [22]. All these multiple advantages encourage many veterinarian practitioners incorporate these surgical techniques to their daily surgical practice. However, there are few references available regarding the use of single portal access in veterinary laparoscopy. Some of them describe single incision laparoscopic ovariectomies using traditional laparoscopic portals [12,17]. Recently, two new published studies describe the use of a commercial single incision device with good results [21,31]. Single incision laparoscopic surgery represents an evolution of the laparoscopy as it further reduces the associated surgical trauma. However, it is challenging for the surgeon, as triangulation is limited, tending to restrict the range of motion and resulting in a potential conflict between instruments and scope, which in turn impairs ergonomics [5,29,]. Previous studies report that a combination of articulated instruments increase the range of motion and triangulation, facilitating maneuverability in the surgical procedures [2]. Additionally, the use of a bipolar vessel sealer/divider device, which facilitates sealing and dividing the ovarian pedicle, has shown to be feasible, safe and reduces surgical times in both LESS-OVE and Lap-OVE approach [7,25]. Other technical difficulties associated to this approach are less traction capability, resulting in a worst surgical field exposure and poor bleeding control, if inadvertent hemorrhage occurs [7]. Our experience confirms these findings and shows the need to develop new more ergonomic and more functional devices and instruments for this laparoscopic approach [28]. We strongly believe that currently single incision laparoscopy surgery is limited by technological development of LESS-specific instrumentation. Questionnaires provided by our surgeons revealed that LESS-OVE is highly technically and skill-demanding. In fact, main limitations of laparoscopic surgery and other minimal invasive techniques are inadequate training and poor surgical experience [6]. For this reason we consider that laparoscopic training programs, especially those simulator-based, are essential to overcome gradually the steep learning curve, as it has been demonstrated in human and veterinary surgery [11,14,20,33].

Most complications in laparoscopic surgery are related to abdominal cavity access and pneumoperitoneum establishment, hemorrhage, viscera perforation and tissue damage due to energy application [26]. These complications are frequent at initial phases of the steep learning curve in laparoscopy, being less frequent in trained and experienced surgeons like those enrolled in our study. Moreover, the use of Veress needle might increase the risk of abdominal viscera damage [13]. Finally, it is important to note that, in this study the Veress needle was not used, and pneumoperitoneum was created using an open technique.

Limitations of this study include the small size population, the fact that the same surgeon performed all the procedures and the lack of use of an objective postoperative pain scale evaluation. Thus, we believe that further studies have to be done with a larger number of animals in order to obtain more representative data. This should be done whit different surgeons from multiples institutions. Therefore, we strongly believe that it is essential to further evaluate this novel approach in clinical veterinary practice, along with a proper laparoscopic training program for veterinary surgeons, which surely will lead to benefits for patients.

In conclusion, LESS-OVE using a commercial single portal access device seems to be feasible and safe in healthy bitches. Total surgical time required for this technique, although slightly greater compared to traditional Lap-OVE, is acceptable. During application of this technique we observed a faster recovery in all cases and no postoperative complications associated to any approach. However, experienced surgeons still considered LESS-OVE to be a more skill-demanded technique.

Conflict of Interest

The authors do not have any potential conflict of interest to declare.

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Table 1. Total surgical time and surgical wound length measurements (LESS-OVE).

Case	Total surgical time (min)	Surgical wound length (cm)
1	38	3.0
2	42	3.1
3	35	2.9
4	34	3.0
5	34	3.1
(Mean ± SD)	36.0 ± 3.5	3.0 ± 0.1

Table 2. Total surgical time and surgical wound length measurements (Lap-OVE).

Case	Total surgical time (min)	Surgical wound length (cm)
1	35	2.2
2	33	2.0
3	28	2.4
4	30	2.2
5	34	2.5
(Mean ± SD)	32.0 ± 3.0	2.2 ± 0.2

Table 3. Scores obtained with subjective survey 1-5 point Likert scale*.

Survey questions	LESS-OVE	Lap-OVE
- Difficulty of approach	2.0 ± 0.7	2.0 ± 0.7
- Difficulty port or device introducing	2.0 ± 0.7	1.8 ± 0.5
- Difficulty of surgical maneuvers	2.4 ± 0.5	1.4 ± 0.5
- Difficulty in viewing anatomical structures	2.0	1.6 ± 0.6
- Hemorrhage and control of hemostasis	2.4 ± 0.5	1.4 ± 0.6
- Maneuverability and instrument collision	3.4 ± 0.5	1.0
- Physical fatigue	2.6 ± 0.5	1.6 ± 0.6
- Mental fatigue	2.6 ± 0.5	1.6 ± 0.5
(Mean ± SD)	**2.4 ± 0.6**	**1.5 ± 0.5**

Difficulty degree of the surgical approaches

* 1= none; 2= low; 3= moderate; 4= high; 5= very high

Fig. 1. Insertion of the LESS Port under visual control.

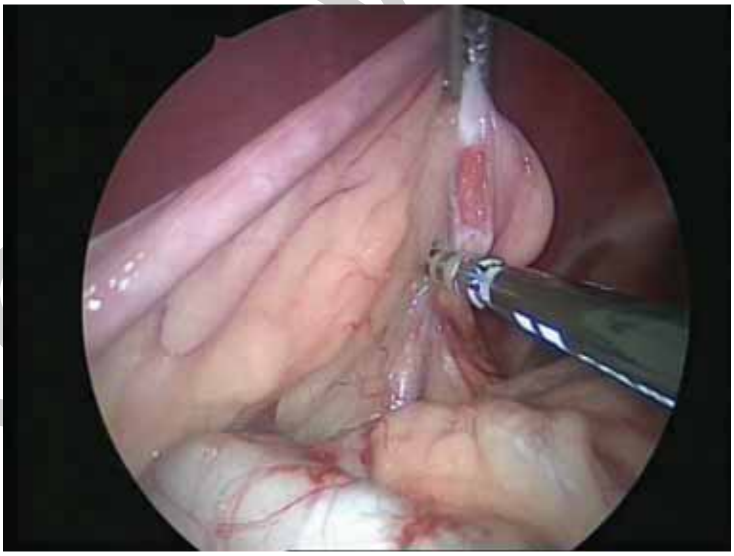

Fig. 2. Exposure and coagulation of the ovarian pedicle area accomplished by traction of the proper ovarian ligament.

XI. Relevant Published Works and Performed Research

Participation in Research Projects

Feasibility and surgical outcome of minilaparoscopy and single incision intragastric surgery for resection of experimental intragastric pseudotumours. Experimental study on animal model. September 2013 – September 2014. “Jesús Usón” Minimally Invasive Surgery Centre. Cáceres. Spain - Collaborator.

Feasibility and surgical outcome transrectal hibryd endoscopy surgery nephfrectomy in pig model. March 2014 – November 2014. “Jesús Usón” Minimally Invasive Surgery Centre. Cáceres. Spain - Collaborator.

INNPACTO. Project title: CARTMAN. Una fábrica de tejidos osteoarticulares personalizados. 2013-2015 - “Jesús Usón” Minimally Invasive Surgery Centre. Cáceres. Spain - Collaborator.

Proyecto Regional Interdiciplinario (PRI). Project title: Tratamiento Inmunosupresor de la Osteoartritis con Factores Solubles de células madre mesenquimales: prueba de concepto en modelo porcino: Acrónimo: TRIO. 2014-2015. “Jesús Usón” Minimally Invasive Surgery Centre. Cáceres. Spain - Collaborator.

Labret - Universidad de Málaga. Project title: Tratamiento de lesión del cartílago articular en la rodilla de un modelo ovino. 2014-2015. “Jesús Usón” Minimally Invasive Surgery Centre. Cáceres. Spain - Collaborator.

Involvement as a professor in more than 30 Courses of Laparoscopic Surgery at the “Jesús Usón” Minimally Invasive Surgery Centre 2012-2015. Cáceres. Spain

Visitor November 2013: Surgery Department of the Small Animal Hospital, University of Bristol School of Veterinary Science, Langford. UK. Ivan Doran, BVCS, Cert SAS DSAS (Soft Tissue), MRCVS.

Visitor March 2014: Surgery Department of the Queen Mother Hospital for Animals. Royal Veterinary College, University of London. UK. Pilar Lafuente, DVM, PhD, DECVS and DACVS, MRCVS.

Scientific Articles

Francisco M. Sánchez-Margallo, **Angelo E. Tapia-Araya**, Idoia Díaz-Güemes Martin-Portugués. Laparoendoscopic single-site ovariohysterectomy in dogs: technique and outcome. Sent to Journal Veterinary Record. Under review June 2015.

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Verónica Álvarez Pérez, Francisco M. Sánchez-Margallo, Rebeca Blázquez Durán, Alejandra Usón Gracia, **Angelo E. Tapia Araya**, Javier Casado. Aislamiento y caracterización de células madre mesenquimales de líquido sinovial para ensayos pre-clínicos en modelo porcino. AETEL - La Revista del Técnico de Laboratorio (2013), Vol. 89 pp. 38-42.

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A. Tapia-Araya, FM. Sánchez-Margallo, FJ. Vela González, Rebeca Blázquez, V. Álvarez, R. Alberdi, J. García Casado. Desarrollo de un modelo quirúrgico de lesión condral en la especie porcina para la evaluación de scaffolds y células madre Mesenquimales. XV GEVO-AVEPA Orthopaedics Congress. 29th April - 2 May 2015. Ibiza. Spain

R. Blázquez, FM. Sánchez-Margallo, V. Álvarez, **A. Tapia-Araya**, FJ. Vela González; J. García Casado. Establecimiento de líneas de células madre mesenquimales para el tratamiento de enfermedades osteoarticulares en perro. XV GEVO-AVEPA Orthopaedics Congress. 29th April - 2 May 2015. Ibiza. Spain

FJ. Vela González, FM. Sánchez-Margallo, **A. Tapia-Araya**, R. Blázquez, V. Álvarez, JG. Casado. Exosomas derivados de células madre mesenquimales para el tratamiento de la sinovitis: prueba de concepto en un modelo de animal grande. XV GEVO-AVEPA Orthopaedics Congress. 29th April - 2 May 2015. Ibiza. Spain

FM. Sánchez-Margallo, M. Pérez, **A. Tapia-Araya**. Cirugía intragástrica por incisión única y minilaparoscopia en la resección de pseudotumores submucosos en la región antral en modelo porcino. 19th Certamen Internacional de Cine Médico, Salud y Telemedicina (VIDEOMED), 17th – 21th November 2014. Badajoz, Spain.

FM. Sánchez-Margallo, **A. Tapia-Araya**, M. Pérez. Nefrectomía transrectal híbrida en modelo porcino. 19th Certamen Internacional de Cine Médico, Salud y Telemedicina (VIDEOMED), 17th – 21th November 2014. Badajoz, Spain.

FM. Sánchez-Margallo, **A. Tapia-Araya**. Cirugía por incisión única para el tratamiento del cáncer ovárico en la especie canina. 19th Certamen Internacional de Cine Médico, Salud y Telemedicina (VIDEOMED), 17th – 21th November 2014. Badajoz, Spain.

J. Usón-Gargallo, **A. Tapia-Araya**, M. Sánchez Hurtado, L. Correa, FM. Sánchez-Margallo. Simulvet: Simulador para laparoscopia, NOTES y puerto único en veterinaria. 19th Certamen Internacional de Cine Médico, Salud y Telemedicina (VIDEOMED), 17th – 21th November 2014. Badajoz, Spain.

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FM. Sánchez-Margallo, M. Pérez López, **A. Tapia-Araya**, F. Pérez Duarte, M. Sánchez Hurtado, JM. Usón Casaús. Análisis de la factibilidad de la minilaparoscopia y cirugía por incisión única para el tratamiento experimental de pseudotumores submucosos gástricos. 20th Annual Congress - Congreso de la Sociedad Española de Investigaciones Quirúrgicas (SEIQ) 23th – 24th October 2014. Albacete, Spain.

Tapia-Araya, A. Pedraza-Reales, I. Díaz-Güemes, FM. Sánchez-Margallo. Case Report: Laparoendoscopic Single-Site (LESS) surgery cryptorchidectomy in a dog. *Southern* European Veterinarian Conference - SEVC-AVEPA 49th Congress, 16th - 18th October 2014. Barcelona, Spain.

V. Álvarez Pérez, A. Usón Gracia, R. Blázquez durán, FM. Sánchez-Margallo, **A. Tapia-Araya**, J. García Casado. Caracterización de células madre mesenquimales porcinas de líquido sinovial. 27th Annual Congress - Congreso Nacional Inmnodiagnóstico, 23th - 24th May 2014. Cordoba, Spain.

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A. Tapia-Araya, I. Díaz-Güemes Martín-Portugués, F. Pérez-Duarte, MA. Sánchez-Hurtado, FM. Sánchez-Margallo. Estudio comparativo de la ovariectomía laparoscópica por incisión única frente a laparoscopia tradicional en la especie canina. 30th Annual Congress AMVAC- Vet Madrid, 7th – 9th March 2013. Madrid, Spain.

FM. Sánchez-Margallo, **A. Tapia-Araya**, I. Díaz-Güemes Martin-Portugués. Single Incision Laparoscopic Ovariohisterectomy using a new single port device (SILS Port). *Southern* European Veterinarian Conference - SEVC-AVEPA 47th Congress, 18th - 21th October 2012. Barcelona, Spain.

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A. Tapia-Araya, A. Pedraza-Reales, I. Díaz-Güemes, FM. Sánchez-Margallo. Cryptorchidectomy by Single Incision Laparoscopy Surgery in two Dogs. The British Small Animal Veterinary Association (BSAVA) Congress, 9rd - 12th April 2015. Birmingham, UK.

A. Tapia-Araya, Bláquez Durán, V. Álvarez Pérez, FM. Sánchez-Margallo. J. Garcia Casado. Development of canine adipose stem cell lines for the allogeneic treatment of osteoarticular diseases. The British Small Animal Veterinary Association (BSAVA) Congress, 9rd - 12th April 2015. Birmingham, UK.

R. Bláquez Durán, **A. Tapia-Araya**, V. Álvarez Pérez, FM. Sánchez-Margallo. Aislamiento, caracterización y expansión In Vitro de células madres adiposas caninas para el tratamiento alogénico de enfermedades osteoarticulares. 1st Congress Latinoamericano de Traumatología, Ortopedia e Imagenología Veterinaria. (SOCHITOV), 11th - 14th September 2014. Santiago, Chile.

A. Tapia-Araya, M. Díaz-Bertrana, I. Durall Rivas. Estudio retrospectivo: osteotomía tibial en cuña como tratamiento de la rotura del ligamento cruzado anterior. 1st Congress Latinoamericano de Traumatología, Ortopedia e Imagenología Veterinaria. (SOCHITOV), 11th - 14th September 2014. Santiago, Chile.

FM. Sánchez-Margallo, **A. Tapia-Araya.** A feasibility study of minilaparoscopy and single incision intragastric surgery for resection of experimental pre-pyloric pseudotumors in pigs. European Association for Endoscopic Surgery and other interventional techniques (EAES), 25th – 28th June 2014. Paris, France.

FM. Sánchez-Margallo, **A. Tapia-Araya**, Idoia Díaz-Güemes. Granulosa cells tumour management by laparoendoscopic single-site ovariohysterectomy (LESS-OVH). 11th Veterinary Endoscopy Society (VES) Conference, 15th - 17 May 2014. Florence, Italy.

A. Tapia-Araya, FM. Sánchez-Margallo, S. Enciso-Sanz, F. Pérez-Duarte, J. Usón-Gargallo. Assessment of laparoscopic skills in veterinarians in the canine laparoscopic simulator. The British Small Animal Veterinary Association (BSAVA) Congress, 3rd - 6th April 2014. Birmingham, UK.

A. Tapia-Araya, FM. Sánchez-Margallo, F. Pérez-Duarte, JA. Sánchez-Margallo, I. Díaz-Güemes, J. Ergonomics in Veterinary Laparoscopic: Analysis of surface electromyography and hand motion. Usón-Gargallo. 47th European Veterinary Conference Voorjaarsdagen, 17th – 19th April 2014. Amsterdam, the Netherlands.

I. Díaz-Güemes, AM. Matos-Azevedo, S. Enciso Sanz, **A. Tapia-Araya**, FM. Sánchez-Margallo. Case Report: Laparoscopic cholecystoduodenostomy on canine cadaver. 47th European Veterinary Conference Voorjaarsdagen, 17th – 19th April 2014. Amsterdam, the Netherlands.

C. Báez Díaz, F. Sun, V. Crisóstomo Ayala, **A. Tapia-Araya**, J. Galiana, JR. Lima, FM. Sánchez-Margallo. Modified stent-coil embolization of an extrahepatic portosystemic shunt in a dog. 47th European Veterinary Conference Voorjaarsdagen, 17th – 19th April 2014. Amsterdam, the Netherlands.

A. Tapia-Araya, FM. Sánchez-Margallo, S. Enciso Sanz, F. Pérez-Duarte, J. Usón-Gargallo. Assessment of laparoscopic skills in veterinarians in the SIMULVET®. 10th Congress –Hospital Veterinario Montenegro, 8th – 9th February 2014. Santa Maria da Feira, Portugal.

J. Usón-Gargallo, **A. Tapia-Araya**, M. Sánchez-Hurtado, I. Díaz-Güemes, FM. Sánchez-Margallo. Development of a realistic simulator for minimally invasive surgery training. 46th European Veterinary Conference Voorjaarsdagen, 19th – 20th April 2013. Amsterdam, the Netherlands.

FM. Sánchez-Margallo, **A. Tapia-Araya**, I. Díaz-Güemes Martin-Portugués. J. Usón-Gargallo. Case report: a single-port laparoscopic ovariohysterectomy in a dog. 46th European Veterinary Conference Voorjaarsdagen, 19th – 20th April 2013. Amsterdam, the Netherlands.

Other Acknowledgements and Awards

Degree: Máster Oficial de Investigación Clínica Aplicada en Ciencias de la Salud - Universidad Autónoma de Barcelona. 2012.

Degree: Formación para Personal Investigador Usuario de Animales Para Experimentación y Otras Finalidades Científicas. Universidad Autónoma de Barcelona. 2012.

Degree: Especialista Universitario Endoscopia y Cirugía de Mínima Invasión en Pequeños Animales. Universidad de Extremadura. 2014.

Award: VideoMed Categoria: Veterinaria. Salud animal y antropozoonosis.: SIMULVET® - Simulador de Laparoscopia, NOTES y Puerto Único en Veterinaria. 19th Certamen Internacional de Cine Médico, Salud y Telemedicina (VIDEOMED), 17th – 21th November 2014. Badajoz, Spain.

Admitted to Membership of the Royal College of Veterinary Surgeons on 6 February 2015 by virtue of the qualification of Médico Veterinario awarded by the Universidad de Chile which has been recognised by the Ministry of Education, Spain, and accepted by the Royal College of Veterinary Surgeons for registration under section 5B of the Veterinary Surgeon Act 1996.