EVALUATION OF A SINGLE INCISION LAPAROSCOPIC SURGERY PORT FOR FELINE LAPAROSCOPIC AND LAPAROSCOPIC ASSISTED SURGERY

By

JAMES G. COISMAN

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2013
© 2013 James G. Coisman
To Natalie, Olivia, Kira, Adyson, and Sawyer
ACKNOWLEDGMENTS

I would like to thank my wife and girls for without your support and understanding this would not have come to fruition. I would also like to thank Brad Case and Gary Ellison for providing time, mentorship and advice over the course of these studies. Thank you to Andre Shih, Natalie Isaza, and Kelly Harrison for your advice and participation. Special thanks to Cat Monger for the coordination and scheduling of the lab, housing and technical assistance. We could not have done it without you. Additionally, many thanks are given to the cats and the rescue groups who provided them and then found them homes.
# TABLE OF CONTENTS

ACKNOWLEDGMENTS ........................................................................................................... 4

LIST OF FIGURES .................................................................................................................. 7

LIST OF ABBREVIATIONS ..................................................................................................... 9

ABSTRACT .............................................................................................................................. 10

CHAPTER

1 AN INTRODUCTION TO LAPAROSCOPIC AND LAPAROSCOPIC ASSISTED SURGERY IN CATS ............................................................................................................. 12

   Background ...................................................................................................................... 12
   History ............................................................................................................................... 12
   Laparoscopic Equipment ............................................................................................... 15
      Telescopes .................................................................................................................... 16
      Insufflators ................................................................................................................... 16
      Cannulas and Ports ..................................................................................................... 17
      Basic Hand Instruments ............................................................................................ 18
   Hemostasis in Laparoscopic Surgery ............................................................................ 19
      Bipolar Sealing Devices .............................................................................................. 19
      Extracorporeal Knots ................................................................................................. 20
   Scientific Reports of Laparoscopy and Laparoscopic Assisted Surgery in Cats ......... 20
   Summary .......................................................................................................................... 21

2 EFFICACY OF DECONTAMINATION AND STERILIZATION OF SINGLE-USE SINGLE INCISION LAPAROSCOPIC SURGERY PORTS ........................................................................ 30

   Background ...................................................................................................................... 30
   Materials and Methods .................................................................................................. 31
      SILS Ports .................................................................................................................... 31
      Sampling ...................................................................................................................... 31
      Microbial Contaminants ............................................................................................ 32
      Negative Control ....................................................................................................... 32
      Positive Control ....................................................................................................... 32
      Treatment Port ........................................................................................................... 33
   Decontamination and Sterilization .............................................................................. 33
      Culture Methodology ................................................................................................. 34
      Data Analysis ............................................................................................................ 34
   Results .............................................................................................................................. 35
   Discussion ....................................................................................................................... 35
   Summary .......................................................................................................................... 40
COMPARISON OF SURGICAL VARIABLES IN CATS UNDERGOING SINGLE-INCISION LAPAROSCOPIC OVARIECTOMY USING A LIGASURE OR EXTRACORPOREAL SUTURE VERSUS OPEN OVARIECTOMY

Background
Materials and Methods
Test Groups
Inclusion Criteria and Group Assignment
Anesthesia
Surgery
SILOVE-LS
SILOVE-ECS
Open-OVE
Closure
Data Collection
Surgical Time
Pain Scoring
Data Analysis
Results
Signalment
Surgical Time
Surgical Complications
Pain Evaluation
Visual analog score
Simple descriptive scale
Mechanical stimulation
Discussion
Signalment
Surgery Time
Surgical Complications
Pain Evaluation
Limitations
Summary

CONCLUSION

LIST OF REFERENCES

BIOGRAPHICAL SKETCH
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Tele Pack; this system includes the monitor, light source and image capture device in one unit (photo courtesy of author)</td>
<td>22</td>
</tr>
<tr>
<td>1-2</td>
<td>High definition camera used for laparoscopy and other minimally invasive surgery (photo courtesy of author)</td>
<td>23</td>
</tr>
<tr>
<td>1-3</td>
<td>Fiberoptic light cable used for laparoscopy and other minimally invasive surgery (photo courtesy of author)</td>
<td>24</td>
</tr>
<tr>
<td>1-4</td>
<td>Scopes used for laparoscopy and thoracoscopy. From top to bottom and left to right—11mm operating scope, 10 mm 0 degree scope, 10 mm 30 degree scope, 5 mm 0 degree scope, and 5 mm 0 degree scope (photos courtesy of author)</td>
<td>25</td>
</tr>
<tr>
<td>1-5</td>
<td>Insufflator used to control CO\textsubscript{2} for creation and maintenance of the pneumoperitoneum (photo courtesy of author)</td>
<td>26</td>
</tr>
<tr>
<td>1-6</td>
<td>Variety of re-usable and disposable cannulas available for laparoscopy. The SILS\textsuperscript{TM} port with 5 mm cannula set is on the bottom right (photo courtesy of author)</td>
<td>27</td>
</tr>
<tr>
<td>1-7</td>
<td>5 mm basic hand instruments for laparoscopy and thoracoscopy. From top to bottom—5 mm curved metzenbaum scissors, 5 mm Babcock grasping forceps, 5 mm curved Kelley grasping/ dissecting forceps (photos courtesy of author)</td>
<td>28</td>
</tr>
<tr>
<td>1-8</td>
<td>LigaSure\textsuperscript{TM} bipolar vessel sealing device with a 5 mm – 37 mm handpiece (photo courtesy of author)</td>
<td>29</td>
</tr>
<tr>
<td>2-1</td>
<td>A-Foam portion of the SILS port. Note the concave central area. B-The inset shows the porous nature of the foam. Not included in the image are the rigid cannulas that come with the port (photo courtesy of author)</td>
<td>41</td>
</tr>
<tr>
<td>2-2</td>
<td>SILS port with holes created by sampling with a 6 mm Baker punch (photo courtesy of author)</td>
<td>42</td>
</tr>
<tr>
<td>3-1</td>
<td>Intra-operative image of the uterine horn and ovarian pedicle being elevated using the laparoscopic Babcock forceps. The inset shows the port and instruments (photo courtesy of author)</td>
<td>59</td>
</tr>
<tr>
<td>3-2</td>
<td>Illustration depicting the tying of a Meltzer knot through the SILS\textsuperscript{TM} cannulas with instrumentation in place (Illustration courtesy of C. Moats)</td>
<td>60</td>
</tr>
</tbody>
</table>
3-3  Box and Whisker plot illustrating surgery time by group: SILOVE-LS, open-OVE, and SILOVE-ECS. The box represents the interquartile range, the center line the median, and the whiskers the minimum and maximum values. Different letters are present where significant differences exist ($P < 0.05$). ....... 61

3-4  Visual analogue pain scores by group: open-OVE, SILOVE-LS, and SILOVE-ECS. Different letters are present where significant differences exist ($P < 0.05$). ........................................................................................................ 62

3-5  Simple descriptive pain scores by group: open-OVE, SILOVE-LS, and SILOVE-ECS. Different letters are present where significant differences exist ($P < 0.05$). ........................................................................................................ 63

3-6  Von Frey Filament palpation scores by group: open-OVE, SILOVE-LS, and SILOVE-ECS. Different letters are present where significant differences exist ($P < 0.05$). ........................................................................................................ 64
## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIS</td>
<td>minimally invasive surgery</td>
</tr>
<tr>
<td>SILS</td>
<td>single incision laparoscopic surgery</td>
</tr>
<tr>
<td>TSB</td>
<td>trypson soy broth</td>
</tr>
</tbody>
</table>
Laparoscopic surgery is a well established minimally invasive surgical modality in cats and dogs. Currently, more emphasis is being placed on reducing the number of incisions required for laparoscopic procedures in order to reduce pain and morbidity associated with multiple incisions. To date, no evaluations of Single Incision Laparoscopic Surgery (SILS) ports have been reported in cats. The purpose of this study was to show that the use of these ports is both economically feasible and clinically applicable.

Three SILS™ ports were utilized in the in vitro evaluation. The negative control port underwent decontamination and ethylene oxide sterilization without bacterial inoculation, the positive control port underwent bacterial inoculation without decontamination sterilization and the treatment port underwent bacterial inoculation followed by decontamination and ethylene oxide sterilization. Five testing cycles were conducted; during each time, a sample of the foam portion of each port was obtained and bacteriologic culture was performed. None of the treated port samples had positive culture results. All 5 positive control port samples had positive culture results. One
negative control port sample grew a spore-forming Bacillus sp organism which was thought to be an environmental contaminant.

In vivo evaluation of the port was performed by comparing three methods of laparoscopic sterilization in twenty-four healthy, female, domestic cats. Cats were randomly assigned to one of three groups: single incision laparoscopic ovariectomy-LigaSure (SILOVE-LS (n=8)), single incision laparoscopic ovariectomy-extracorporeal suture (SILOVE-ECS (n=8)) or open ovariectomy (open-OVE (n=8)). Single-incision laparoscopic ovariectomy was successful in (n=8) SILOVE-LS cats and (n=5) SILOVE-ECS cats. Surgical time was longer and more complications occurred in the SILOVE-ECS group. Post-operative pain was not different between groups.

Our study demonstrates that decontamination and sterilization was effective for eliminating bacterial viability in a contaminated SILS™ port model. Also, ovariectomy performed with the SILS™ port is clinically applicable and safe in cats. Further in vitro and clinical testing is warranted to identify potential complications of reuse of this device, such as infection or port malfunction, before routine reuse of the port can be recommended.
CHAPTER 1
AN INTRODUCTION TO LAPAROSCOPIC AND LAPAROSCOPIC ASSISTED SURGERY IN CATS

Background

Over the last three decades minimally invasive surgical techniques have found acceptance and in some cases have replaced open surgical procedures in humans.\textsuperscript{1-4} In the last decade, advances and availability of instrumentation, techniques, and client demand have been instrumental in the development of routine arthroscopic, flexible endoscopic, thoracoscopic, and laparoscopic evaluation and therapies in veterinary medicine.\textsuperscript{5-11} Laparoscopy is now a well established modality for abdominal surgery in veterinary medicine.\textsuperscript{12-17} Reported laparoscopic and laparoscopic-assisted procedures in cats include ovarietomy, ovariohysterectomy, liver biopsy, pancreatic biopsy, and recently enterotomy, as well as intestinal resection and anastomosis.\textsuperscript{12-17} A main advantage of laparoscopic surgery is better visualization during the procedure, which may result in less risk of hemorrhage\textsuperscript{18,19} and minimization of surgical inaccuracy, potentially reducing the chance of incomplete tissue excision and complications such as ovarian remnant syndrome.\textsuperscript{20} Other benefits attributed to laparoscopy include reduction of pain in the postoperative period,\textsuperscript{21-24} more expeditious recovery compared to laparotomy,\textsuperscript{25,26} and less risk of infection.\textsuperscript{27}

History

The history of endoscopy and therefore laparoscopy in both human and veterinary medicine begins with the ancient physicians’ interest in viewing into the orifices and internal cavities of their fellow man. In early civilization, Hippocrates (460-375 BC) is credited with the first use of a rectal speculum.\textsuperscript{28,29} A section in the Babylonian Talmud, thought to be recorded around 65 BC, describes the use of a
vaginal speculum to distinguish vaginal from uterine bleeding. In the 9th century, Abulkaism, an Arabian physician, is credited for using reflected light instead of direct light to visualize the inside of the vagina. These precursors to current methods were all largely limited by the use of ambient light for illumination.

In 1805, Phillipe Bozzini developed an instrument he named the Liechleiter or light conductor. This marked a transition to the use of an external light source. Bozzini’s instrument used candle light for illumination through a tube for inner cavity visualization and he published on its construction in 1806 and potential uses in 1807. Unfortunately he succumbed to typhus in 1809. It wasn’t until almost 50 years later in 1853 that Antonin Desormeaux, considered by many to be the father of modern endoscopy, was the first to use an instrument similar to Bozzini’s in a clinical patient. Desormeaux’s endoscope used an alcohol lamp for illumination. The invention of a relatively durable incandescent lamp by Edison in 1879 and the incorporation of lenses into the scope to broaden the field of view, along with moving the light source to the distal end of the device by Maximillian Nitze in 1887 greatly improved effective illumination.

Up to the end of the 19th century, endoscopy was confined to procedures such as vaginoscopy, female cystoscopy, esophagoscopy, and gastroscopy. In 1901, the first reported endoscopic intra-abdominal evaluation was attempted by Dimitri Ott. Dr. Ott, a Russian gynecologist, used a lamp, head mirror and speculum to peer into the abdominal cavity via a small incision through the posterior vaginal fornix. Also in 1901, the first true laparoscopy in a live dog was performed by George Kelling, a German surgeon. Kelling used a Nitze cystoscope and a self-made insufflation device
using sterile cotton filtered air to create a pneumoperitoneum. Kelling reported his findings in 1902 naming the procedure coelioscopy and the pneumoperitoneum *Luft tamponade* or air tamponade.\textsuperscript{37,38} In 1910 Hans Christian Jacobaeus published a number of clinical reports on laparoscopy, thoracoscopy, and pericardoscopy in humans making him one of the fathers of modern human endoscopy and he is credited with coining the term “laparoscopy.”\textsuperscript{37,39}

While there are multiple reports of laparoscopic advances in humans during the first half of the 20\textsuperscript{th} century\textsuperscript{37} only Anderson in 1937 reported using live dogs to investigate and improve laparoscopic skills and applications for use in human patients.\textsuperscript{40} Anderson is also the first to report on laparoscopic sterilization in women using an electrode for endothermic coagulation.\textsuperscript{40} From the mid 1950’s through the 70’s a growing interest in veterinary reproductive medicine lead to the use of laparoscopy to visualize the reproductive organs and more specifically the ovaries in several livestock, laboratory animal and exotic species.\textsuperscript{37} Laparoscopic approaches developed during this time of growth ranged from standing vaginal and paralumbar in mares\textsuperscript{41} and cows\textsuperscript{42} to ventral midline in sheep,\textsuperscript{43} goats,\textsuperscript{44} and pigs.\textsuperscript{45,46}

Along with the investigations in livestock in the 1970s, researchers started performing and reporting on laparoscopic techniques used in research dogs and cats.\textsuperscript{37} In 1972, Lettow reported on the first laparoscopic-assisted liver biopsy in the dog.\textsuperscript{47} Wildt et al were the first to report on laparoscopic evaluation of the internal organs of cats and dogs in 1977.\textsuperscript{48} That ground breaking report demonstrated the potential for laparoscopy to be a safe and practical method of abdominal evaluation in cats and
dogs. Since then there has been exponential growth in research and clinical reporting on the use of laparoscopy in the cat and dog.\textsuperscript{12-15,17,18,21-23,26,27,49-54}

**Laparoscopic Equipment**

Laparoscopy in small animal practice requires a monitor, camera, image capture device, light source, light transmitting cable, telescope, insufflator, telescope, cannulas or ports, hand instruments, and an ability to provide hemostasis when needed.\textsuperscript{55} This instrumentation set can be tailored to the needs of a particular clinic setting or patient.

The monitor can be as simple as a television set or computer screen, however, higher grade medical monitors may provide better imaging (Figure 1-1).\textsuperscript{55} The camera and image capture device provides real time imaging of the surgical site, which is useful for recording images and video documentation of surgical findings and procedures. Digital three-chip and high-definition cameras provide the best color and image quality (Figure 1-2). The high-definition camera produces the most color accurate, highest quality video and real-time images with enhanced depth perception that may improve technical skills.\textsuperscript{56} The image capture device is important for documentation and historical archiving of procedures and intraoperative findings.

A light source provides the illumination to the surgical field via fiber optic light cable (Figure 1-3). Xenon and halogen light sources are the most commonly used with xenon producing a more white and consistent light.\textsuperscript{55} Adequate wattage must be available to illuminate all intra-abdominal areas. Additionally, the ability to control the intensity of the light is useful in areas where serosal or instrument reflection can be a problem.\textsuperscript{57} This light control may be a function of the camera itself or in combination with the light source.\textsuperscript{57}
Telescopes

The most common rigid telescopes used in small animal laparoscopy are 2.7 mm and 5 mm diameter telescopes. The 2.7 mm telescope is frequently used in smaller patients but is more fragile and typically requires the use of a 3.5 mm operating sleeve to protect the telescopes narrow shaft from bending during use. Additionally, there are larger 10 mm scopes that allow more light and a wider field of view, but this is at the expense of larger cannula and incision size. Alternatively, there is a 12 mm operating laparoscope that has an incorporated 5 mm telescope and 7 mm working channel; has been used in both cats and dogs (Figure 1-4). The telescopes also come in a variety of viewing angles, the most common of which are the zero and thirty degree variety. The zero degree scope gives a “straight on” view of the surgical field and is technically easier to maneuver than an angled telescope; it is adequate for the majority of laparoscopic procedures performed in small animals. However, telescopes with a thirty degree angle allow the laparoscopist to visualize structures “from the side”. This is especially advantageous for navigating around fixed anatomy like the liver or kidneys, visualizing deep or distant regions in the abdomen such as the lateral peritoneal gutters, and in triangulating instruments within the field of view when there is limited working space.

Insufflators

An insufflator is used to pump carbon dioxide into the abdomen to create a “working space” between the viscera and body wall (Figure 1-5). Landmark work done in the 1970s showed that cardiac output declines when intra-abdominal pressure (IAP) exceeds 10 mm Hg and can be detrimentally effected if the pressure exceeds 15 mm Hg with up to 50% reduction in cardiac output at 20 mm Hg. Quality insufflators
possess both IAP and gas flow regulators to maintain a safe working pressure within the peritoneal cavity. Most surgeons use 12-15 mm Hg IAP for initial trocar insertion. This higher pressure provides greater distension creating more space between the body wall and viscera allowing safer entry of the initial trocar and cannula. The IAP is then reduced to 6-8 mm Hg in order to maintain an adequate working space while limiting the potential deleterious effects on cardiac output and ventilation.\textsuperscript{61} Although not commonly utilized, some insufflators are equipped with gas warmers and humidifiers to help mitigate potential adverse sequelae such as hypothermia and peritoneal desiccation, which can be seen with cold non-humidified gas insufflation.\textsuperscript{21,62-64}

**Cannulas and Ports**

Cannulas and ports come in a wide range of sizes, materials, and designs (Figure 1-6). A typical small animal laparoscopy set comes with three 5mm cannulas with two sharp and one blunt obturator for insertion, a 10 mm cannula with obturator and a cannula reducer from 11 mm to 5.5 mm.\textsuperscript{55} In an effort to decrease the incidence of trocar induced injuries, screw in or threaded cannulas (Ternamian EndoTip\textsuperscript{TM}, Karl Storz, Veterinary Endoscopy, Goleta, CA) that don't require trocars for insertion were developed. Also available are several single-use cannulas made from hard plastics that come in both threaded and smooth shaft styles. Some of these single-use cannulas are available with self-retracting trocars that immediately retract on penetration of the body wall and others that allow visualization at the tip of the trocar so that penetration into the abdominal or thoracic cavity can be visualized throughout placement.

Recently, a movement towards fewer incisions in both human and veterinary minimally invasive surgery (MIS) has been recognized. To this end, several single-incision multi-cannulated surgical ports have been developed. The EndoCone\textsuperscript{TM} is a
resterilizable single-incision multi-instrument port developed by Karl Storz. This port allows the passage of multiple instruments through a single 3 cm incision; however, its conical design and rigid walls necessitate using special sigmoid shafted or articulated instruments in order to overcome the difficulties of triangulation and instrument clashing inherent to single-incision instrumentation. Several single-use ports are also available including the Single Incision Laparoscopic Surgery (SILS)™ port from Covidien, the Uni-x™ from Pnavel, as well as the Triport™ and Quadport™ series from Advanced Surgical Concepts. The material and design of these ports vary in stiffness and flexibility, which can necessitate using special sigmoid shafted or articulated instrumentation for many procedures.

**Basic Hand Instruments**

Laparoscopic hand instruments come in a vast array of types and configurations representing almost all of the instruments used in traditional surgery. Scissors, forceps, and retraction/ manipulation devices are the most commonly used in small animal laparoscopy (Figure 1-7). Instrumentation is available in both 5 mm and 10 mm diameters allowing use through most laparoscopic cannulas. The most basic 5 mm set of laparoscopic hand instruments should include a palpation probe, Babcock forceps, curved Kelley forceps, biopsy forceps, and curved Metzenbaum scissors. Many instruments are also available with curved or sigmoid shafts for improved triangulation when used in specialized single-incision ports. However, most veterinary laparoscopic procedures can be performed utilizing straight-shafted instruments. Additionally, many hand instruments can be attached to monopolar electrocautery for aid in hemostasis.
Hemostasis in Laparoscopic Surgery

Halstead’s 4th Tenet of Surgery, control of hemorrhage, applies to both open and laparoscopic surgery; however, extra diligence is essential for successful laparoscopic surgery as even small amounts of blood in the laparoscopic surgical field can hinder visualization and result in conversion to an open celiotomy.\(^{12,52}\) Multiple modalities for controlling hemorrhage have been developed for use during laparoscopic surgery. Anderson is the first to report using endothermic coagulation to provide hemostasis during laparoscopic sterilization in women in 1937. However, it wasn’t until the 1970’s that Semm reported on and championed thermocoagulation, extracorporeal knotting and Roeder Loop applicators for controlling bleeding during laparoscopic gynecological surgeries.\(^{65}\) Since the 1970’s, advances in hemorrhage control for laparoscopic surgery include the development of endoclips, endostaplers, laser, ultrasound sealing devices, bipolar tissue sealing devices, and advancements in intra- and extracorporeal suturing.\(^{16,18,19,24,53,55,66-68}\) In our study a bipolar device was chosen for its relative ease of use\(^{18,50,55}\) and an extracorporeal suture knot for its technical difficulty.\(^{18,55,68}\)

Bipolar Sealing Devices

Laparoscopic use of bipolar electrocoagulation was first reported in 1971 by Semm.\(^{69}\) However, it wasn’t until the late 1990’s the first reported use of a feedback-controlled bipolar vessel sealing emerged.\(^{70}\) The principle behind this technology is that as the tissue is heated the impedance change is reported to a microprocessor in the generator. This feedback ensures the appropriate amount of heating and compression is provided to the tissue to melt collagen and elastin proteins into a sealing coagulum.\(^{70}\) Two of these sealers, the LigaSure™ (Figure 1-8) made by Covidien and the ENSEAL™ by Ethicon are reported to seal up to 7 mm vessels with similar amounts of thermal...
spread.\textsuperscript{71,72} In addition, numerous veterinary studies have demonstrated the efficacy and safety of these devices in sealing vessels and tissue.\textsuperscript{14,15,18,21,22,26,49,51,53,67,71,72}

**Extracorporeal Knots**

Several extracorporeal slip knots have been described for use in laparoscopic surgery.\textsuperscript{66,68,73} These include, but are not limited to, the Roeder knot, modified Roeder knot (Meltzer knot), 4S modified Roeder (4SMR) knot, and Weston knot. The Weston knot requires the addition of two or three intra-corporeal throws for security thus greatly adding to its difficulty.\textsuperscript{68} The Roeder knot, first widely used by Semm, has been shown to be significantly weaker than more recent modifications that include additional throws.\textsuperscript{73-76} In addition to the number of throws, suture material and size also affect knot security.\textsuperscript{74-76} In a recent study comparing the 4SMR and modified Weston knots the 4SMR had a higher slippage rate when tied with polyglactin 910 though all ligatures withstood testing with supraphysiologic pressures.\textsuperscript{68} While the Meltzer knot was not compared in the recent study, the results in Shimi’s work suggest that the additional friction created in the Metzler knot may provide additional resistance to slippage with braided suture such as the polyglactin 910.\textsuperscript{68,76}

**Scientific Reports of Laparoscopy and Laparoscopic Assisted Surgery in Cats**

While reporting of laparoscopic advances has been prolific in human and canine literature in the last two decades little has been published in cats. Ovariectomy\textsuperscript{14,16} is the most commonly reported procedure with several studies evaluating either ports or methods of hemostasis. Other reported procedures include ovariohysterectomy\textsuperscript{6}, cryptorchidectomy,\textsuperscript{15} liver biopsy,\textsuperscript{6} pancreatic biopsy,\textsuperscript{6,77} enterotomy,\textsuperscript{78} intestinal resection and anastomosis,\textsuperscript{12,13} renal biopsy,\textsuperscript{79,80} splenic biopsy\textsuperscript{81} and splenectomy.\textsuperscript{82}
Summary

The history of laparoscopy stretches from the ancients, yet only in the last 30 years have significant breakthroughs and real development occurred. These recent advances in equipment and instrumentation have paved the way to wide acceptance of laparoscopic procedures in both human and veterinary patients. The benefits of laparoscopic surgery including better visualization, reduction of pain, faster recovery, and lower infection rate are well documented. Additionally, client’s personal experience and demand have been instrumental in establishing laparoscopy as an accepted modality for abdominal surgery in veterinary medicine. Though still lagging in numbers in the literature when compared to human and canine studies, reported laparoscopic and laparoscopic-assisted procedures in cats include ovarietomy, ovariohysterectomy, liver biopsy, pancreatic biopsy, enterotomy and intestinal resection and anastomosis.
Figure 1-1. Tele Pack; this system includes the monitor, light source and image capture device in one unit (photo courtesy of author).
Figure 1-2. High definition camera used for laparoscopy and other minimally invasive surgery (photo courtesy of author).
Figure 1-3. Fiberoptic light cable used for laparoscopy and other minimally invasive surgery (photo courtesy of author).
Figure 1-4. Scopes used for laparoscopy and thoracoscopy. From top to bottom and left to right—11mm operating scope, 10 mm 0 degree scope, 10 mm 30 degree scope, 5 mm 0 degree scope, and 5 mm 0 degree scope (photos courtesy of author).
Figure 1-5. Insufflator used to control CO₂ for creation and maintenance of the pneumoperitoneum (photo courtesy of author).
Figure 1-6. Variety of re-usable and disposable cannulas available for laparoscopy. The SILS™ port with 5 mm cannula set is on the bottom right (photo courtesy of author).
Figure 1-7. 5 mm basic hand instruments for laparoscopy and thoracoscopy. From top to bottom—5 mm curved metzenbaum scissors, 5 mm Babcock grasping forceps, 5 mm curved Kelley grasping/ dissecting forceps (photos courtesy of author).
Figure 1-8. LigaSure™ bipolar vessel sealing device with a 5 mm – 37 mm handpiece (photo courtesy of author).
CHAPTER 2
EFFICACY OF DECONTAMINATION AND STERILIZATION OF SINGLE-USE SINGLE INCISION LAPAROSCOPIC SURGERY PORTS

Background

Decontamination and sterilization of laparoscopic SUDs for humans undergoing MIS is controversial. Such devices are typically reused because of economic concerns, however reuse of disposable instruments may increase the risk infection for patients. Single-use surgical devices are typically made of less robust materials (plastics and rubber) than are non-disposable surgical devices; therefore, decontamination and sterilization of SUDs can be difficult and such devices are prone to mechanical malfunction when reused.

Reuse of SUDs is common in the field of veterinary surgery. There are few reports of mechanical failure or adverse effects for animals when SUDs are reused for performance of surgery. To the authors’ knowledge, it is unknown whether this scarcity of information is attributable to a lack of such effects or to underreporting of adverse events.

Veterinarians typically reuse laparoscopic SUDs because of the high cost of such devices. Veterinary surgeons and surgeons performing procedures for humans in developing or poor countries may have justification for reuse of SUDs during MIS because of economic concerns. However, adverse effects of such reuse of devices may be different for humans and other animals.

A disposable instrument port has been developed for use during single-incision laparoscopic surgery of humans. Although the material composition of that port is proprietary information of the manufacturer, the device has a gross appearance similar to firm, malleable foam (Figure 2-1). The advantage of this port for performance of
laparoscopic surgery is that 3 to 4 instruments can simultaneously be used though a single short incision. Preliminary studies for dogs and cats indicate the device is useful for MIS in such animals.\textsuperscript{51,54} However, the cost of the device is approximately $400; therefore, use of the device by veterinarians for single-incision laparoscopy of animals may be economically impractical.

The purpose of the study reported here was to determine the efficacy of decontamination and sterilization of a disposable port intended for use during single-incision laparoscopy. We hypothesized that a commonly used method of surgical instrument decontamination and sterilization would be efficacious for elimination of bacteria on this laparoscopic instrument port.

**Materials and Methods**

**SILS Ports**

Three SILS\textsuperscript{TM} ports were utilized for five test cycles in this study. Prior to the start of the study, the ports were randomly assigned as a negative control, a positive control, and a treatment port by drawing a number from a bag. This port assignment remained the same for the duration of the study.

**Sampling**

All handling of the port and sampling was done using aseptic technique including using single use sterile biopsy punches, blades and surgical latex gloves. Each port was sampled in the same manner, using a sterile 6 mm baker biopsy punch (Biopsy Punch; Integra Miltex, York, PA), following its respective treatment. The location of sampling for all ports was in the central concave region of the port (Figure 2-2). The plastic inner cannulas and insufflation tubing were not included during testing.
**Microbial Contaminants**

The test microorganisms used in this study were *Escherichia coli* ATCC #25922, *Staphylococcus aureus* ATCC #29123, and *Mycobacterium fortuitum* (clinical isolate). Each isolate was grown separately in sterile tryptic soy broth (TSB) (TSB; Hardy Diagnostics, Santa Maria, CA) which was incubated at 95 +/- 2% humidity in 5% to 10% CO₂ at 35 to 37°C. The bacteria were combined and suspended in sterile deionized water with an approximate cell density of ca. 1.5 x 10⁵ CFU/mL for each species.

**Negative Control**

For the negative control group, no treatment was performed. Instead, a SILS port was maintained in sterile wrap and resterilized in Ethylene Oxide (EtO) (EO Gas Series 3; Andersen Sterilizers, Inc. Haw River, NC) immediately following sampling. All handling of the port and sampling was done using aseptic technique including using single use sterile biopsy punches, blades and surgical latex gloves. The port was sampled in the same manner from the central concave region using a sterile 6 mm baker biopsy punch (Biopsy Punch; Integra Miltex, York, PA) at each test cycle and placed in a 5ml aliquot of sterile TSB which was incubated in 95 +/- 2% humidity and 5% to 10% CO₂ at 35 to 37°C. Samples were examined at 18 to 24 hours and again after a minimum of 48 hours for growth.

**Positive Control**

The positive control port was exposed to *E coli* American Type Culture Collection No. 25922, *S aureus* American Type Culture Collection No. 29123, and *M fortuitum* (isolated from a clinical patient and identified via DNA sequence analysis). Each bacterial isolate was incubated separately in TSB at 95 +/- 2% humidity in 5% to 10% CO₂ at 35° to 37°C. The bacteria were combined and suspended in sterile deionized...
water with a cell density of approximately $1.5 \times 10^5$ CFUs/mL of each species. The positive control port was submerged in the bacterial suspension for 30 minutes at approximately 21°C. Then, port material samples were collected with a sterile biopsy punch. Port material samples obtained at each of the 5 testing times were placed in 5 mL of sterile TSB and incubated at 95 +/- 2% humidity in 5% to 10% CO₂ at 35° to 37°C. Bacteriologic cultures of positive control port material were examined at 18 to 24 hours after the start of incubation to detect *E coli* and *S aureus* growth and from 48 hours to 1 week after that time to detect *M fortuitum* growth.

**Treatment Port**

The treatment port was exposed to the same mixture as the positive control port of the following bacteria: *Escherichia coli* ATCC #25922, *Staphylococcus aureus* ATCC #29123, and *Mycobacterium fortuitum* (clinical isolate). Each isolate was grown separately in TSB and incubated as described for the negative controls. The bacteria were combined and suspended in sterile deionized water with an approximate cell density of ca. $1.5 \times 10^5$ CFU/mL for each species. The port was submerged in the bacterial composite solution for 30 minutes.

**Decontamination and Sterilization**

Instead of immediate sampling, the treatment port was decontaminated via rinsing with tap water for 1 minute and soaked in a enzymatic cleaner (dilution, 3:100) (Bio-zyme; Osceola Supply, Tallahassee, FL) and brushed with a sponge scrub brush and pipe cleaner brush for 5 minutes. The port was then rinsed with tap water, dried with compressed air, and packaged and heat-sealed in plastic wrap. The wrapped port was then exposed to ethylene oxide for 16 hours by use of a standard protocol at 50°C and > 30% humidity, as determined by use of a humidity chip (Humidichip;
Andersen Products, Haw River, NC). Sterilization indicators (EtO Gas dosimeter; Andersen Products, Haw River, NC) were used to ensure sterile conditions were attained during the ethylene oxide sterilization cycle. After sterilization, a port material sample was collected and aerobic bacteriologic culture was performed via the same method used for negative and positive control ports.

**Culture Methodology**

Each TSB tube was visually inspected for growth (turbidity) and sub-cultured onto Columbia Base with 5% sheep blood (CBA; Hardy Diagnostics, Santa Maria, CA), Columbia base with 5% sheep blood and colistin and nalidixic acid (CNA; Hardy Diagnostics, Santa Maria, CA), and MacConkey (MAC; Hardy Diagnostics, Santa Maria, CA) agar to confirm the presence or absence of each species of bacteria. Plates were incubated at 95 +/- 2% humidity in 5% to 10% CO₂ at 35 to 37°C for 18 to 24 hours for detection of *E coli* and *S aureus* and for ≥ 48 hours for detection of *M fortuitum*.

**Data Analysis**

For each species of bacteria detected for each port material sample, an ordinal score was assigned. Scores assigned for each port material sample included 0 (no bacteria detected), 1 (1 species of bacteria detected), 2 (2 species of bacteria detected), or 3 (3 species of bacteria detected). Data were expressed as median and range values. A Wilcoxon signed rank test and a Kruskal-Wallis rank sum test with χ² approximation were used to determine statistical differences in bacterial culture scores among ports. Values of *P* < 0.05 were considered significant. Statistical analysis was performed by use of software (JMP 9.0; SAS, Cary, NC).
Results

Significant ($P = 0.003$) differences in bacterial culture scores were detected among groups of port material samples. Bacteriologic culture scores for the 5 positive control port material samples (median score, 3 [range, 1 to 3]) were significantly ($P = 0.010$) higher than those for the 5 negative control port material samples (median score, 0 [range, 0 to 1]). For the negative control port sample obtained during the first test, bacteriologic culture results were positive for a spore-forming *Bacillus* sp. The positive control port material sample obtained during that time had positive bacteriologic culture results for all 3 species of inoculated bacteria and the treated port material sample obtained during that time had negative bacteriologic culture results. None of the treated port material samples had positive bacteriologic culture results. A significant difference in the bacterial growth score was detected between the treated port material samples (median, 0 [range, 0 to 0]) and positive control port material samples ($P = 0.006$) but not between the treated port material samples and negative control port material samples ($P = 0.42$).

Discussion

Results of the present study indicated decontamination and sterilization of the multichannel laparoscopy port was effective. These findings suggest that this port may be reused for performance of MIS in animals. However, further studies are indicated to determine whether reuse of the device would cause complications such as infection in animals or equipment malfunction.

The multichannel single-use laparoscopy port is a unique peritoneal access device because it permits simultaneous passage of 3 to 4 cannulas through a single 20- to 30-mm incision.$^{51,54}$ This method may have advantages over traditional laparoscopic
techniques, which require creation of an incision for each instrument. A main benefit of a single-incision laparoscopic technique are creation of a small incision and minimization of the number of incisions created and instrument cannulas used during a procedure. Use of techniques in which the number and size of incisions are reduced is becoming common in MIS for humans, and other animals. In the authors’ experience, the port used in the present study has been useful for performance of laparoscopic-assisted gastrointestinal tract exploratory surgery. Further, for small patients, the port allows exteriorization of organs (such as portions of the intestinal tract) for performance of extracorporeal procedures without increasing the size of the original incision. This technique may decrease morbidity of animals undergoing MIS, compared with that for animals undergoing traditional open surgical techniques.

Therefore, use of this port by veterinarians may become more common for performance of MIS in animals. However, the port has a high cost ($400). Because this port is labeled as an SUD, decontamination and sterilization of the device are not advised by the manufacturer. However, results of the present study suggested that decontamination and sterilization of the device may be effective for reduction of the number of bacteria, which may allow safe reuse of the port for laparoscopic procedures in animals.

Reuse of SUDs for laparoscopy of humans is controversial. Because few complications of reuse of such devices have been detected and the devices are expensive, reuse of SUDs may be justifiable. Results of other studies indicate adverse clinical sequela of reuse of SUDs have not been detected and the cost of surgical materials for open and laparoscopic surgical procedures for humans may be
substantially (> $3,000) different. However, total costs of open and laparoscopic surgical procedures (including hospitalization costs) may be similar or such costs for laparoscopic procedures may be less than those for open surgical procedures for some human patients.\textsuperscript{90} Findings for veterinary patients may be similar.

Reuse of SUDs has potential disadvantages. Patients undergoing surgical procedures in which SUDs are reused may have higher risk of infection versus patients undergoing surgical procedures in which such devices are not reused, because of incomplete decontamination of SUDs or injury attributable to mechanical failure of such devices.\textsuperscript{83-86} Incomplete removal of organic material (determined via scanning electron microscopy and radionuclide labeling techniques) may occur in up to 100% of contaminated SUDs that have been cleaned.\textsuperscript{85,86} Although low amounts of residual organic material were found on SUDs in those studies, appropriate disinfection of microbial organisms was achieved via the methods that were used in the studies.\textsuperscript{85,86} Determination of the clinical relevance of the results of those studies may be difficult, because multiple factors may affect such findings, including type of device used, amount of prior use of a device, species of animal undergoing surgical procedures, and procedures used for decontamination and sterilization of a device. Little information is available regarding clinical complications associated with reuse of SUDs in animals undergoing surgery. Other authors\textsuperscript{91} estimated that infection is caused by contaminated endoscopic instruments in only 1 of 1.8 million procedures for humans. Further studies may be indicated to determine the risks and complications associated with reuse of SUDs for animals undergoing surgical procedures.
In the present study we attempted to determine the possibility of transmission of infectious bacteria to animals by a reused multichannel laparoscopy port via assessment of the efficacy of decontamination and sterilization techniques that are typically used for surgical instruments. This was thought to be important information because of the malleable and porous properties of the ports. The species of bacteria used for inoculation of ports in the present study were selected because they were thought to be representative of various bacteria that typically cause contamination of instruments and infection of animals after surgery. The concentration of each species of bacteria used in the present study (1.5 X 10^5 CFUs/mL) was intended to simulate instrument contamination severe enough to cause infection in animals. A *Mycobacterium* sp was included because the response of organisms of this genus to disinfectants is different from that of *Staphylococcus* spp and organisms of the family Enterobacteriaceae, and this organism is a reported cause of infection in humans that undergo laparoscopy in countries in which sterilization and reuse of SUDs is commonly performed.

The technique used to decontaminate and sterilize laparoscopic ports in the present study was the same technique used in our hospital for cleaning and sterilization of similar surgical materials. Results of this study indicated bacteria were not detected in treated port material samples after decontamination and sterilization. Thus, the decontamination and sterilization protocol used in the present study may be appropriate for preparation of SUDs for reuse in a clinical setting. Further studies of this decontamination and sterilization technique for SUDs used during clinical procedures of animals are warranted.
Several limitations of the present study were identified. The ports were not tested to detect viruses, fungi, or protozoa. Although transmission of viruses among human patients is an important concern, it may not be as important for dogs undergoing surgery because viral diseases of dogs may have lower prevalence and virulence than those of humans. However, transmission of some viral pathogens of dogs undergoing surgery, such as hepatitis C virus, may be an important concern. In addition, FIV and FeLV may be transmitted on instrument between cats undergoing surgery. Postoperative fungal infections in humans (especially infections caused by Candida spp organisms) are increasing in prevalence, and further studies of disinfection techniques for fungi are warranted.

Another limitation of the present study was that laparoscopic ports were not exposed to blood or other biological fluids of animals; exposure of ports to such fluids might alter the efficacy of the cleaning and sterilization technique used for devices in the study. Additionally, none of the ports were subjected to mechanical trauma in this study and each port was tested only 5 times. The structural integrity of such ports, and therefore the ability to effectively decontaminate and sterilize them, may be altered with repeated use; however, this was not evaluated in the present study and conclusions regarding that possibility could not be determined. Finally, only the foam portions of laparoscopic ports were tested via bacteriologic culture. Plastic cannulas and insufflation tubing of ports were not tested. We did not test those portions of the ports because we thought that these rigid structures would be less likely to harbor bacteria after decontamination and sterilization versus the foam portions of the ports.
Summary

Results of this study suggested that decontamination and sterilization was effective for reducing the number of bacteria on laparoscopic ports intended for single use. These results may support reuse of this SUD for MIS of animals. Reuse of the laparoscopic port may be safe for animals and economically beneficial for veterinarians. However, further in vitro and clinical testing is warranted to identify potential complications of reuse of this device, such as infection in animals or port malfunction, before routine reuse of the port can be recommended.
Figure 2-1. A-Foam portion of the SILS port. Note the concave central area. B-The inset shows the porous nature of the foam. Not included in the image are the rigid cannulas that come with the port (photo courtesy of author).
Figure 2-2. SILS port with holes created by sampling with a 6 mm Baker punch (photo courtesy of author).
CHAPTER 3
COMPARISON OF SURGICAL VARIABLES IN CATS UNDERGOING SINGLE-INCISION LAPAROSCOPIC OVARIECTOMY USING A LIGASURE OR EXTRACORPOREAL SUTURE VERSUS OPEN OVARIECTOMY

Background

Ovariohysterectomy (OHE) and ovariectomy (OVE) are common surgical procedures performed in small animal practice. Laparoscopy is an established surgical modality in veterinary surgery. Currently reported laparoscopic and laparoscopic-assisted procedures in cats include ovariectomy, ovariohysterectomy, liver biopsy, pancreatic biopsy, and recently, enterotomy, as well as intestinal resection and anastomosis. A reported advantage of laparoscopic surgery in dogs is better visualization during the procedure, which may result in less risk of hemorrhage, potentially reducing the chance of incomplete tissue excision resulting in ovarian remnant syndrome. Other benefits include reduction of pain in the postoperative period, more expeditious recovery compared to laparotomy, and less risk of infection. The severity of postoperative pain is likely related to the degree of soft tissue trauma, pH of the peritoneal fluid, and duration of the surgical procedure.

Because of the known advantages of MIS in other species, there is increased interest in performing new MIS techniques in cats. Ligation of ovarian blood vessels during open ovariectomy involves direct vessel ligation whereas vessel attenuation during laparoscopic ovariectomy can be done using extracorporeal placed sutures or by using electronic sealing devices. Additionally, specially designed single-incision devices, such as the SILS port (SILSTM port, Covidien, Mansfield, MA) have allowed the use of multiple instruments through a single port and have helped to facilitate such advances. However, use of new devices, especially those designed for
different species, requires cautious preliminary evaluation prior to advocating use. Ovariectomy should be an appropriate model to evaluate the feasibility and versatility of the SILS port for laparoscopic abdominal surgical procedures in cats.

Thus, the aims of this study were to 1) evaluate the feasibility and versatility of the SILS port for laparoscopic ovariectomy (SILOVE), and 2) to compare operative time, complications and postoperative pain in cats undergoing SILOVE using either a bipolar-sealing device (5mm Blunt Tip LigaSure™, Covidien, Mansfield, MA) or extracorporeal modified-Roeder knot of 3-0 polyglactin 910 (Vicryl, Ethicon Inc., Somerville, NJ), versus traditional open ovariectomy.

Our hypotheses were that laparoscopic SILOVE in cats using a SILS port was feasible, safe, and associated with a longer operative time, but no more postoperative discomfort compared to open OVE via a 20 mm incision. To evaluate these hypotheses, we performed SILOVE in cats using a LigaSure (SILOVE-LS; n=8) and extracorporeal suture (SILOVE-ECS; n=8). Open OVE was also performed in (n=8) cats for comparison. Surgery time, operative complications, and postoperative pain scores were recorded and compared between groups.

Materials and Methods

Test Groups

This study was approved by the University of Florida, Institutional Animal Care and Use Committee. Twenty-four, intact, not pregnant female cats were recruited over a three-week period from local animal rescue groups. All cats were admitted and examined at least one day prior to surgery.
Inclusion Criteria and Group Assignment

Signalment, estimated age, and body weight were recorded for all cats. All cats were assessed as normal based on physical examination, Packed Cell Volume (30-45%), Total Protein (6.3-8.6) and Blood Urea Nitrogen (5-15) analysis (Azostix, Siemens Healthcare Diagnostics Inc., Tarrytown, NY) prior to anesthesia and surgery. Cats were randomly assigned to one of three treatment groups, single incision laparoscopic ovariectomy-LigaSure (SILOVE-LS (n=8)), single incision laparoscopic ovariectomy-extracorporeal suture (SILOVE-ECS (n=8)), or open-ovariectomy (OVE (n=8)) by drawing numbers from an opaque bag.

Anesthesia

Cats were premedicated with 0.02 mg/kg buprenorphine (Buprenex, Reckitt Benckiser Pharmaceuticals Inc, Richmond, VA) given intramuscularly (IM). After five minutes, an intravenous (IV) catheter was placed in a cephalic vein. Anesthesia was induced with 4-10 mg/kg propofol (Propoflo, Abbott Laboratories, North Chicago, IL) IV to effect, and maintained with isofluorane in 100% oxygen using mechanical ventilation (Hallowell Model 2000, Hallowell EMC, Pittsfield, MA), Electrocardiography (ECG), pulse oximetry, indirect blood pressure, capnography, venous blood gas analysis, and trans-esophageal echocardiography were used for anesthesia monitoring.

Surgery

All cats were positioned in dorsal recumbency and aseptically prepared for surgery. A standardized 20mm ventral midline celiotomy was created directly over the umbilicus in all cats.
SILOVE-LS

Stay sutures using 3-0 Glycomer 631 (Biosyn, Covidien, Mansfield, MA) were placed through the rectus sheath on each side of the celiotomy and lifted to aid in port insertion. Two curved carmalt forceps were used to compress the bottom lip of the SILS port and a small amount of sterile lubrication (Surgilube, Savage Labs, Melville, NY) was applied to the port. The port was advanced into the celiotomy up to the box lock of the first Carmalt which was then released and removed. The remainder of the port was then advanced and the second carmalt released and removed. Once the SILS port was inserted into the celiotomy, three 5 mm inner cannulas were inserted into the port and the abdomen insufflated to 6 mmHg with CO₂ (20L High Flow Insufflator, Stryker Endoscopy, Santa Clara, CA). A 5 mm, 0° rigid telescope (Hopkins II telescope, Karl Storz, Veterinary Endoscopy, Goleta, CA) was inserted through the SILS and a limited abdominal explore was performed. The cat was tilted into left dorsal-oblique recumbency and the right ovary was located, grasped at the proper ligament and elevated ventrally with 5 mm laparoscopic Babcock Forceps [(Clickline, Babcock Forceps, Karl Storz, Veterinary Endoscopy, Goleta, CA) Figure 3-1]. A 5 mm LigaSure was used to ligate and divide the ovarian pedicle, suspensory ligament, and proper ligament. The abdomen was then desufflated to facilitate removal of the SILS and ovary. The cat was returned to dorsal recumbency and the SILS placed back into the celiotomy. The cat was then tilted into right dorsal-oblique recumbency and the left ovary was removed in the same manner.

SILOVE-ECS

The SILS was inserted, peritoneal insufflation accomplished and initial exploration performed in the same manner as for the SILOVE-LS group. The cats were
initially tilted into left dorsal-oblique recumbency and the right ovary was located, grasped by the proper ligament and elevated ventrally with 5 mm Babcock Forceps. A 5 mm laparoscopic scissor (Clickline, Scissors, Karl Storz, Veterinary Endoscopy, Goleta, CA) was used to fenestrate the mesovarium between the ovarian artery and proper ovarian ligament. 3-0 polyglactin 910 was passed through an inner cannula and through the fenestration with 5mm laparoscopic Kelly forceps (Clickline, Kelly Forceps, Karl Storz, Veterinary Endoscopy, Goleta, CA) and released. The tissue was then relaxed dorsally and the free end of the suture recovered from the other side of the tissue with the Kelly forceps and brought back out the inner cannula. An extracorporeal modified-Roeder knot\textsuperscript{66} (Figure 3-2) was tied and then tightened using a laparoscopic knot pusher (Knot Pusher 66173K, Karl Storz, Veterinary Endoscopy, Goleta, CA). This was repeated for each ovarian pedicle and uterine horn (adjacent to the proper ovarian ligament). The ovarian pedicle and uterine horn (adjacent to the proper ovarian ligament) were each ligated with 3-0 polyglactin 910 using extracorporeal modified-Roeder knots\textsuperscript{66} tightened using a laparoscopic knot pusher (Knot Pusher 66173K, Karl Storz, Veterinary Endoscopy, Goleta, CA). The ovarian pedicles and uterine horns were then transected approximately 5mm distal to the ligatures using the 5mm laparoscopic scissors. The abdomen was then desufflated to facilitate removal of the SILS and ovary. The SILS and ovary were then removed from the abdominal cavity. The cat was returned to dorsal recumbency and the SILS placed back into the celiotomy. The cat was then tilted into right dorsal-oblique recumbency and the left ovary was removed in the same manner.
Open-OVE

The right ovary was located with a spay hook and then exteriorized by strumming the suspensory ligament. A mosquito forceps was used to grasp the proper ovarian ligament. A fenestration was made in the mesovarium. The ovarian pedicle was ligated with 3-0 Glycomer 631 using a single encircling ligature and transected. The uterine horn was ligated, adjacent to the proper ovarian ligament, using 3-0 Glycomer 631 and transected. The left ovary was removed in the same manner.

Closure

Closure was standardized for all three treatment groups. The linea was closed using 3-0 Glycomer 631 in a simple continuous pattern. The subcutis was closed using 3-0 Glycomer 631 in a simple continuous subcuticular pattern. Tissue glue (GLUture, Abbott Laboratories, North Chicago, IL) was used to seal the skin. All cats were administered 0.1 mg/ kg meloxicam (Metacam, Boehringer Ingelheim Vetmedica, St. Joseph, MO) subcutaneously (SC) at extubation.

Data Collection

Surgical Time

Surgical time was defined as time of skin incision to time of skin closure for all groups. Surgical complications were recorded and coded based on whether or not further surgical intervention was required. Scores were 0—none, 1—minor, requiring no intervention, 2—minor, requiring surgical intervention but no alteration of the incision, 3—major, requiring enlargement of the incision and conversion to exploratory laparotomy.
Pain Scoring

Pain scores were assigned by one of two observers (Isaza and Harrison) who were blinded to the surgical treatment. Pain scores were determined prior to anesthesia, and at 1, 2, 3, and 4 hours after extubation using, in the following order, a Visual Analogue Scale (VAS)\textsuperscript{97-99}, a Simple Descriptive Scale (SDS)\textsuperscript{99-101} (table 1), and via mechanical stimulation of the incision site with an automated von Frey meter (VFF [The ProD, Top Cat Metrology LTD, CAMBS])\textsuperscript{97,102,103}. The VFF was set to a ramp rate of 0.5N/sec and a 4mm tip was used for all evaluations. At each time point, VFF stimulation was performed and recorded three times at a negative control site (right lateral abdomen) and three times in the center of the incision. The average of the 3 results was used for comparison between groups.

Data Analysis

Continuous data was summarized as median and range or as mean ± SD if normally distributed. One-way ANOVA using Welch’s method to assess for unequal variance was used to test for differences in age, body weight, and surgical time. A Tukey-Kramer test was used for post-hoc analysis. Complications were compared using Pearson’s chi-squared contingency analysis. Repeated measures ANOVA was used to test for differences in VAS, SDS, and VFF pain scoring. The Wilcoxon Method was used to make nonparametric comparisons between pairs. All analyses were performed with standard commercial software (JMP 8; SAS Institute INC, Cary, NC). Values of $P<0.05$ were considered significant.
Results

Signalment

Twenty-Four healthy, intact, female cats (n=8/group) were included in this study. The mean ± SD age of the cats was 16.5 ± 6.8 months and did not differ significantly between groups (P=0.73). The mean ± body weight of the cats was 3.02 ± 0.35 kg and also did not differ significantly between groups (P=0.16).

Surgical Time

Median surgical time was 25.5 minutes (range, 16-30 minutes) for the SILOVE-LS group, 71 minutes (range, 50-128 minutes) for the SILOVE-ECS group, and 17.5 minutes (range, 13-23 minutes) for the open-OVE group (Figure 3-3). Surgical time was significantly different between groups (P<0.001). Extracorporeal suture SILOVE took significantly longer than SILOVE-LS (P<0.001) as well as open-OVE (P<0.001). There was no significant difference in surgery time between the SILOVE-LS and open-OVE groups (P = 0.55).

Surgical Complications

Surgical complications were more frequent in the SILOVE-ECS group than the SILOVE-LS (P=0.049) and the open-OVE (P=0.008) groups. The frequency of complications was not significantly different between the SILOVE-LS and open-OVE groups (P=0.13). Surgical complications included hemorrhage from the right uterine horn distal to the ligature (n=1) and from the left uterine horn distal to the ligature (n=2) in the SILOVE-ECS group. In each case, hemorrhage was considered mild and was controlled by exteriorizing the horn through the original celiotomy and tying a second ligature. In this same group, one of the modified Roeder knots either failed to slide (n=2) or broke (n=1) during tightening. No hemorrhage was seen and each suture was
replaced with a new extracorporeal modified-Roeder’s knot. Mild hemorrhage from the uterine horn (n=1), a dropped ovary (n=1) and a small peritoneal thermal injury (n=1) occurred in the SILOVE-LS group. The hemorrhage was controlled easily with a second application of the LigaSure; the dropped ovary was easily retrieved through the existing incision after removal of the port and the thermal injury required no treatment.

There was no mortality associated with this study. Follow up was conducted by phone interview with or in the case of adoptions through the rescue groups at ten days and six months post-operatively. No complications were reported by the rescue groups or new owners.

Moderate (5-8mm, measured intra-operatively with a graduated scalpel handle) stretching of the original 20 mm incision was observed immediately following removal of the SILS port in both the SILOVE-LS (n=8) and SILOVE-ECS (n=8) groups.

**Pain Evaluation**

**Visual analog score**

No significant differences in preoperative pain scores were present between groups (P=0.99) according to the VAS. Cats in each group had significantly higher VAS pain scores at 1 hour postoperative when compared to preoperative VAS scores (P=0.0025), but VAS scores were not different across groups (P=0.76) (Figure 3-3). However, at the four hour time point alone, the SILOVE-ECS group pain score was significantly higher compared to SILOVE-LS (P= 0.011) but not significantly higher than the open-OVE cats (P=0.18). No significant difference was seen between SILOVE –LS and open-OVE cats (P=0.31)
**Simple descriptive scale**

No significant differences in SDS preoperative pain scores existed between groups \((P = 0.99)\). Cats in each group had significantly higher SDS pain scores at 1 hour postoperative when compared to preoperative SDS scores \((P=0.0001)\), but SDS scores were not different across groups (Figure 3-4) at any postoperative time point (1 hr, \(P=0.42\); 2 hr, \(P=0.76\); 3 hr, \(P=0.99\); 4 hr, \(P=0.49\)).

**Mechanical stimulation**

No significant differences in preoperative response to Von Frey Filament palpation existed between groups \((P=0.12)\). Cats in each group had significantly higher percent change in VFF pain scores at 1 hour postoperative when compared to preoperative VFF scores \((P<0.0001)\), but percent change in VFF score was not different across groups (Figure 3-5) at any postoperative time point (1 hr, \(P=0.27\); 2 hr, \(P=0.40\); 3 hr, \(P=0.20\); 4 hr, \(P=0.13\)).

**Discussion**

We have demonstrated that use of a SILS for SILOVE is feasible and versatile in cats. Although extracorporeal suturing via the SILS was effective the use of a modified-Roeder knot failed in 3 cats, increased the risk of hemorrhage and took significantly longer than the LigaSure technique. Further, SILOVE using the SILS (regardless of technique) resulted in similar post-operative pain as an open OVE of equal incision length. Laparoscopic ovariectomy using a SILS appears to offer few advantages over traditional open ovariectomy in cats, but may be beneficial in maintaining a minimally-invasive environment for other advanced laparoscopic and laparoscopic-assisted procedures when compared to traditional celiotomy approaches.
Signalment

Young, healthy, intact, female cats were included to eliminate variability in patient characteristics and to model patients seen in a typical clinical practice. No significant differences in age and body weight were seen between groups, which further limited the opportunity for bias between groups. Laparoscopic procedures were jointly performed by the same two surgeons (Case and Coisman), to maintain clinical consistency. This was particularly important in the modified-Roeder knot group, which would have been difficult to perform safely without the second surgeon. Conversely, all open OVE procedures were performed by a single surgeon (Case or Coisman), which supports open OVE as a better option for routine sterilization in cats.

All cats were anesthetized using the same protocol and no anesthetic complications occurred. The protocol used was consistent with what might be performed in clinical practice. Insufflation pressure was also standardized between SILOVE groups and was limited to 6 mmHg. This low insufflation pressure provided adequate working space within the peritoneal cavity as reported in a previous study.16

Surgery Time

Average surgical time was 25 minutes for the SILOVE-LS group and 17 minutes for the open-OVE group, which is consistent with the previous studies reported in dogs and cats.16,18,19,21-23,49,51,63,96 Although operative times did not differ significantly between these groups, it is possible that type-2 statistical error may have precluded such a finding. However, only in the laparoscopy cats was a limited exploration of the peritoneal cavity performed. The ability to evaluate the peritoneal cavity is one of the advantages of the SILS techniques over an open-OVE. Because initial exploration of the peritoneum is recommended after port insertion during laparoscopic procedures, we
did not consider the limited exploratory as a separate procedure; it was included in the surgery time. Subjectively, the additional time required to explore the abdominal cavity was less than 1 minute, but argues against the chance of statistical type-2 statistical error affecting surgical time comparison. Not surprisingly, these operative times were both significantly shorter than the SILOVE-ECS group, which averaged about 70 minutes.

The much longer operating time in the SILOVE-ECS group was due to inherent technical difficulties associated with the procedure. First, each suture had to be passed via an inner cannula through the mesovarium, then grasped and passed back around the mesovarium before exteriorizing through the same inner cannula. Careful coordination between the surgeon and assistant was required to perform this safely. It was also important that half the length of the suture, be placed intracorporeally; the pedicle be brought to the inner cannula as the suture was passed and exteriorized to avoid sawing of the tissue during suture passage. Once the suture was passed, the extracorporeal modified-Roeder knot was formed while the assistant maintained intracorporeal visualization of the ovarian pedicle and suture. The knot pusher was then used to slide and tighten the knot for ligation of the ovarian and uterine tissues. This procedure was completed 4 times in each cat in the SILOVE-ECS group; it is the major reason as to why operating time was significantly longer in this group.

This is in contrast to the SILOVE-LS group in which ligation and division of the ovarian tissues is accomplished efficiently without the use of suture.\textsuperscript{18} The reason we included the SILOVE-ECS group in our study was to better evaluate the versatility of the SILS. The success with the modified-Roeder procedure offers support for use of the
SILS in this application and may also be helpful with other extracorporeal suture procedures, such as pancreatic or lymph node biopsy. Of course, careful attention to technique and the risk of bleeding should be considered prior to this application.

**Surgical Complications**

Although complications were more frequent in the SILOVE-ECS group compared to both SILOVE-LS and open-OVE groups, the procedure was considered to be safe, as alteration of the incision was not necessary to correct the observed complications. However, removal of the SILS port was required to complete the procedure in 3 cats. The ability to remove the port and to exteriorize the ovarian pedicle via the 20 mm celiotomy is interesting in that it demonstrates the port's versatility and potential for laparoscopic-assisted applications, such as laparoscopic-assisted gastrointestinal procedures.\(^6\)

Surgical complications were typical of those previously reported for laparoscopic ovariectomy.\(^1,3,5,7,8,10-12\) Mild hemorrhage was the most common complication and was easily controlled in the SILOVE-ECS group by exteriorizing the uterine horn through the celiotomy and by tying a second ligature. The one cat in the SILOVE-LS group that had mild bleeding was controlled with a second application of the LigaSure.

An unanticipated, but interesting observation was moderate (5-8mm) stretching of the original incision, which was seen in the SILOVE cats. This observation is not reported with SILS port use in other veterinary species. The tissue stretching did not alter the seal formed around the port and no CO2 leakage was appreciated. Additionally, after tissue recoil and closure there was no appreciable difference in the lengths of the closed incisions in either SILP or open groups. It is unknown if or how incisional stretching may have affected surgery time and or postoperative pain, but it
may be another potential benefit in laparoscopic-assisted procedures where exteriorization of bowel and other organs is indicated.\textsuperscript{6}

\section*{Pain Evaluation}

Significant differences in preoperative and postoperative pain using the VAS, SDS and incisional palpation with VFF for up to 4 hours following surgery were not seen between groups, with a single exception at the 4-hour postoperative time point in which cats in the SILOVE-ECS group were more painful than cats in the SILOVE-LS group. The overall similarity in postoperative pain scores between groups was not unexpected given that incision length and the amount of soft tissue resection was kept consistent between groups. However, there were distinct differences between the three procedures, which may have impacted the level of postoperative discomfort. First, there is speculation that insufflation of the abdomen with CO\textsubscript{2} gas may play a role in discomfort for a number of possible reasons including elevated intra-abdominal pressure, which may stretch the phrenic nerves, peritoneal acidosis, and desiccation of the peritoneal surface due to the lack of humidification of the insufflated peritoneal CO\textsubscript{2} gas.\textsuperscript{21,62-64} Further, stretching of the incision, which was seen in the SILOVE cats, may have caused increased discomfort compared to the open OVE cats which did not experience incisional stretching. In human patients, single-incision techniques tend to be associated with similar postoperative discomfort compared to traditional multiport procedures. Thus, incisional stretching noted here may not have a significant effect on postoperative pain, but this is not known.

Another consideration is the method of ligation of the ovarian pedicle, which was different between groups. It is possible that strumming or tearing of the suspensory ligament from the peritoneum as was performed in our open OVE cats, may lead to
more postoperative pain versus ligation via bipolar cautery or scissors. Again, no significant differences were seen between groups and other differences also existed, which makes answering this question outside the scope of the study.

Finally, at the 4-hour postoperative time point, cats in the SILOVE-LS group were found to have lower pain scores via the VAS than were cats in the SILOVE-ECS group. Whether or not this was an isolated finding or the beginning of a trend is unknown. It is possible that the longer operative time in the SILOVE-ECS group played a role; conversely, statistical error may be to blame.

**Limitations**

A number of limitations must be acknowledged when interpreting results of the present study. First, sample size was relatively small, which may have precluded detection of significant differences between groups. For example, cats undergoing open OVE had an average surgery time of 17 minutes while cats in the SILOVE-LS group had an average surgery time of 25 minutes. While this difference was not statistically important, it is possible that with the addition of more cases, statistical significance may have been reached. Second, the research setting is a more controlled environment and may not reflect the conditions of the clinical setting, making extrapolation of some results difficult. While all pain scales used in the current study have been validated in small animals, there are inherent limitations with interpreting animal behaviors as painful and this is always done with caution. Thirdly, two pain scorers were used. While no statistically significant differences were seen between the two scorers this may inherently add variability to the data. Additionally, while we did not include traditional two port laparoscopic ovariectomy in our study, this could be considered as an area for future investigation.
Summary

In conclusion, SILOVE using a SILS is feasible, versatile, and safe in cats. Use of a LigaSure for ovarian pedicle ligation was faster and associated with fewer complications than the extracorporeal suture method, but not different that open OVE. Single-incision laparoscopic ovariectomy using a SILS alone appears to offer few advantages over traditional open ovariectomy, but may be beneficial in minimizing tissue trauma in more advanced laparoscopic and laparoscopic-assisted procedures such as laparoscopic-assisted gastrointestinal surgery when compared to traditional celiotomy approaches.
Figure 3-1. Intra-operative image of the uterine horn and ovarian pedicle being elevated using the laparoscopic Babcock forceps. The inset shows the port and instruments (photo courtesy of author).
Figure 3-2. Illustration depicting the tying of a Meltzer knot through the SILS™ cannulas with instrumentation in place (Illustration courtesy of C. Moats).
Figure 3-3. Box and Whisker plot illustrating surgery time by group: SILOVE-LS, open-OVE, and SILOVE-ECS. The box represents the interquartile range, the center line the median, and the whiskers the minimum and maximum values. Different letters are present where significant differences exist ($P < 0.05$).
Figure 3-4. Visual analogue pain scores by group: open-OVE, SILOVE-LS, and SILOVE-ECS. Different letters are present where significant differences exist ($P < 0.05$).
Figure 3-5. Simple descriptive pain scores by group: open-OVE, SILOVE-LS, and SILOVE-ECS. Different letters are present where significant differences exist ($P < 0.05$).
Figure 3-6. Von Frey Filament palpation scores by group: open-OVE, SILOVE-LS, and SILOVE-ECS. Different letters are present where significant differences exist ($P < 0.05$).
Chapter 1 provided an historical overview of the history of laparoscopy in humans and veterinary medicine including the development of instrumentation and equipment essential to performing these techniques. Recent advances in minimally invasive surgical equipment and instrumentation have paved the way for wide acceptance of laparoscopic procedures in both human and veterinary patients. The benefits of laparoscopic surgery including better visualization, reduction of pain, faster recovery, and lower infection rate are well documented. Client demand has been instrumental in establishing laparoscopy as an accepted modality for performing abdominal surgical procedures in veterinary practice. Literature fully supporting the justification and establishing the efficacy of laparoscopic procedures in cats is still lacking, however, reported laparoscopic and laparoscopic-assisted procedures in cats include ovariectomy, ovariohysterectomy, liver biopsy, pancreatic biopsy, enterotomy and intestinal resection and anastomosis. None of these studies report using the SILS port for laparoscopic or laparoscopic assisted surgeries in cats.

While the re-use of SUD’s in veterinary medicine is widely accepted in veterinary practice, the ability to effectively decontaminate the SILS™ port was unknown. Unlike many of the re-useable SUDS that are composed of hard plastics and metals, the body of the SILS™ port is proprietary, semi-porous porous foam. In Chapter 2, we evaluated the SILS™ ports soiled with bacterial species representative of those commonly encountered during abdominal surgery and also been previously implicated in post-operative infections. Our culture results suggest that decontamination and sterilization
was effective in reducing the number of bacteria on this SUD and may support reuse of the port in animals.

In vivo evaluation of the port was performed in Chapter 3. We recruited twenty-four healthy, intact female cats for the study. Cats were randomly divided into one of three surgical groups: SILOVE-LS (n=8), SILOVE-ECS (n=8), and open-OVE (n=8). Surgery time, intra and post-operative complications, and post-operative pain were compared between groups. Surgery time was significantly longer and complications were more frequent in the SILOVE-ECS when compared to the SILOVE-LS and open-OVE groups. Post-operative pain was not different between the three groups. Incidentally, incisions in the two SILS port groups revealed stretching immediately after port removal. This stretching of the incision did not affect any of the outcome parameters measured in these cats. Surgery was safely performed in all cats without any major complications or mortality. Cats were returned to rescue groups and adopted at the completion of the evaluation.

Based on the results of this study we conclude that the SILS™ port can be safely used for laparoscopic ovarietomy and is clinically applicable for other laparoscopic and laparoscopic assisted surgery in cats. Additional in vitro and clinical testing is warranted to identify potential complications, such as infection in animals or port malfunction, associated with reuse of this device before routine reuse of the port can be recommended.
LIST OF REFERENCES


Bozzini P: Der Lichtleiter oder die Beschreibung einer einfachen Vorrichtung innerer Höhlen und Zwischenräume des lebenden animalischen Körpers. Verlag des landes Industrie Comptoir, Weimar, 1807.

Desormeaux AJ: The Endoscope, and Its Application to the Diagnosis and Treatment of Affections of the Genito-urinary Passages: Lessons Given at Necker Hospital, R. Fergus' sons, printers, 1867.


54 Wilson DM, Monnet E: The use of single incision laparoscopic surgery (SILS Port) in dogs: Description of the technique and initial impressions after 22 consecutive cases. Proc 9th Annual Scientific Meeting of the Veterinary Endoscopy Society, Park City, Utah, p 22, 2012


BIOGRAPHICAL SKETCH

MAJ "Jay" Coisman grew up on a small farm in upstate New York. He graduated from the University of Central Florida in 1999 with a bachelor’s degree in biology and a minor in microbiology and molecular biology. In 2004, he earned a Doctorate of Veterinary Medicine from the University of Florida.

MAJ Coisman first joined the military in 1989 when he went through Marine Corps boot camp at Parris Island, SC. As a marine, he was stationed in Twenty Nine Palms, CA; Fort Gordon, GA; Camp Lejeune, NC; and Okinawa Japan. In November 1993 MAJ Coisman left active duty and entered the Marine Corps Reserve. While most of his reserve duties revolved around Special Operations Command, McDill AFB, Tampa, FL, he performed several periods of active duty in support of various other commands. From 2001-2004 MAJ Coisman was on a Health Professions Scholarship while attending the University of Florida, College of Veterinary Medicine. He then returned to active Duty in June of 2004 as a clinical intern at the Military Working Dog Center at Lackland AFB in San Antonio, Texas. He has since served as Officer in Charge of the Moody Air Force Base Veterinary Treatment Facility in Valdosta, Georgia and as Chief, Fort Shafter Branch Veterinary Services, Fort Shafter Hawaii. In July 2010 the Army selected MAJ Coisman to return to the University of Florida, College of Veterinary Medicine to complete a residency in small animal surgery. He is currently finishing his last year of the residency.

MAJ Coisman is married to the former Ms. Natalie Carse of Chagrin Falls, Ohio. They have three daughters, Olivia, Kira, Adyson and a son, Sawyer.