Comparison of Postoperative Pain Following Ovariohysterectomy via Harmonic Scalpel-Assisted Laparoscopy versus Traditional Celiotomy in Dogs

Robert B. Hancock

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Otto I Lanz, Chair

Richard V. Broadstone

Don R. Waldron

Robert B. Duncan Jr.

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By
Robert B. Hancock
Department Of Small Animal Clinical Science

ABSTRACT

The objective of this study was to compare the effects of postoperative pain following ovariohysterectomy via harmonic scalpel assisted laparoscopy (HALO) and traditional ovariohysterectomy (OVH) in dogs. The study was designed as a randomized, blinded, prospective study. Sixteen, purpose-bred, intact female, Beagle dogs were used to complete the study. Dogs were placed into two groups. Group 1 included (8 dogs) that underwent ovariohysterectomy via HALO. Group 2 included (8 dogs) that underwent ovariohysterectomy via traditional OVH. Physiologic data, abdominal nociceptive threshold scores, and University of Melbourne pain scores (UMPS) were recorded at 2, 6, 12, 24, 48, and 72 hours following surgery. Blood samples for plasma cortisol, glucose, and creatine phosphokinase (CPK) were taken at the time of the incision and 2, 6, 12, 24, 48, and 72 hours following surgery.

No significant surgical complications were encountered in either group. The HALO mean surgical time was significantly longer (55.7 minutes) than the traditional OVH (31.7 minutes). No significant differences were observed between the two groups for the pain measures of heart rate, respiratory rate, temperature, CPK, and glucose. The OVH group had significantly higher mean plasma cortisol levels at hour 2 following surgery than the HALO group (P=0.0001). The mean UMPS were significantly higher in the OVH group than the HALO group at all postoperative times (P=0.0001). Mean nociceptive threshold measurements revealed significantly higher tolerated palpation pressures in the HALO than the OVH group at all postoperative times, except hour 72 (P=0.0002).

Dogs in this study appeared to be less painful with HALO procedures versus traditional OVH. The harmonic scalpel coagulated ovarian and uterine vessels completely with minimal collateral damage to surrounding tissues. The clinical relevance of this study demonstrates that harmonic scalpel-assisted laparoscopic ovariohysterectomy is a safe alternative to traditional OVH and offers a minimally invasive and less painful method of surgery.

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LIST OF ABBREVIATIONS

HALO: Harmonic Scalpel Assisted Laparoscopic Ovariohysterectomy

OVH: Traditional Celiotomy Ovariohysterectomy

CPK: Creatine Phosphokinase

UMPS: University Of Melbourne Pain Scale

MIS: Minimally Invasive Surgery

VAS: Visual Analogue Scale

INTRODUCTION

A. FUNDAMENTALS OF MINIMALLY INVASIVE SURGERY

Laparoscopic techniques have become increasingly more important in veterinary medicine in the last 10 years. In human medicine, laparoscopy has become the gold standard of many abdominal procedures.[1-4] MIS in humans has been shown to have numerous advantages over traditional celiotomy techniques including: decreased postoperative stress and pain, faster recovery periods, decreased hospital stays, improved cosmesis, and improved visualization of abdominal organs.[1,5] However, some veterinary surgeons have avoided this modality due to inherent limitations of minimally invasive surgery, including cost of equipment, procedural learning curve, and increased time of the procedure compared to traditional surgical techniques.[6]

The equipment required for laparoscopy consists of a laparoscope, light source, insufflator, and video imaging capabilities. Laparoscopes come in a variety of sizes ranging from 2.7mm to 10mm and angles ranging from 0 to 70 degrees.[7,8] The obliquity of the angled telescopes gives the ability to see around corners, especially when working in a compact area. It is common in veterinary medicine to use a 10-mm scope with a 30 degree angle.[7] Light is transmitted to the telescope via fiber optic cable from a remote light source. Xenon (300-watt) and halogen (150-watt) are the most commonly used light sources.[6] The magnification of the telescope and light source allows the surgeon to see details and pathology not observable to the naked eye.[8]

Insufflation is performed using carbon dioxide, nitrous oxide, or room air. Air is insufflated into the abdominal cavity via a Veress needle or retractable camera portal. Abdominal pressure should be insufflated to 10-12 mmHg.[8] Pressures higher than 15mmHg can result in decreased venous return to the heart and impair ventilation.[7] A complication of laparoscopic surgery is the possibility of air embolism. Carbon dioxide is the preferred gas for insufflation due to its high solubility and rapid absorption. The risk for emboli increases when insufflation occurs in a hollow viscous and when room air is used, due to it's poor solubility.[7]

Video capabilities are directed around the camera and its video output system. Charge-coupled semiconductor cameras, also called "chip cameras", have differing levels of resolution based upon the number of chips provided internally. Three-chip cameras operate with 1 chip for each of the primary colors and have the best resolution.[6] Cameras with high resolution output require less light source for image detail. Video capture systems can allow for procedural documentation of pathology, photos, and facilitates teaching. Most laparoscopic equipment setups place the video tower in direct view of the camera operator to reduce operator fatigue in surgery.[9]

It has been well documented in humans that laparoscopic surgery results in less pain and morbidity, as well as, shorter hospital stays when compared to open surgical techniques.[1,5,10] Laparoscopic surgery is presumably less painful due to smaller incisional size, decreased muscular trauma, and earlier return to function.[11] Studies using canine models to perfect human techniques, as well as limited published veterinary case reports and data based publications have described the feasibility, safety, and efficacy of laparoscopic surgery for gastropexy[12], ovariohysterectomy[9,13-15], nephrectomy[16], proximal gastric vagotomy[17], Biliroth II[18], cholecystectomy[19], prostatectomy[20], cryptorchidectomy[21], small intestinal anastomosis, and colectomy. [22]

B. The Harmonic Scalpel

The harmonic scalpel has been used for hemostasis in hysterectomy and other abdominal procedures for humans,[5,23] ovariohysterectomy procedures in horses,[24] and dogs[9,13]. The harmonic scalpels' design was created to be used through laparoscopic and thorascopic instrument portals.[9,24] This scalpel is able to cut, coagulate, and seal vessels simultaneously at much lower temperatures (50-100ºC) than electrosurgery or laser surgery (150-400ºC).[25] The ability to seal vessels at low temperatures with a protein coagulum is referred to as coaptive coagulation. Because of the lower temperatures, less collateral tissue damage is present when compared to monopolar and bipolar cautery.[15] The risk of stray electricity and electrical burn is eliminated with the harmonic scalpel. Lasers and cautery units vaporize cells via rapid heating and cellular explosion, resulting in eschar and smoke formation. [25,26] Smoke decreases visualization while in a hollow cavity and slows procedural times. The harmonic scalpel produces no smoke, thus allowing rapid coagulation with excellent visualization of the field. [24]

The harmonic scalpel consists of an electrical generator, handpiece, an active and inactive blade system, and a foot pedal. Electrical energy is produced via an external generator and is then converted to ultrasonic energy by means of a piezoelectric, ceramic transducer located within the handpiece. This small piezoelectric crystal vibrates at approximately 55,000 hertz, causing longitudinal movement against the inactive part of the blade.[23,24] Mechanical energy from the oscillating blades results in energy transfer to tissue proteins, leading to protein denaturization and the formation of a sticky protein coagulum. This protein coagulum is capable of sealing vessels as large as 5-mm in size.[25] Harmonic scalpel technology also allows for dissection of tissue planes using force-directed energy. Oscillation of the active blade tip results in tissue cavitation, which creates pressure differentials at the shear ends of the instrument. These pressure differentials lead to cellular vaporization and facilitates tissue dissection.[24,25]

C) Laparoscopic Ovariohysterectomy

Anatomically, the ovaries are approximately 1-3cm in length, as determined by the body size of the dog. They are located along the dorsolateral wall of the abdomen, just distal to the caudal pole of the kidney.[27] The mesovarium and mesometrium attach the ovary and uterine body to the body wall. The suspensory ligament runs to the level of the 13th rib from the cranial pole of the ovary. The ovarian blood supply is via the ovarian artery, a direct branch of the aorta. The left ovarian vein empties into the left renal vein, while the right ovarian vein empties directly into the caudal vena cava. The uterine body and horns are supplied by the ovarian artery and veins, as well as the uterine artery and vein, a branch of the internal pudendal.[27]

Numerous uterine medical diseases have been reported in intact dogs and cats. This is one reason why elective ovariohysterectomy procedures have been recommended for non breeding animals.[27-29] Follicular cysts have been reported in 16% of intact dogs and can result in prolonged estrus, cystic mammary hyperplasia, and genital fibroleiomyomas.[27] Ovarian and uterine neoplasia are uncommon in dogs, but can account for 0.4-1.2 % of canine neoplasms.[27] One of the most serious and potentially life threatening diseases of the intact female dog is pyometra. Pyometra is a result of cystic endometrial hyperplasia, which is caused by exogenous progesterone secretion. The end result of this disease is a pus filled, infected uterus, glomerulonephritis, and possible septicemia.[27] The pyometra complex is preventable with ovariohysterectomy procedures. OVH has also been shown to reduce the incidence of mammary cancer in dogs. Dogs that underwent ovariohysterectomy prior to their first heat cycle decreased the incidence of mammary tumors to less than 0.5% versus 26% incidence after two heat cycles.[27-29]

Traditional ovariohysterectomy has been associated with numerous complications.[27,29,30] Hemorrhage from the ovarian pedicle can be divided into intraoperative and postoperative bleeding. Erosion of the vessels occluded by ligatures has been reported 4-16 days postoperatively.[27] Uterine stump pyometra and recurrent estrus can be the result of poor visualization of ovarian tissue and incomplete removal of ovarian tissue.[29] Fistulous tracts have been reported as result of an inflammatory reaction to the suture material. These tracts usually form in the flank region and are the result of nonabsorbable suture material (eg. silk or linen).[29,30] Incisional dehiscence is a risk in any celiotomy procedure and may result in herniation of abdominal viscera.[29,30] Pain associated with traditional celiotomy is a growing concern for this common elective procedure. Much research has been directed at studying the effects of pain in animals treated by traditional ovariohysterectomy.[9,14,28,31-33]

Ovariohysterectomy is the most common elective surgical procedure performed for small animal sterilization in the United States.[27] It is well documented that traditional ovariohysterectomy procedures inflict pain and morbidity in veterinary patients as a result of tissue trauma, organ manipulation, and inflammation.[28,31,34] Pet owners have become increasingly concerned about postoperative pain and morbidity associated with open abdominal procedures. The result of these concerns has lead to an increased demand for minimally invasive surgical techniques from the public.

Pain control, although only one of the beneficial aspects of MIS, is a crucial factor for patient treatment in veterinary surgical patients. Laparoscopic ovariohysterectomy has been described in veterinary medicine.[6,7,9,14,15,35] A study by Van Goethem, et al. evaluated laparoscopic ovariectomy in 103 dogs using either monopolar or bipolar cautery.[15] The authors of this study concluded that laparoscopic ovariectomy performed with bipolar cautery decreased ovariectomy operative time, decreased postoperative hemorrhage, and made exteriorization of the ovaries much easier.[15] A second, more recent study, demonstrated decreased pain in laparoscopic ovariohysterectomy procedures, in which the ovarian pedicle ligations were performed with intracoporeal wire ligatures and bipolar cautery .[14] However, the authors of this study concluded that while laparoscopic ovariohysterectomy could be performed successfully in dogs greater than 10kg, a significantly higher complication rate and surgical time was found in the laparoscopic group. The authors of this study describe the difficulties encountered in working with intracoporeal wire ligatures and bipolar cautery.[14] A third study, reported the technique of laparoscopic OVH in 9 dogs treated with the harmonic scalpel.[9] The authors of this study reported median surgical times of 60 minutes, but complications were minimal.[9] All of these studies reported longer surgical times than traditional OVH, however the complication rates were similar to reported OVH complications. [9,14,15,29,30]

D) Pain Physiology and Assessment in Small Animals

Nociceptive processing of painful stimuli occurs through the process of transduction, transmission, and modulation within the brain.[36] A painful stimulus in the periphery transports that signal through the primary afferent neuron to the level of the dorsal horn of the spinal cord. From the spinal cord, a second order neuron, typically located in the spinothalamic tract, transmits the signal to the level of the thalmus. From the thalamus, a tertiary neuron relays the signal to the cerebral cortex, where perception of the pain is realized.[37,38] A similar system then responds through transmission to the efferent peripheral nerves to create a reaction to the stimulus.

Nociceptors are typically classified into the neurologic nomenclature as two categories of fibers. The A-fiber receptors are often referred to as “first pain” receptors. These fibers are responsible for the stinging or pricking sensation that occurs when a noxious stimulus in encountered. These A-mechanoheat receptors relay to medium diameter, thinly myelinated A-δ primary afferent neurons, which have rapid conduction velocities between 2.5-30m/second. The C-Fiber mechanoheat receptors are often referred to as “second pain” fibers.[37] These fibers generate a deep pain or burning sensation after stimulation. The C-mechanoreceptors relay signals to small diameter, unmyelinated C-fibers, reducing conduction velocities to less than 2.5m/sec.[36]

When signals reach the dorsal horn of the spinal cord through the dorsal root ganglion, most impulses synapse in the gray matter area of lamina I or II. The neurons then synapse with inhibitory or excitatory neurons, segmental reflex neurons, and projection neurons.[36,37] The projection neurons are most responsible for the transmission of noxious stimuli from Aδ-fibers and C-fibers to the thalamus and cerebral cortex. These projection neurons are transmitted through the spinothalamic tract to the thalamus where the signal is further modulated and perceived.[36,37,39-41]

Painful stimuli can be acute or chronic in nature. Acutely repetitive, painful stimuli can lower the nociceptors threshold, which results in a enhanced response to further stimulation[36] This occurs through a process of sensitization. If cells are damaged the release of cytokines, histamine, nitric oxide, prostaglandins, bradykinin, substance P, inflammatory cells, mast cells, and neurokinin A, all have direct effects on excitability of these fibers.[36] When these mediators work synergistically together, the end result is lowered cell potentials and enhanced neural responses, leading to hyperalgesic states. However, these receptors can also become fatigued after chronic stimulation and decrease the intensity of pain.[36] In these cases, the neural response will undergo habituation, where those sensory fibers lead to a diminished response due to chronic or repeated stimulus. Certain analgesics can be useful in surgical patients to prevent "wind up" of painful stimuli.[36,42,43] By decreasing the intensity of the initial noxious event, the sensitivity of the neurons involved become decreased.[41] It is recognized in humans, that patients can undergo different categories of pathologic pain. These are recognized as causalgia, a dull or burning pain. Also recognized is allodynia, which refers to pain produced from a normally unpainful stimulus. Hyperalgesia is considered an exaggerated pain response or a highly sensitive patient. [36,41,44]

Uncontrolled pain in veterinary patients can result in complications, including cardiovascular stress, immunosuppression, anorexia, and cachexia.[37,45] Because of the deleterious effects of pain on patients, much research has been focused on different types of noxious stimuli, the systemic consequences to the body, and the neural pathways involved in the transmission of pain.[37] Many of the methods used in evaluating veterinary patients have been gleaned from similar assessment methods used in human pediatrics.[46,47] Physiologic (eg. heart rate, respiratory rate, temperature) and biochemical measures (eg. plasma cortisol, glucose) are commonly used as objective, indirect measures of pain.[31,48,49] However, the results of many veterinary studies have shown inconsistent results when these measures are used alone to evaluate pain.

1) Physiologic Assessment of Pain

Physiologic parameters such as heart rate, respiratory rate, temperature, arterial blood pressure, and pupil dilation have all been used in the assessment of noxious stimuli. These parameters often become less useful in animals that are experiencing longer periods of conscious pain. Initially, the body responds to the painful stimulus with increases in many of the physiologic parameters.[37] But as the cardiovascular system equilibrates, these dynamic factors may not remain constant, giving a poor indication of pain.[37,50] By themselves, physiologic parameters are often not specific enough to differentiate anxiety, pain, and fear, all which can affect the cardiovascular system. Also, the cardiovascular effects of pain medication (specifically narcotics) may depress many physiologic responses even when analgesia may not be sufficient.[41,42,51] Two veterinary studies revealed a poor correlation between physiologic parameters and behavioral scoring using a numerical rating scale when assessing postoperative patients. [31,52,53] A poor correlation has also been observed between nociceptive scores and physiologic scores in veterinary patients.[53,54]

Nociceptive threshold readings have been used in previous animal pain studies.[53,54] Nociception is the transduction, conduction, and central nervous system processing of nerve signals generated by a nociceptor. The stimulus is derived from thermal, chemical, or mechanical stimuli (eg. a pinprick). The nervous impulse then travels to the dorsal horn of the spinal cord, traverses the spinothalmic tract to the thalamus and cortex, where the pain sensation is perceived.[36] The use of algometric scoring allows for more sensitive and objective measurements of pain in animals than categorical measures.[53] Nociceptive scoring allows a number to be assigned to a specific pressure value. In most cases, the pressure is recorded when the animal makes a conscious reaction to a stimulus. However, in some cases, this may be subtle such as a change in posture or behavior.[50]

2) Biochemical Assessment of Pain

Biochemical markers are commonly used as markers of pain and stress in veterinary medicine. Plasma cortisol has been used in veterinary research as a biochemical marker of stress and pain.[49,55] In one study using ovariohysterectomy procedures, physiologic parameters in cats did not correlate with increases in cortisol. However, cortisol levels were significantly higher in operated animals treated with butorphanol postoperatively than control cats that did not receive butorphanol.[55] Cats that had longer anesthetic procedures were also found to have higher cortisol concentrations in that study.[55] Another study, demonstrated significantly higher cortisol levels for 24 hours postoperatively in dogs that had ovariohysterectomy procedures compared to dogs that were only anesthetized. One difficulty in interpretation of cortisol is differentiating painful responses from stress. However, some consider stress and pain to be interrelated.[55] Not unlike physiologic parameters, cortisol would likely be best used as a marker for pain in conjunction with other assessment techniques.

Glucose has been used as a marker for pain and stress in animals and neonates.[49,56] Catecholamines released during stressful events lead to increased glucose levels in an attempt to cope with increasing metabolic demands. The body's response to epinephrine and endorphins, is gluconeogenesis and glycogenolysis.[36] In the liver, glycogen stores are broken down and fatty acids and proteins are converted to glucose for energy. The net effect of chronic pain is strong demand on glucose stores that leads to fatigue, immunosuppression, and cachexia.[36,56,57] Glucose is inconsistent in its reliability as a marker of stress and does not always correlate with other methods of pain assessment. [11,49]

Creatine Phosphokinase is well known as a marker of muscle damage in veterinary medicine. In one study, CPK values were markedly higher in sled dogs post racing compared to pre-racing levels. The increased CPK was directly correlated to the degree of muscle damage incurred while racing.[58] CPK has also been found to increase after anesthesia with halothane gas, thus potentially producing false positive increases if used as a diagnostic parameter post anesthesia.[59] However, CPK is not traditionally used as a marker of pain in animals.[60] A veterinary report demonstrated increased CPK from preoperative levels in laparoscopic ovariohysterectomy procedures, however this study did not show CPK as a predictable indicator of pain.[9] More recently, a study in human neonates used CPK as a parameter for pain following laparoscopic fundoplications and extramucosal pyloromyotomy procedures.[61] Muscle trauma can be related to inflammation and pain, and CPK may prove to be a useful marker of pain in veterinary patients as well.[58]

3) Behavioral Assessment of Pain

Numerous pain assessment scoring systems have been developed in veterinary medicine, including the visual analogue scale, numerical rating scales, simple descriptive scales, and behavioral and physiologic response scales.[37,46,50,62,63] Pain assessment in human pediatrics and veterinary medicine is often a daunting task. Objective and subjective pain scoring systems have been used in both of these medical services.[37,40,46,62] It is generally well accepted that pain assessment in animals is best performed with multiple assessment techniques, so as not to weigh any one subjective or objective measurement too heavily.[37,45] Unfortunately, as with pediatric patients, none of the scoring systems are all inclusive. Sensitivity of certain parameters and minute changes in behavior may be overlooked with improper use of these systems. As a result, no behavioral gold standard has been identified for the evaluation of pain in veterinary medicine. [45]

The visual analogue scale (VAS) is widely accepted as a sensitive behavioral assessment scale.[38,64,65] The VAS is a semi-objective scoring system in which the observer draws a vertical mark on a 100mm horizontal line. The line is marked as 100 (maximal pain) to 0 (minimal pain).[66] The mark recorded by the observer is made in response to how painful the subject is. This system is widely accepted by human medical hospitals, however it is more difficult to assess in pediatric subjects and animals. Variability between assessors remains a problem and it is mandatory that the assessor be trained in painful behaviors before the use of such a scale.[50]

Numerical rating scales and simple descriptive scales are also popular and easy to use behavioral assessment scales.[50,63,66] These systems are semi-objective scales in which painful behaviors are assigned numerical values, indicating severity. The potential inaccuracy of these systems is that they place bias on certain painful behaviors over others. Also, certain behaviors may not be included in the score, thus painful animals may go unnoticed or be underscored. These scales have been incriminated as being too insensitive in the postoperative period, especially when an animal is under the influence of analgesics. [50,63,66]

The University of Melbourne Pain Scale was developed in 1999 and was based on a modification of the Children's Hospital of Eastern Ontario Pain Scale, a scale that was developed for the monitoring of postoperative pain in young children. [46] This scale uses multiple descriptors in six categories and utilizes both behavioral and physiologic responses. This scoring system has been used to evaluate pain in animals and is believed to be more sensitive and specific than many simple descriptive or numerical scales.[46] The UMPS assigns weights to certain behaviors, thus eliminating some potential observer bias.[45] The UMPS scale is reported to have certain advantages over other behavioral pain scales. It uses multiple factors when evaluating a subject, which allows for increased sensitivity and specificity of the assessment. The UMPS scale relies on specific, well documented, animal behaviors thereby decreasing bias and limiting individual differences between assessors. Lastly, UMPS evaluates changes in behavior, adding additional sensitivity to the analysis.[46,50] Disadvantages of this scale include the inability to detect small changes in behavior, its' design for postoperative patients, and assessors must be familiar with painful behaviors.[50]

The use of laparoscopic procedures has proven to be less painful in human medicine.[3,4,23,26,61,67] The purpose of this study was to assess whether laparoscopic OVH is less painful than the traditional open celiotomy technique in dogs. The ovariohysterectomy procedure was chosen for this study because it is the most common elective surgical procedure performed in the United States.[27] The information derived from this study may be applicable to other laparoscopic procedures.

CHAPTER II: Comparison of Postoperative Pain Following Ovariohysterectomy via Harmonic Scalpel-Assisted Laparoscopy versus Traditional Celiotomy in Dog

A. Abstract

Objective: To compare the effects of postoperative pain following ovariohysterectomy via harmonic scalpel assisted laparoscopy (HALO) and traditional ovariohysterectomy (OVH) in dogs.

Study Design: A randomized, blinded, prospective study.

Sample Population: Sixteen, purpose-bred, intact female, Beagle dogs

Methods: Group 1 included (8 dogs) that underwent ovariohysterectomy via HALO. Group 2 included (8 dogs) that underwent ovariohysterectomy via traditional OVH. Physiologic data, abdominal nociceptive threshold scores, and University of Melbourne pain scores (UMPS) were recorded at 2, 6, 12, 24, 48, and 72 hours following surgery. Blood samples for plasma cortisol, glucose, and creatine phosphokinase (CPK) were taken at the time of the incision and 2, 6, 12, 24, 48, and 72 hours following surgery.

Results: No significant surgical complications were encountered in either group. The HALO mean surgical time was significantly longer (55.7 minutes) than the traditional OVH (31.7 minutes). No significant differences were observed between the two groups for the pain measures of heart rate, respiratory rate, temperature, CPK, and glucose. The OVH group had significantly higher mean plasma cortisol levels at hour 2 following surgery than the HALO group (P=0.0001). The mean UMPS were significantly higher in the OVH group than the HALO group at all postoperative times (P=0.0001). Mean nociceptive threshold measurements revealed significantly higher tolerated palpation

pressures in the HALO than the OVH group at all postoperative times, except hour 72 (P=0.0002).

Conclusions/Discussion: Dogs in this study appeared to be less painful with the HALO procedure versus traditional OVH. The harmonic scalpel coagulated ovarian and uterine vessels completely with minimal collateral damage to surrounding tissues.

Clinical Relevance: Harmonic scalpel-assisted laparoscopic ovariohysterectomy is a safe alternative to traditional OVH and offers a minimally invasive and less painful method of surgery.

B. Introduction

In human medicine, laparoscopy has been shown to have numerous advantages over traditional celiotomy techniques including: decreased postoperative stress and pain, faster recovery periods, decreased hospital stays, improved cosmesis, and improved visualization of abdominal organs.[1,5] However, some veterinary surgeons have avoided this modality due to inherent limitations of minimally invasive surgery, including cost of equipment, procedural learning curve, and increased time of the procedure compared to traditional surgical techniques.[6] It is expected that some degree of technical training and familiarization with laparoscopic surgery would be required to perform such procedures.

Pain control, although only one of the beneficial aspects of MIS, is an important factor for patient treatment in veterinary surgical patients. Uncontrolled pain in veterinary patients can result in complications, including cardiovascular stress, immunosuppression, anorexia, and cachexia.[37,45] These complications can also lead to economic concerns, as they are often associated with increased length of hospitalization. Veterinary surgeons are continually looking for more progressive, less painful ways to evaluate and treat disease in patients. The ovariohysterectomy procedure was chosen for this study, as it is a commonly performed in North America. However, other techniques, such as ovariectomy may be similarly approached using MIS.

Many of the methods used in evaluating veterinary patients for pain have been taken and accepted from similar assessment methods used in human pediatrics.[46,47] This is especially true when comparing neonates and animals. Both subjects are difficult to assess, due to the inability to communicate directly.[39] Physiologic (eg. heart rate, respiratory rate, temperature) and biochemical measures (eg. plasma cortisol, glucose) are commonly used as objective, indirect measures of pain.[31,48,49] However, the results of many veterinary studies have shown inconsistent results when these measures are used alone to evaluate pain.[53,55] We thought it important to include both objective and subjective measurements in order to increase the validity of the study. Behavioral assessment is most likely to be beneficial when used in conjunction with other pain assessment parameters.

The primary purpose of this study was to evaluate differences in pain in dogs undergoing ovariohysterectomy procedures performed with HALO or traditional OVH methods. Our evaluation of pain in each animal consisted of multiple objective and subjective measurements. The objective measurements included measured physiologic responses, biochemical responses, and nociceptive threshold measurements. Our subjective pain scores were derived from the University of Melbourne Pain Scoring system. The use of multi-modal pain measurement was attempted in an effort to add sensitivity and credibility to this randomized, prospective study. The hypothesis of this study states that HALO procedures would be less painful than traditional OVH procedures.

C. **Materials and Methods**

Sixteen, female, purpose-bred beagles were used for this study. The mean weight of the dogs was 11-kg, (range 10.1-12.2 kg). All animal use was approved by the Animal Care and Use Committee. All dogs had normal physical examination findings, complete blood count, biochemical profile, and urinalysis prior to entering the study. Dogs were randomly assigned to one of two groups. Group 1 consisted of (8) dogs that underwent an ovariohysterectomy procedure via HALO. Group 2 consisted of (8) dogs that underwent an ovariohysterectomy procedure via OVH. All dogs were then randomly assigned to 8 blocks. One dog from each of the two surgical groups was randomly placed into each of the 8 individual blocks. Two surgeons and one resident performed the HALO and OHE procedures. Each surgeon performed both surgeries in that block.

Each block of dogs (2) was housed in an individual room for a total period of 96 hours. The purpose of placing dogs in an individual room was to decrease the influence of environmental stressors on the behavioral changes following surgery. The same handler was used for all animal interactions and assessments over the four day period. The handler was blinded to treatment by the placement of an abdominal bandage on all dogs following completion of the surgery. An initial 24-hour acclimation period was used prior to the start of any surgical procedure. Handler-animal interaction was performed throughout the acclimation period, in order to familiarize each dog with the handler. During the acclimation period, physiologic parameters (heart rate, respiratory rate, and temperature), blood samples (plasma cortisol, glucose, and CPK), nociceptive threshold measurements, and a University of Melbourne Pain Score (UMPS) were taken. These parameters allowed the investigators to establish preoperative baseline objective and subjective data for each of the studied variables and address any differences between the two groups prior to surgery.

Anesthesia

One block, consisting of two dogs, underwent surgery each day of the study, for a total of 8 days. Each block of dogs was fasted 12 hours prior to surgery. The morning of surgery, each dog was premedicated with acepromazine (0.03mg/kg SQ) and morphine sulfate (0.25mg/kg SC). Dogs were then induced with thiopental (10mg/kg IV to effect) and each dog was maintained under general anesthesia with isofluorane and oxygen. Physiologic monitoring was conducted with an indirect blood pressure monitor (Ultrasonic Doppler Flow Detector Model 811-B, Parks Medical Electronic, Aloha, Oregon), esophageal stethoscope, electrocardiogram (Propaq 106, Protocol System Inc., Beaverton, Oregon), and pulse oximeter (Nellcor, N-20PA P/O, Protocol System Inc, Beaverton, Oregon). Anesthesia monitoring parameters were evaluated and recorded every 5 minutes until extubation.

Surgical operating time was defined in both groups as the beginning of the first incision and placement of the last skin suture. Following the first skin incision in both groups, blood samples were collected, via jugular catheter, for plasma cortisol, glucose, and creatine phosphokinase. Heart rate, respiratory rate, and temperature were recorded as well.

Each dog was placed in dorsal recumbency and the ventral abdomen was surgically clipped and aseptically prepared for surgery. A 16 gauge, 8-french, jugular catheter (Blitt Central Venous Catheter, Argon Medical, Athens TX) was placed in the right jugular vein to facilitate collection of the blood samples and to minimize stress associated with repeated blood collection. The catheter was bandaged and maintained for 72 hours following surgery.

HALO Procedure

The surgical procedure for the HALO is described. Each dog was placed in dorsal recumbency. Four quarter drapes were placed approximately 2-cm lateral to each row of mammary teats, at the xyphoid, and the pubis. The dog was then placed in a Trendelenburg[9] position to facilitate craniad displacement of the visceral contents. A small 1-cm skin incision was made at the level of the umbilicus to expose the linea alba.

The abdomen was entered through the linea alba with a surgical trocar (Endopath® 355S Surgical Trocar Ethicon Endo-Surgery, Cincinnati OH) using the Hasson[1,9] technique. Pneumoperitoneum was established with an insufflator (Electronic Insufflator Model 26012, Karl Storz,) to a pressure of 10-mmHg using carbon dioxide gas.[6,7] A 30° forward-oblique, 5-mm telescope (Hopkins II, Karl Storz, Charleston, MA) was placed through the umbilical port and used to identify the epigastric blood vessels in order to facilitate placement of the paramedian instrument ports under camera supervision (5X Hunt Trocar / 5-mm Pyramidal Tip, Apple Medical Corp, Bolton, MA). These ports were introduced 1-cm lateral to the mammary teat in the caudal abdomen, being sure to avoid the caudal superficial epigastric artery and vein. (Figure 1) Babcock forceps (Endopath – 5mm Babcock Forceps, Ethicon Endo-Surgery Inc, Cincinnati, OH) were placed through the right paramedian portal and clamped to the proper ligament of the right ovary. The harmonic scalpel (Ultracision LCS-C5, Ethicon Endo-Surgery Inc, Cincinnati, OH) was placed through the left paramedian port and the suspensory ligament, ovarian pedicle, and broad ligament of the uterus were transected and coagulated to the level of the uterine body. (Figure 2) Next, the uterine artery and vein were transected just proximal to the cervix, followed by the body of the uterus. The procedure was repeated in reverse order on the left side transecting the broad ligament of the uterus first, followed by the left suspensory ligament, and finally the ovarian pedicle. All areas of transection were inspected for hemorrhage after completion of the procedure. The camera was removed from the umbilical port and placed into the instrument port. Babcock forceps were then introduced through the umbilical port, clamped to the uterine body, and the entire reproductive tract was withdrawn through the umbilical port under direct camera visualization. Pressure was applied to each side of the abdominal wall to facilitate the escape of carbon dioxide gas prior to closure. The umbilical port was closed with 1 simple interrupted suture using 2-0 PDS. The subcutaneous tissue of the umbilical port was apposed with one, simple interrupted cruciate suture using 3-0 PDS, followed by a single simple interrupted cruciate skin suture with 3-0 nylon. The paramedian ports were apposed with one, simple interrupted cruciate suture using 3-0 PDS, followed by a single simple interrupted cruciate skin suture with 3-0 nylon.

Traditional Ovariohysterectomy Procedure

For the OVH procedure, each dog was placed in dorsal recumbency and four, quarter drapes were applied to the surgical field. A 6-cm, ventral midline incision, beginning 1-cm caudal to the umbilicus, was made through the skin and subcutaneous tissues to the level of the linea alba. The abdomen was opened with a number-10 scalpel blade on the linea alba along the entire length of the skin incision. The OVH procedure was performed using a modified three-clamp technique.[27] The linea alba was closed in a simple continuous pattern followed by routine closure of the subcutaneous tissues and skin.

Recovery Period

Following surgery, dogs were administered morphine sulfate (0.5mg/kg SC) at extubation. Each dog had a light abdominal bandage applied to blind the handler in the postoperative period as to which surgical procedure was performed. Each bandage was placed so that the thickness was the same in all animals. At each time interval (2, 6, 12, 24, 48, and 72 hours postoperatively) the physiologic parameters of heart rate, respiratory rate, and temperature, University of Melbourne Pain score, and abdominal nociceptive threshold measurements were recorded by the handler. Additionally, at each designated hour, blood samples for glucose, creatine phosphokinase, and plasma cortisol were collected via jugular catheters. Each dog was recovered on an external heating pad until sternal and maintaining a body temperature of 99° F. If at any time during the study dogs had UMPS scores greater than 10, additional pain medication (morphine sulphate 0.25mg/kg) was given subcutaneously.

Abdominal Palpation Scores

At each postoperative time interval, each dog underwent nociceptive threshold measurements via abdominal palpation. An algometer was created using a number-5, pediatric blood pressure cuff, three-way stopcock, and sphyngmomonometer. This algometer was used on all dogs throughout the study. A handheld tensiometer (Omega D670-44, Stanford, Ca) was used to test this system to ensure consistent and reliable results on pressure readings prior to the study. The cuff was preinflated to a pressure of 20 mmHg before each nociceptive test was performed. The cuff was applied over the abdominal bandage in the area of the umbilicus on each dog. Gentle pressure was applied to the cuff until a conscious reaction was observed from the animal. A dog that did not react was assigned a recording of 300 mmHg, the maximal pressure reading. The degree of abdominal discomfort was interpreted by the investigators to be inversely proportional to the pressure reading. Higher palpation pressures were correlated with less abdominal pain and vice versa.

Blood Sampling

Blood samples were collected via jugular catheter at each time interval. Plasma cortisol was collected into an EDTA tube and was centrifuged immediately for 15 minutes, at 15° Celsius. The plasma was removed via pipet and placed into two aliquots. The samples were placed in a freezer for storage at -80° Celsius. After completion of the study, all serum samples were sent to the Michigan State Diagnostic Lab for analysis. Blood samples for CPK and glucose were collected in a lithium-heparin tube and were centrifuged immediately for 15 minutes, at 15° Celsius. The serum was removed via pipet and each was placed into two aliquots. These samples were also placed in a freezer for storage at -80° Celsius. After completion of the study, glucose and CPK samples were submitted to Virginia Tech's Laboratory for analysis.

University of Melbourne Pain Score

All dogs were evaluated by means of the same handler with the University of Melbourne Pain score (UMPS).(Figure 3) [46] The handler was blinded to which procedure was performed by means of the abdominal bandage placed postoperatively. The pain scale included multiple descriptors including, physiologic and behavioral scoring parameters. More painful behaviors were assigned with increasingly higher scores. Maximal pain was given a score of 27 and no pain scored 0. The handler evaluated each dog at the designated postoperative times without disturbing the patient through an enclosed window. After observations were performed, the physiologic parameters were assessed on each dog.

Histopathology

All reproductive tracts from both groups were placed in 10% buffered neutral formalin and submitted for gross examination by a pathologist to ensure complete removal. Reproductive tracts from the HALO surgical group were examined histologically to assess changes produced by the harmonic scalpel on tissue interfaces. Specifically, tissue sections from the harmonic scalpel induced tissue interfaces were selected, processed routinely, embedded in paraffin sectioned at 5-microns, and stained with hematoxylin and eosin.

Statistical Analysis

The study was developed as a randomized, controlled, block design. Dogs were paired into blocks randomly as either HALO or OVH group members. SAS System software was used to perform all statistical analysis. Repeated analysis of variance was used to evaluate the data means of heart rate, respiratory rate, temperature, glucose, CPK, cortisol, nociceptive threshold measurements, and the UMPS scores for significant differences between the OVH and HALO surgical groups. Variable means and the corresponding 95% confidence intervals were recorded. Ad hoc analysis using analysis of variance was performed to detect any nuisance effects of surgical time on the OVH and HALO procedures on all of the measured variables. Analysis of variance was also performed to detect differences in length of surgical time between both the OVH and HALO groups. Significance for all analysis was set at $P \leq 0.05$.

D. Results

The physiologic measures of heart rate, respiratory rate and temperature revealed no significant difference between surgical groups at any postoperative times. Mean heart rates in the HALO group ranged from (113.5-126.3) beats per minute. Mean heart rates in the OVH group ranged from (111.1-135.9) beats per minute. No significant differences (P=0.07) were found in heart rate values between the HALO and OVH surgical groups (Figure 4). The mean respiratory rate in the HALO group ranged from (20.8-37.6) respirations per minute. The mean respiratory rate in the OVH group ranged from (19.6-39.6) respirations per minute. No significant difference (P=0.96) in respiratory rate was found between the HALO and OVH surgical group (Figure 5). The mean rectal temperature in the HALO group ranged from (98.7-101.9) degrees F. The mean temperature in the OVH group ranged from (98.6-102.0) degrees F. No significant difference (P=0.78) in rectal temperature was noted between the HALO and OVH surgical groups (Figure 6).

All preoperative plasma cortisol samples were not significantly different between surgical groups. The mean plasma cortisol levels in the HALO group, at each of the 7 time intervals, ranged from (64.6-226.5 nmol/l). The mean plasma cortisol level in the OVH group, at each of the 7 time intervals, ranged from (70.5-527.4 nmol/l). At hour 2, the mean OVH cortisol levels were 42.9% higher (527.4 nmol/l) than the mean HALO cortisol levels (226.5 nmol/l). There was a significant difference (P=0.0001) in cortisol levels between the 2 surgical groups at hour 2 postoperatively. There was no difference between the two surgical groups at any other time and cortisol levels returned to normal levels by hour 6 in both groups of dogs (Figure 7).

Preoperative creatine phosphokinase levels were within normal limits (54-430 U/L) for all but one dog (604). Dog 604, who underwent HALO, had a preoperative CPK value of (2269 U/L). The mean CPK in the HALO group, at each of the 7 time intervals, ranged from (126.4-652.3 U/L). The mean CPK in the OVH group, at each of the 7 time intervals, ranged from (184.5-559.3 U/L). At hours 6 and 12, both groups had significant increases in mean serum CPK values from preoperative values (P=0.0001), however there were no significant differences (P=0.77) in CPK values between the HALO and OVH surgical groups at any time (Figure 8).

All glucose values taken preoperatively were within normal limits as defined by serum glucose of (65-120 mg/dL). The mean glucose in the HALO group, at each of the 7 time intervals, ranged from (108.1-140.4 mg/dL). The mean glucose in the OVH group, at each of the 7 time intervals, ranged from (106.2-136.2 mg/dL). At hours 2 and 6, both groups had significant increases in mean serum glucose levels (P=0.0001) from preoperative measurements, however no significant differences (P=0.50) in glucose levels were seen between the HALO and OVH surgical groups at any time (Figure 9).

Abdominal palpation pressures were measured at (300mmHg) preoperatively in all dogs. The mean palpation pressure in the HALO group, at each of the 7 time intervals, ranged from (200-270 mmHg). The mean palpation pressures in the OVH group, at each of the 7 time intervals, ranged from (122.5-233.7 mmHg). Palpation pressures were significantly lower (P=0.0002) in the OVH group at all postoperative times, except at hour 72 (Figure 10).

The University of Melbourne pain score was scored by assigning a maximal pain score of 27 and a minimal score of 0. All dogs were given scores of 0 preoperatively. The mean UMPS score in the HALO group, at each of the 7 time intervals, ranged from (1.1-4.8). The mean UMPS in the OVH group, at each of the 7 time intervals, ranged from (3.2-7.5). There were significantly higher (P=0.0001) UMPS scores in the OVH group when compared to the HALO group at all times following surgery (Figure 11). No dogs in either group received a pain score of 10 or greater and no dog received additional pain medications at any time in the study.

No major surgical complications occurred in either of the treatment groups. Only 1 minor complication occurred in the HALO group. This complication involved a small <1-cm puncture of the spleen with Babcock forceps. The bleeding caused by splenic injury obscured visualization of the left ovary and lengthened the surgery time to 98 minutes, which was a significantly longer operating time than any of the other 7 HALO procedures. No intervention was required to resolve the hemorrhage. The OVH group had mild redness and swelling of the incisional site in all dogs, however no further treatment was required and all erythema resolved 72 hours following surgery. The mean surgical time for the OVH group was (31.7, +/- 24.7-38.7) minutes. The mean surgical time for the HALO group was (55.7, +/- 48.7-62.7) minutes. The OVH group had significantly lower (P=0.0001) surgical times than the HALO group. Surgical time had no significant nuisance effects on any of the measured objective or subjective pain variables at any recorded time.

All reproductive organs removed were examined by a board certified pathologist and all surgical margins were assessed as adequate. Excisional margins of ovarian pedicle and uterine body induced with the harmonic scalpel were described as having slight tissue rarefaction at the cut edge. The tissue at the excisional margin was hyperchromatic in a zone approximating 100-microns in thickness. Soft tissues containing large muscular veins and arteries within 300-microns of the excisional margin lacked any evidence of hemorrhage (Figure 12-a and 12-b).

E. <u>Discussion</u>

This study demonstrated decreased pain and stress in dogs having laparoscopic ovariohysterectomy as compared to traditional celiotomy.[10,11] This investigation attempted to include numerous pain measurements, both objective and subjective, in order to increase the sensitivity and decrease bias in our pain evaluations. Numerous pain assessment scoring systems have been developed in veterinary medicine, including the visual analogue scale, numerical rating scales, simple descriptive scales, and behavioral and physiologic response scales.[45] Unfortunately, as with pediatric human patients, none of these scoring systems are all inclusive. Sensitivity of certain parameters and minute changes in behavior may be overlooked with improper use of these systems.

The present study revealed higher UMPS scores at all times postoperatively in the OVH group when compared to the HALO group. These findings suggest that HALO is the less painful of the two operative procedures when evaluating both behavioral and physiologic responses. The UMPS system was used in a previous study that compared dogs that underwent ovariohysterectomy procedures and those that were only anesthetized.[46] In that study, UMPS revealed significantly higher pain scores in operated versus non-operated control animals. That study also revealed excellent agreement among two blinded assessors, demonstrating the repeatability of the UMPS scoring system.[46] Our study revealed similar results; however patients in the present study were assessed by only one, blinded observer. No attempt was made in our study to assess the repeatability of each score by multiple observers.

The OVH group had significantly higher mean cortisol levels at hour two following surgery when compared to the HALO group. There was no difference between the two surgical groups at any other time and cortisol levels returned to normal levels by hour six. Because all animals were treated with the same anesthesia protocol, anesthesia alone does not explain the difference in cortisol concentrations observed between the two groups at hour 2 postoperatively. Cortisol has been associated with increased plasma elevations in cats that have undergone long surgical procedures as compared to those with shorter procedures.[55] However, all dogs in the OVH group in our study had significantly lower surgical times than the HALO group. Thus, the elevated cortisol concentration may truly reflect an increased stress response in the OVH group at hour two following surgery.

In this study, glucose levels increased during hours two and six in both operated groups, and then returned to more normal levels at all other times. However, at no time during this study did glucose distinguish a more painful group from the other.

Creatine phosphokinase has been shown to elevate in response to anesthesia with halothane and propofol, as well as with intramuscular injections.[59,68] All premedications and pain medications were given either subcutaneously or intravenously in this study. Anesthesia was performed using thiopental and isofluorane, which was an identical protocol in all cases, thus eliminating anesthesia as a possible source of error in interpreting CPK values. Creatine phosphokinase was elevated above normal limits at 6, 12, and 24 hours postoperatively in both groups. However, CPK was unable to distinguish any difference in pain between the two surgical groups, thus supporting the findings of a similar study that CPK may not be a good indicator of pain in dogs.[9]

Our study found no significant differences between the HALO and OVH groups as related to the physiologic parameters of heart rate, respiratory rate, and temperature. These results are not surprising, as many of these parameters have been shown to be unreliable measurements of pain when used alone. However, physiologic parameters can provide useful information in assessing responses to noxious stimuli.[45] These physiologic pain parameters have been used in several pain assessment studies.[32,53] However, when used as the sole means of assessing pain, these variables may not correlate well with painful behaviors demonstrated by the patient.[53] Also, physiologic responses are affected by inherent cardiopulmonary reflexes and interactions with humans.[37] Thus, we conclude that while physiologic parameters can offer valuable information, they should be used in conjunction with other measurement and assessment techniques when assessing patient pain. This statement is confirmed by the results of other studies in which physiologic parameters did not often correlate with behavioral or algometric scoring.[49,53] One inherent limitation in this study was the inability to measure pain parameters without human interaction. The animals in this project were housed in kennels of two, in an attempt to limit environmental stresses. However, many of the animals became excited when the handler entered for measurement recordings. Differences in heart rate and respiratory rate may have been falsely affected and directly attributable to the excitement of human interaction. [51]

All abdominal palpations in this study were recorded as a pressure in mm/Hg when the dog made a conscious reaction to palpation. The same handler performed all palpations and recordings, to eliminate some bias in technique. In this study, the HALO group tolerated significantly higher palpation pressure at all times, except hour 72. Dogs in the OVH group were consistently more reactive and sensitive to lower palpation pressures than the HALO group, indicating more abdominal discomfort. This supports the findings of another recent study that found subjective abdominal palpation scores to be significantly more tolerated in laparoscopically treated ovariohysterectomy patients.[14] Another inherent limitation in this study was the abdominal bandage that was applied to blind the observer as to which operative procedure had been performed. Every attempt was made to place the bandage on each animal as consistently as possible, to avoid difference in the thickness of the bandage, however it is possible that variation in bandage application occurred.

A further limitation to our study is the difficulty in differentiating the effects on pain scores between surgical approach and the use of the harmonic scalpel. One surgical variable, the difference in surgical approach, (laparoscopic versus abdominal incision) has intuitive and measurable influences on pain scores. The laparoscopic group had smaller incisions and less soft tissue injury than the traditional abdominal incision, thus would be expected to have lower pain scores. The second surgical variable however, concerns the effects of the harmonic scaplel versus suture ligation on ovarian pedicles. In this study, the harmonic scalpel was used as a hemostatic and excisional instrument to perform HALO, but was not intended to be used as a variable to measure differences in pain. Thus, the conclusions of this study cannot differentiate between harmonic scalpel hemostasis and ovarian pedicle ligation influences on pain. However, the aim of this study was to differentiate a less painful laparoscopic surgical group from the traditional ovariohysterctomy group and the results clearly show HALO as the less painful technique.

Laparoscopic surgery requires experience with both the equipment and surgical fundamentals of minimally invasive surgery to maximize efficiency. Laparoscopy can create some difficulties for the inexperienced surgeon, due to the lack of depth perception, decreased tactile ability, and difficulty in operating in a 2-diminsional surgical field. Lack of minimally invasive surgical skills can lead to increased operating times initially. The mean surgical time for the HALO group in this study was 55 minutes, with a range of (25-98 minutes). HALO surgical times were significantly longer than OVH surgical times.

There were two surgeons and one resident involved in the eight laparoscopic procedures performed. All three surgeons had varying degrees of experience and training with laparoscopic surgery. The duration of the procedure appeared to decrease in dogs performed later in the study, as more experience was gained by the surgeons. Because of the varying differences in expertise, we thought it important to demonstrate that surgical time would not influence the pain variables recorded, as more experienced surgeons had shorter operating times. When analyzed, there was no significant nuisance effect of surgical time on any of the measured pain variables at any time in this study.

The laparoscopic technique described here was perfected previously in a pilot study. Mean surgical time in that study was (60 minutes), with a range of (35-100 minutes).[9] A recent study of laparoscopic ovariohysterectomy reported higher mean operating times of (120 minutes), with a range of (47-175) minutes. However, the authors of the previous study used laparoscopically placed, 4-0 metric, intracoporeal wire ligatures and bipolar cautery, which may have been more difficult to use for hemostasis in comparison to use of the harmonic scalpel.[14] Another previous study, described laparoscopic ovariectomy, with a mean surgical times of 47 minutes.[15] However, the latter study performed only ovariectomy procedures, a more common surgical procedure in Europe than in the United States. The uterine horns and body were not surgically removed in the ovariectomy study, which likely reduced surgical time.

The harmonic scalpel allows for faster operating times by permitting easier control of hemostasis than ligation techniques. Laparoscopic intracoporeal sutures can be difficult to handle and often require substantial training and practice. Visualization during laparoscopy can also be impaired by smoke when using bipolar cautery units within the abdomen. These affects are more profound in smaller sized animals. The harmonic scalpel produces no smoke and minimal vapor. The harmonic device has the benefit of coagulating vessels up to 5-mm in size with minimal thermal collateral damage to surrounding tissues.[25]

Complications of traditional ovariohysterectomy procedures can include incisional dehiscence, ovarian pedicle and uterine vessel hemorrhage, draining tracts, stump pyometra, seroma formation, and skin incision problems.[29,30] No major complications were associated with either the HALO or OVH procedures in this study. Only 1 minor complication occurred in the HALO group, which consisted of minor hemorrhage that occurred as a result of accidental puncture of the spleen with laparoscopic Babcock forceps. This complication was likely related to the experience level of the operating surgeon. Hemorrhage in this case was minimal and resolved with no intervention. However, the bleeding did lengthen the surgery time to 98 minutes, which was significantly longer than the other laparoscopic procedures. No incisional complications occurred in the HALO group. The only complications observed in the

OVH group were mild cutaneous incisional erythema and swelling. No additional medical treatment was needed in these cases.

Our complication rate appears to be lower in comparison with a previous MIS study, where minor complications were seen in 9 of 16 laparoscopic ovariohysterectomy patients including continued vessel hemorrhage (4), splenic laceration (3), vaginal discharge(1), and fever (1).[14] In the previous study, 4/16 dogs required additional bipolar cauterization after intracoporeal ligation, due to uterine stump bleeding.[14] A second study evaluated laparoscopic ovariectomy using monopolar and bipolar cautery techniques.[15] This study also reported mesovarial arterial bleeding in 8% of dogs treated with bipolar cautery and 13% of dogs in the monopolar group. Additional Endoloop ligatures were required to prevent recurrent hemorrhage in 20 of 103 of their reported cases.[15] In our study, each transected ovarian and uterine site was inspected for hemorrhage prior to abdominal closure. No evidence of vessel bleeding was observed after use of the harmonic scalpel in any of the cases reported here.

Histologic examination of ovarian pedicle and uterine body in the HALO group revealed that margins of transected areas had primary coagulation of vessels and no hemorrhage. The remaining ovarian vascular pedicle and uterine stumps within each animal would have likely appeared similarly at the time of surgery. No samples were collected following surgery to document soft tissue reactions and repair following changes induced with the harmonic scalpel.

CHAPTER III: CONCLUSIONS

Ovariohysterectomy is the most common elective surgical procedure performed for small animal sterilization in the United States.[27] Pet owners have become increasingly concerned about postoperative pain and morbidity associated with open abdominal procedures. The result of these concerns has lead to an increased demand for minimally invasive surgical techniques from the public. Minimally invasive surgical techniques have generated attention in veterinary medicine, just as increased awareness of patient pain control has emerged to the forefront of veterinary research.

The results of this study have proven harmonic scalpel assisted laparoscopic ovariohysterectomy to be a minimally invasive alternative to a commonly performed elective surgical procedure in the United States. Although laparoscopic surgery can be associated with high equipment costs and increased learning curve, the medical value of these techniques seems warranted. We demonstrated in this study that HALO procedures could be safely performed in dogs 10-12kg in size. Further studies are required to determine whether HALO is safe for use in larger dogs.

The potential benefits of HALO include decreased pain and fewer incisional complications. As demonstrated in this study, dogs do appear to be less painful with HALO. These results were demonstrated by lower cortisol levels, increased tolerance of abdominal palpation, and lower University of Melbourne pain scores in the HALO group as compared to the OVH group. These findings allow us to glean information about patient morbidity and early return to function for our patients. Other benefits of minimally invasive surgery, as seen in humans, (shorter hospital stays, decreased medical costs, and decreased intra-abdominal adhesions) should also be evaluated in future studies in the dog.

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APPENDIX I: FIGURES

FIGURE 1- LAPAROSCOPIC SETUP

Figure 1. The laparoscopic ovariohysterectomy involves three portals for instrumentation. The camera port is placed on ventral midline at the level of the umbilicus. Two paramedian ports are placed on each side, lateral to the caudal superficial epigastric vessels, to allow harmonic scalpel and Babcock instrument placement.

FIGURE 2 – HARMONIC SCALPEL

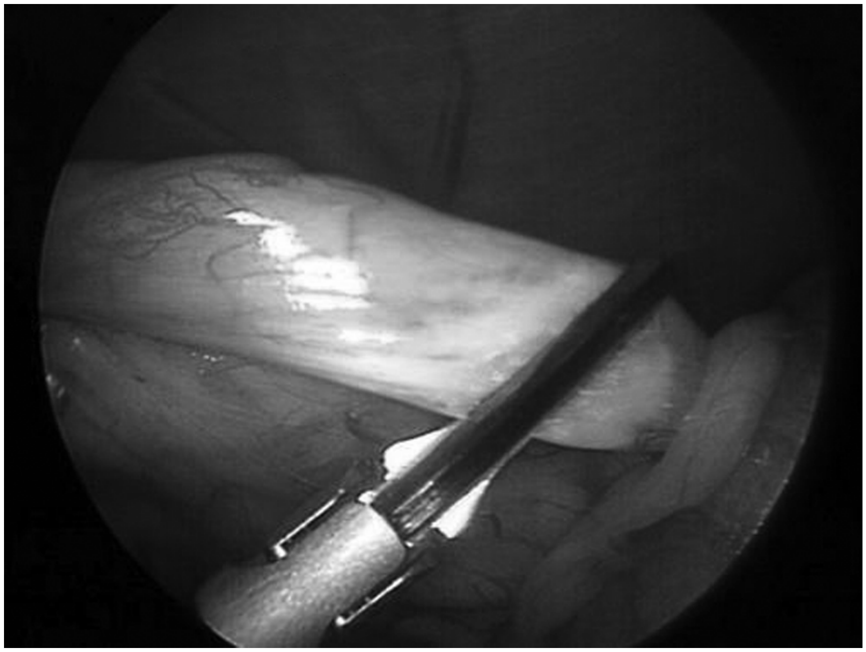

Figure 2. Demonstrates the use of the harmonic scalpel on the suspensory ligament of the right ovary during a laparoscopic ovariohysterectomy procedure

FIGURE 3 – UNIVERSITY OF MELBOURNE PAIN SCALE

University Of Melbourne Pain Scale		Dog ID #							
Category	Descriptor	Score	Pre	2	6	12	24	48	72
1) Physiologic Data									
a.	Physiologic Data Within Reference Range	0							
b.	Dilated Pupils	2							
	Percentage Increase In Heart Rate Relative To Pre-op Rate								
	>20%	1							
	>50%	2							
	>100%	3							
d.	Percentage Increase In Respiratory Rate Relative To Pre-op Rate								
	>20%	1							
	>50%	2							
	>100%	3							
e.	Rectal Temp. Exceeds Reference Range	1							
f.	Salivation	2							
2) Response To Palpation	No Change From Pre-op Behavior	0							
	Guards/Reacts When Touched	2							
	Guards/Reacts Before Touched	3							
3) Activity	At Rest: Sleeping	0							
	At Rest: Semiconcious	0							
	At Rest: Awake	1							
	Eating	0							
	Restless (Pacing Continuously, Getting up and Down)	2							
	Rolling And Thrashing	3							
4) Mental Status	Submissive	0							
	Overtly Friendly	1							
	Wary	2							
	Aggressive	3							
5) Posture									
a.	Guarding/Protecting Affected Area	2							
b. (Choose 1)	Lateral Recumbency	0							
	Sternal Recumbency	1							
	Sitting Or Standing, Head Up	1							
	Standing, Head Hanging Down	2							
	Moving	1							
	Abnormal Posture, (Prayer Position Hunched Back)	2							
6) Vocalization	Not Vocalizing	0							
(Choose 1)	Vocalizes When Touched	2							
	Intermittent Vocalization	2							
	Continuous Vocalization	3							
TOTAL SCORE									

Figure 3. Example of the University Of Melbourne Pain Scale.

FIGURE 4 – HEART RATE

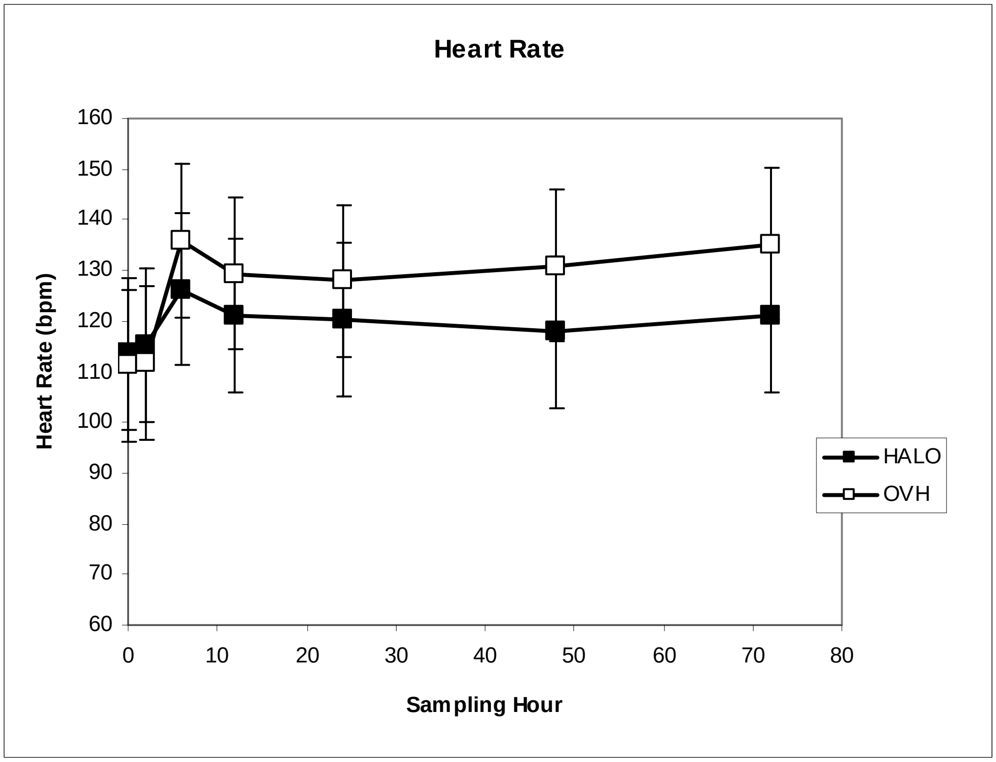

Figure 4. Mean heart rate values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, 72 hours postoperatively. No significant difference (P=0.07) were seen between the two groups.

FIGURE 5 – RESPIRATORY RATE

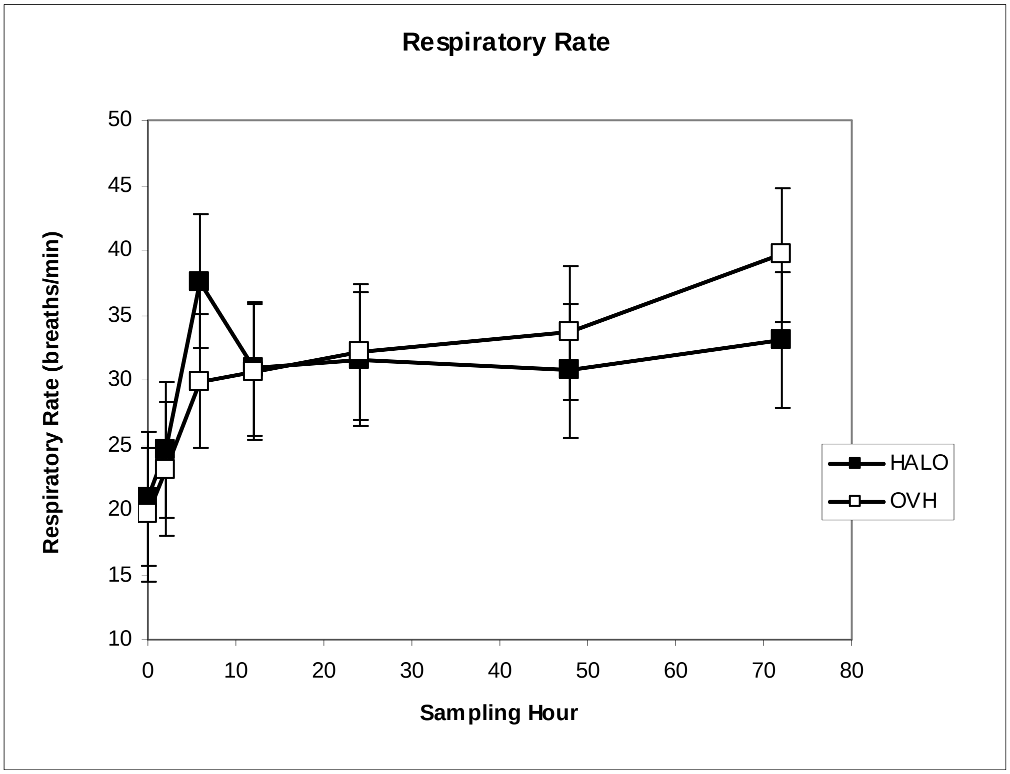

Figure 5. Mean respiratory rate values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, 72 hours postoperatively. No significant difference (P=0.96) were seen between the two groups.

FIGURE 6 - TEMPERATURE

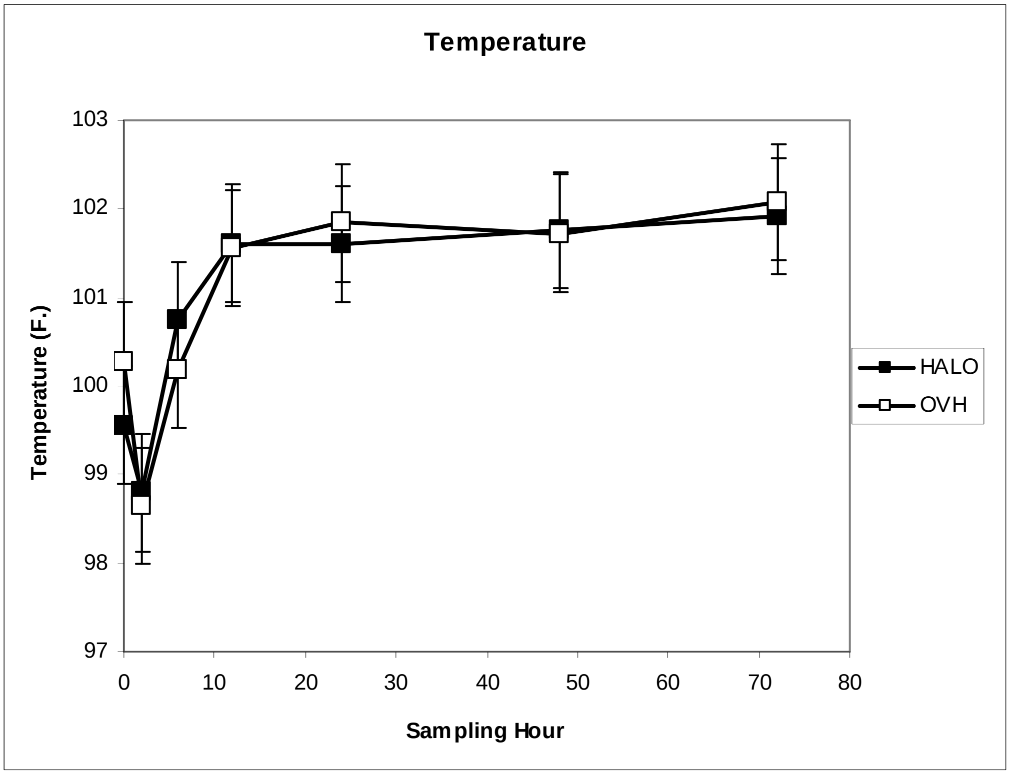

Figure 6. Mean temperature values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, 72 hours postoperatively. No significant difference (P=0.78) were seen between the two groups.

FIGURE 7 - CORTISOL

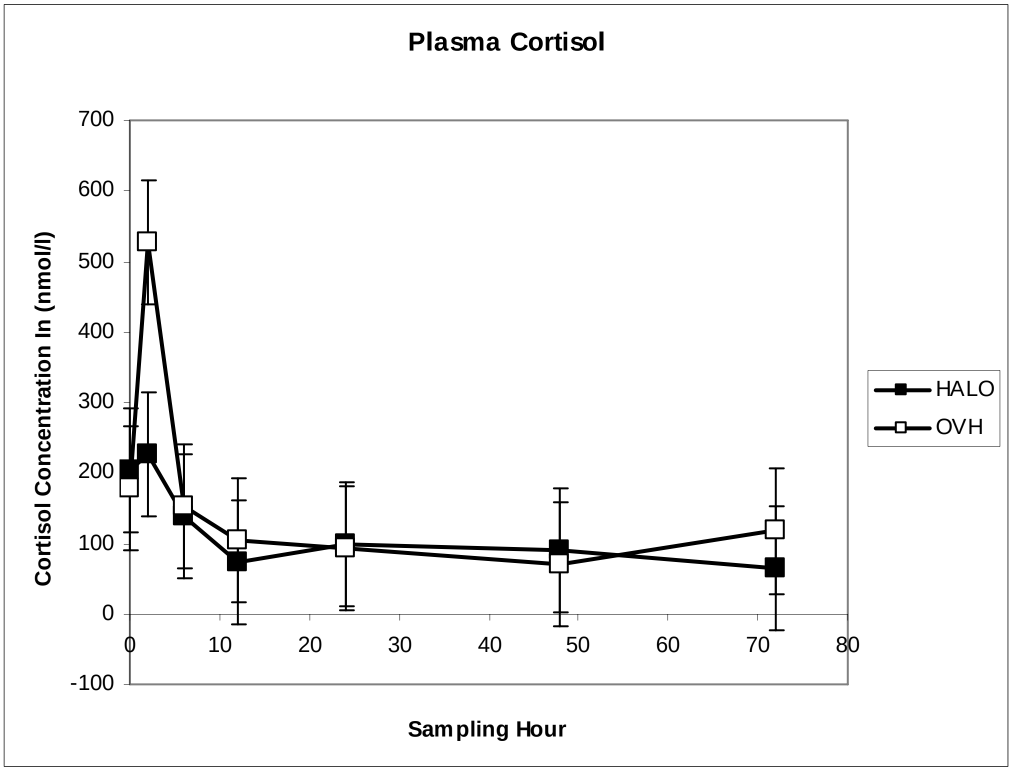

Figure 7. Mean plasma cortisol values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, 72 hours postoperatively. There is a significantly higher plasma cortisol level (P=0.0001) in the OVH group at hour two when compared to the HALO group.

FIGURE 8 - CPK

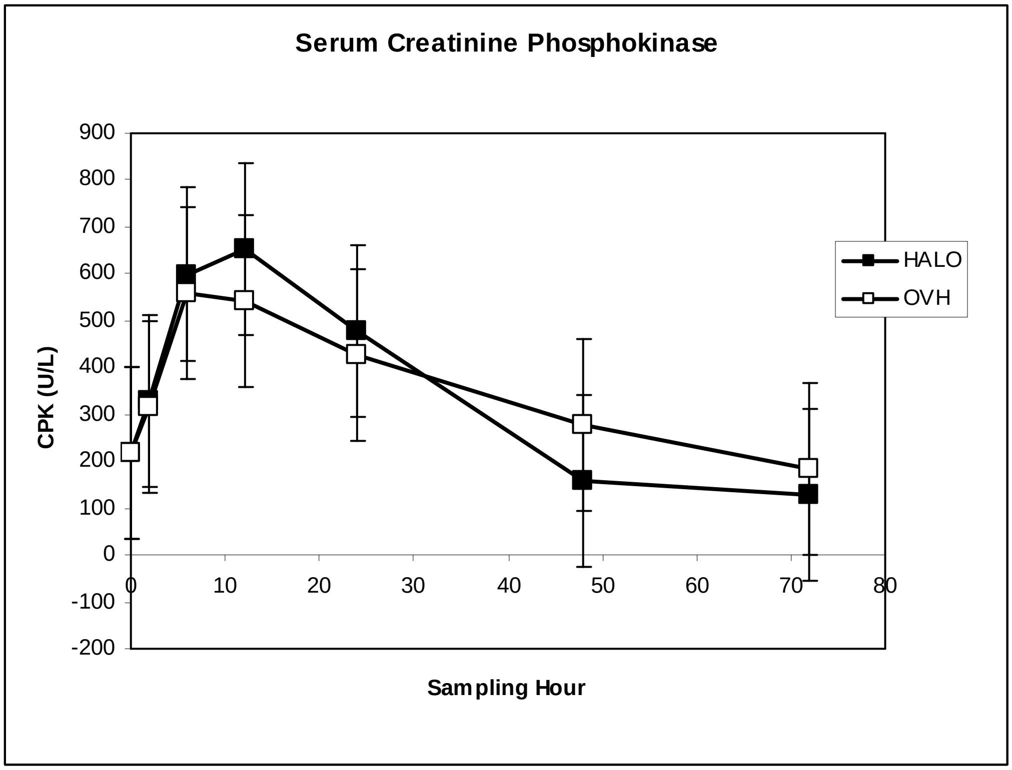

Figure 8. Mean creatine phosphokinase values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, 72 hours postoperatively. No significant difference (P=0.77) was seen between the two groups at any time.

FIGURE 9 - GLUCOSE

Figure 9. Mean glucose values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, 72 hours postoperatively. No significant difference (P=0.50) was seen between the two groups at any time.

FIGURE 10 - NOCICEPTION

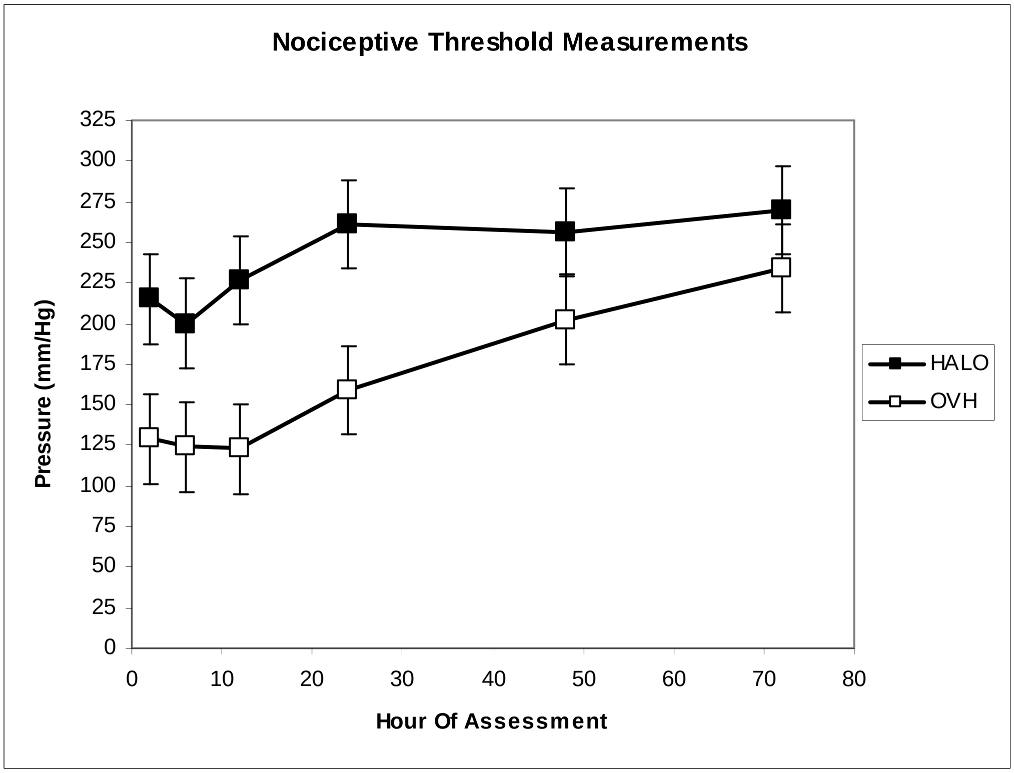

Figure 10. Mean abdominal nociceptive pressures and their corresponding 95% confidence intervals taken from female beagles at 2, 6, 12, 24, 48, 72 hours postoperatively. The HALO group tolerated significantly higher palpation pressures (P=0.0002) than the OVH group at all recorded times, with the exception of hour 72.

FIGURE 11 – UNIVERSITY OF MELBOURNE PAIN SCALE

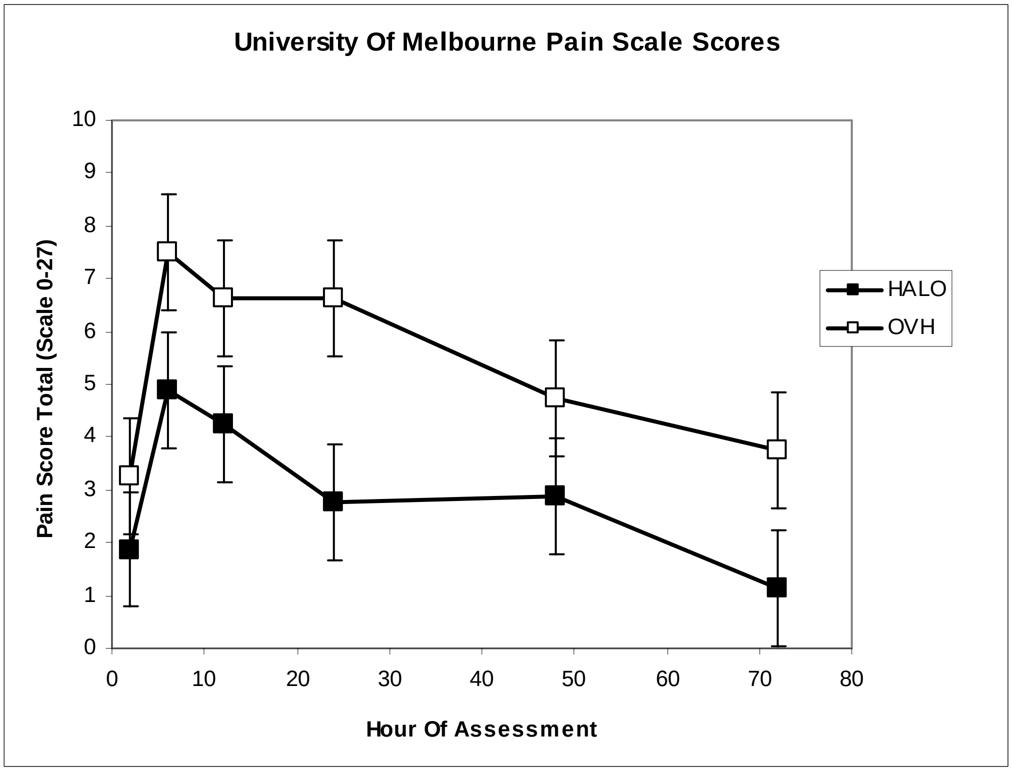

Figure 11. Mean UMPS and their corresponding 95% confidence intervals taken from female beagles at 2, 6, 12, 24, 48, 72 hours postoperatively. The OVH group had significantly higher mean UMPS pain scores (P=0.0001) than the HALO group at all postoperative times.

FIGURE 12-HARMONIC SCALPEL HISTOPATHOLOGY

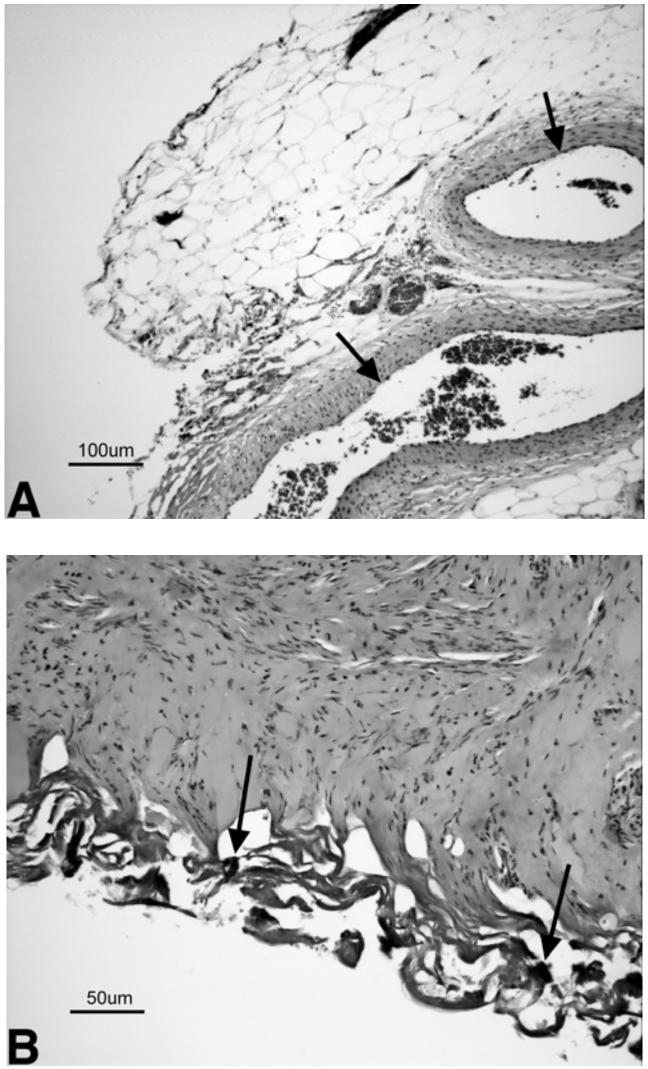

FIGURE 12 - A AND B

A) Large muscular veins and arteries (arrows) are present within 300-microns of the excisional margins. B) Excisional margin of the uterine body. Note the protein coagulum along the cut surface (arrows) of this tissue.

Vita

Robert Hancock was born in New Orleans, Louisiana. He attended the University of Southern Mississippi for undergraduate study. He then went on to complete his DVM at Mississippi State University in 2001. Robert completed a rotating small animal internship at the University of Missouri, Columbia. Currently. Robert is completing the requirements of a residency in small animal surgery and a Master of Science in Veterinary Science.