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Comparison of Postoperative Pain After Ovariohysterectomy by Harmonic Scalpel-Assisted Laparoscopy Compared with Median Celiotomy and Ligation in Dogs

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Objective—To compare the effects of postoperative pain after ovariohysterectomy by 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—Dogs were divided into 2 groups: Group 1 (8 dogs), which had OVH by HALO, and Group 2 (8 dogs), which had 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 after surgery. Blood samples for measurement of plasma cortisol, glucose, and creatine phosphokinase (CPK) concentrations were collected at the time of the incision, and 2, 6, 12, 24, 48, and 72 hours after surgery.
Results—No significant surgical complications occurred. The HALO mean surgical time was significantly longer (55.7 minutes) than traditional OVH (31.7 minutes). No significant differences were observed between groups for the pain measures of heart rate, respiratory rate, temperature, CPK, and glucose concentrations. The OVH group had significantly higher mean plasma cortisol levels at hour 2 after surgery than the HALO group ($P = .0001$). The mean UMPS were significantly higher in OVH than the HALO group at all postoperative times ($P = .0001$). The mean nociceptive threshold measurements revealed significantly higher tolerated palpation pressures in HALO than OVH at all postoperative times, except hour 72 ($P = .0002$).
Conclusions—Dogs appeared to be in less pain with HALO than OVH. The harmonic scalpel coagulated ovarian and uterine vessels completely with minimal collateral damage to surrounding tissues.
Clinical Relevance—HALO is a safe alternative to OVH and offers a minimally invasive and less painful method of surgery.

Key words: laparoscopy, ovariohysterectomy, harmonic scalpel, pain score, University of Melbourne pain score, dog.

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INTRODUCTION

OVARIOHYSTERECTOMY (OVH) is the most common elective surgical procedure used for sterilization of female cats and dogs in the United States.[1] OVH offers benefits of population control and decreased risk of potentially life-threatening diseases such as mammary cancer and pyometra.[2,3] Traditional OVH causes pain and morbidity from tissue trauma, organ manipulation, and inflammation.[4–6] Pet owners have become increasingly concerned about postoperative pain and morbidity associated with open abdominal procedures and this has resulted in increased interest in minimally invasive surgical (MIS) techniques.

In humans, laparoscopy has numerous advantages over traditional celiotomy techniques: decreased postoperative stress and pain, faster recovery periods, decreased hospitalization, improved cosmesis, and improved visualization of abdominal organs.[7,8] Some veterinary surgeons have been reluctant to adopt laparoscopy because of limitations associated with MIS, including equipment cost, procedural learning curve, and increased procedure time compared with traditional surgical techniques.[9] Pain control, although only one beneficial aspect of MIS, is a crucial factor for patient care. Decreased pain was reported after laparoscopic OVH where ovarian pedicle ligations were performed with intracoporeal wire and bipolar cautery.[3] Uncontrolled pain in veterinary patients can result in unwanted complications, including cardiovascular stress, immunosuppression, anorexia, and cachexia.[10,11]

It is generally well accepted that pain assessment in animals is best performed with multiple assessment techniques, to avoid undue weighting of any single subjective or objective measurement.[10,11] As a result, no gold standard has been identified for pain evaluation in veterinary patients. Physiologic (heart rate, respiratory rate, temperature) and biochemical measures (plasma cortisol, glucose) are commonly used as objective, indirect measures of pain.[6,12,13] However, inconsistent results have occurred when these measures are used alone to evaluate pain.[14,15] Assessment of physiologic and biochemical measures will likely be more valuable when behavioral changes are evaluated concurrently.

The University of Melbourne Pain Scale (UMPS) was developed in 1999 based on a modification of the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS). CHEOPS had originally been designed as a tool for monitoring postoperative pain in young children.[16] Multiple descriptors are used in 6 categories including behavioral and physiologic responses, and weighting of certain behaviors eliminates some observer bias.[11] UMPS has been used to evaluate pain in animals and is believed to be more sensitive and specific than many simple descriptive or numerical scales.[16]

A harmonic scalpel consists of an electrical generator, handpiece, an active and inactive blade system, and a foot pedal. Electrical energy produced by an external generator is converted to ultrasonic energy by a piezoelectric, ceramic transducer located within the handpiece. This small piezoelectric crystal vibrates at approximately 55,000 Hz, causing longitudinal movement against the inactive part of the blade.[17,18] Mechanical energy from the oscillating blades results in energy transfer to tissue proteins, leading to denaturation and formation of a sticky protein coagulum, capable of sealing vessels $\leq$ 5 mm in diameter.[19] Harmonic scalpel technology permits 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.[18,19]

Our primary purpose was to evaluate differences in pain responses between OVH performed by HALO or a traditional method (median celiotomy, ligation, and transection; OVH). We hypothesized that HALO procedures would be less painful than OVH because of smaller incisions and decreased soft-tissue trauma. To test our hypothesis, we evaluated pain using multiple objective (physiologic and biochemical responses, and nociceptive threshold measurements) and subjective measurements (UMPS) in 2 groups of dogs sterilized by either HALO or OVH. We used a multi-modal pain measurement strategy in an attempt to increase sensitivity and credibility in a randomized, prospective study of this type.

MATERIALS AND METHODS

Sixteen, female, purpose-bred beagles (mean weight, 11 kg; range, 10.1–12.2 kg) were studied. All dogs had normal physical examination findings, complete blood count, biochemical profile, and urinalysis before entering the study. Dogs were randomly assigned to either group 1 (8 dogs), which had HALO or group 2 (8 dogs), which had OVH. Dogs were then randomly assigned to 8 blocks, with 1 dog from each group randomly assigned to each individual block. Two surgeons and 1 resident performed HALO and OVH; however, only a single surgeon performed HALO or OVH within a block.

Each block of dogs (2) was housed in an individual room for 96 hours to decrease the influence of environmental stressors on behavioral changes after surgery. The same handler was used for all dog interactions and assessments over the 4-day period. The handler was unaware of treatment because each dog had an abdominal bandage applied after surgery. An initial 24-hour acclimation period preceded the surgical procedure and handler–dog interaction occurred throughout acclimation to familiarize each dog with the handler. During acclimation, physiologic variables (heart rate, respiratory rate, and temperature), blood samples (plasma cortisol, glucose, and creatine phosphokinase [CPK]), nociceptive threshold measurements, and UMPS were collected and recorded. This established preoperative baseline objective and subjective data for each variable and allowed detection of any group differences before surgery.

Anesthesia

One block (2 dogs) had surgery each day for 8 days. Dogs had food withheld for 12 hours before surgery, but were allowed free-choice water. Each dog was premedicated by subcutaneous administration of acepromazine (0.03 mg/kg) and morphine sulfate (0.25 mg/kg), anesthetized with thiopental (10 mg/kg intravenously [IV] to effect), and maintained with isoflurane in oxygen. Physiologic anesthesia monitoring consisted of indirect blood pressure monitoring (Ultrasonic Doppler Flow Detector Model 811-B, Parks Medical Electronic, Aloha, OR), esophageal stethoscope, electrocardiogram (Propaq 106, Protocol System Inc, Beaverton, OR), and pulse oximeter (Nellcor, N-20PA P/O, Protocol System Inc.). Variables were evaluated and recorded every 5 minutes until extubation.

Surgical time was defined from the beginning of the 1st skin incision to placement of the last skin suture. After the 1st skin incision, blood samples were collected (jugular catheter) for plasma cortisol, glucose, and CPK concentrations. Heart rate, respiratory rate, and rectal temperature were recorded as physiologic pain variables from anesthesia monitoring equipment during the procedure.

Each dog was positioned in dorsal recumbency, and the ventral abdomen was clipped and aseptically prepared for surgery. A 16 g, 8-Fr jugular catheter (Blitt Central Venous Catheter, Argon Medical, Athens, TX) was inserted in the right jugular vein to facilitate blood collection and to minimize stress associated with repeated blood collection. The catheter was bandaged in place and maintained for 72 hours after surgery.

HALO

Four quarter drapes were placed approximately 2 cm lateral to each row of mammary teats, at the xyphoid, and the pubis. By tilting the table surface, the dog was placed in a Trendelenburg[20] position (20°) to facilitate craniad displacement of the viscera. A 1-cm skin incision was made at 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[7,20] technique. Pneumoperitoneum was established with an insufflator (Electronic Insufflator Model 26012, Karl Storz, Charleston, MA) to 10 mm Hg using CO_2 gas.[9,21]

A 30° forward-oblique, 5-mm telescope (Hopkins II, Karl Storz) was inserted through an umbilical portal and used to identify the epigastric blood vessels to facilitate placement of paramedian instrument portals under direct camera supervision (5X Hunt Trocar/5-mm Pyramidal Tip, Apple Medical Corp, Bolton, MA). Portals were made 1 cm lateral to a teat in the caudal abdomen, avoiding the caudal superficial epigastric artery and vein (Fig 1). Babcock forceps (Endopath—5 mm Babcock Forceps, Ethicon Endo-Surgery Inc.) inserted through the right paramedian portal were clamped to the proper ligament of the right ovary. A harmonic scalpel (Ultracision LCS-C5, Ethicon Endo-Surgery Inc.) inserted through the left paramedian portal was used to coagulate and transect the suspensory ligament, ovarian pedicle, and broad ligament of the uterus (Fig 2). Then, the uterine artery and vein were transected bilaterally just rostral to the cervix, followed by the body of the uterus. The positions of the Babcock forcep and harmonic scalpel were reversed and the procedure was repeated in reverse order on the left side by transecting the broad ligament of the uterus first, followed by

Fig 1. The laparoscopic ovariohysterectomy involves three portals for instrumentation. The camera port is placed on the ventral midline at the level of the umbilicus. Two paramedian ports are placed on each side, lateral to the caudal superficial epigastric vessels, to facilitate instrument use.

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

the left suspensory ligament, and finally the ovarian pedicle. All transection sites were inspected for hemorrhage. The camera was removed from the umbilical portal and inserted through an instrument portal, previously occupied by the harmonic scalpel. Babcock forceps were introduced through the umbilical portal, clamped to the uterine body, and the transected reproductive tract was exteriorized through the umbilical portal under direct camera observation. The abdomen was decompressed by applying hand pressure to the left and right abdominal walls to facilitate escape of CO_2 through the umbilical cannula. The umbilical port was closed with a single simple interrupted suture (2-0 polydioxanone [PDS]) in the linea alba, and then subcutaneous apposition (simple interrupted cruciate suture, 3-0 PDS) and skin closure with a single simple interrupted cruciate suture (3-0 nylon). Paramedian portals were apposed with 1 simple interrupted cruciate suture (3-0 PDS) in the muscular layer, followed by a single simple interrupted cruciate skin suture (3-0 nylon).

OVH

After placing 4 quarter drapes, a 6 cm, ventral median celiotomy (beginning 1 cm caudal to the umbilicus and extending caudally) was made. OVH was performed using a modified 3-clamp technique,[1] with ovarian pedicle ligation using 2-0 PDS. The linea alba was closed in a simple continuous pattern (2-0 PDS), followed by the subcutaneous tissues (3-0 PDS), and skin (3-0 nylon).

Recovery Period

Dogs were administered morphine sulfate (0.5 mg/kg subcutaneously) at extubation. Each dog had an identical light abdominal bandage applied so the handler was unaware of the each dog's specific surgical procedure postoperatively. At each postoperative interval (2, 6, 12, 24, 48, and 72 hours) physiologic variables (heart rate, respiratory rate, and temperature), UMPS, and abdominal nociceptive threshold measurements were recorded by the handler. Additionally, at each designated hour, blood samples for glucose, CPK, and plasma cortisol concentration measurements were collected. Dogs were recovered on a circulating warm water heating pad until they were able to maintain a sternal position and with a body temperature of 99°F. If at any time during the study dogs had UMPS scores >10, morphine sulfate (0.25 mg/kg) was administered subcutaneously.

Abdominal Palpation Nociceptive Threshold Scores

At each postoperative interval, each dog had nociceptive threshold measurements determined in response to abdominal palpation. An algometer was created using a #5 pediatric blood pressure cuff, 3-way stopcock, and sphygmomanometer that was used on all dogs. A handheld tensiometer (Omega D670-44, Stanford, CA) was used to test this system to ensure consistent and reliable pressure readings before the study. The cuff was preinflated to 20 mm Hg before each nociceptive test was performed, and then applied over the abdominal bandage at the umbilicus. Gentle pressure was applied to the cuff until a conscious reaction was elicited from the dog. If no reaction occurred, the dog was scored as 300 mm Hg, 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 correlated with less abdominal pain and vice versa.

Blood Sampling

Specimens were collected by the jugular catheter at each time interval. Blood for plasma cortisol measurement was collected into EDTA, centrifuged immediately for 15 minutes at 15°C, and then plasma was aspirated by pipette; 2 aliquots of plasma were stored at −80°C. Blood samples for CPK and glucose were collected in lithium–heparin and centrifuged immediately for 15 minutes at 15°C. Serum was aspirated by pipette and stored as 2 aliquots at −80°C. All samples were assayed after study completion.

UMPS

Dogs were evaluated by the same handler who was unaware of which procedure had been performed. Pain scale descriptors included physiologic and behavioral scoring variables. More painful behaviors were weighted with increasingly higher scores. Maximal pain was given a score of 27 and no pain was scored as 0. At designated times, the handler evaluated each dog through an enclosed window to avoid disturbing the patient. After observations were recorded, physiologic variables were assessed for each dog.

Histopathology

Reproductive tracts were fixed in 10% buffered neutral formalin and examined by a pathologist to ensure complete removal. Reproductive tracts from the HALO surgical group were also examined histologically to assess tissue interface changes caused by the harmonic scalpel. Selected specimens were processed for histology, sectioned at 5 μm, and stained with hematoxylin and eosin.

Statistical Analysis

The study was a randomized, controlled, block design. Dogs were paired into blocks randomly as either HALO or OVH group members. Software (SAS System, Cary, NC) was used to perform all statistical analysis. Repeated-measures ANOVA was used to evaluate heart rate, respiratory rate, temperature, glucose, CPK, cortisol, nociceptive threshold measurements, and UMPS scores between OVH and HALO surgical groups. Variable means and the corresponding 95% confidence intervals (CIs) were recorded. Ad hoc analysis using ANOVA was performed to detect any nuisance effects of surgical time on the OVH and HALO procedures on all of the measured variables. ANOVA was also used to detect differences in the length of surgical time between OVH and HALO groups. Significance for all analysis was set at $P = .05$.

RESULTS

There were no significant differences in the mean heart rate (HALO: 113.5–126.3 beats/min; OVH: 111.1–135.9 beats/min; $P = .07$), respiratory rate (HALO: 20.8–37.6 breaths/min; OVH: 19.6–39.6 breaths/min; $P = .96$), or rectal temperature (HALO: 98.7–101.9°F; OVH: 98.6–102.0°F; $P = .78$) between groups at any time.

Plasma Cortisol Concentration

Preoperative plasma cortisol concentrations were not significantly different between groups. Mean plasma cortisol concentrations for HALO, at each of the time intervals, ranged from 64.6 to 226.5 nmol/L and ranged from 70.5 to 527.4 nmol/L for OVH. At hour 2, the mean OVH cortisol concentrations were significantly higher (527.4 nmol/L; 42.9% increase) than the mean HALO cortisol concentrations (226.5 nmol/L; $P = .0001$). No other significant differences between groups were detected, and concentrations in both groups were considered to have returned to normal by hour 6 (Fig 3).

Blood Glucose Concentration

Preoperative glucose concentrations were normal (65–120 mg/dL). The mean glucose concentrations for HALO, at each of the 7 time intervals, ranged from 108.1 to 140.4 mg/dL and ranged from 106.2 to 136.2 mg/dL for OVH. Compared with preoperative glucose concentrations, at hours 2 and 6, both groups showed significant increases in the mean serum glucose concentrations ($P = .0001$); however, there were no significant differences ($P = .50$) between HALO and OVH groups at any time.

CPK Concentration

Preoperative CPK concentrations were within normal reference intervals (54–430 U/L) for all but 1 dog (HALO 604), who had a preoperative CPK of 2269 U/L. The mean CPK for HALO, at each of the 7 time intervals, ranged from 126.4 to 652.3 U/L and ranged from 184.5 to 559.3 U/L for OVH. At hours 6 and 12, both groups showed significant increases in the mean serum CPK values compared with preoperative concentrations ($P = .0001$); however, there were no significant differences ($P = .77$) between HALO and OVH groups at any time.

Abdominal Palpation Pressure

Preoperatively, all dogs had abdominal palpation pressures $\geq$ 300 mm Hg. The mean palpation pressure for HALO, at each of the 7 time intervals, ranged from 200 to 270 mm Hg, and from 122.5–233.7 mm Hg for OVH. Palpation pressures were significantly lower ($P = .0002$) in the OVH group at all postoperative times, except hour 72 (Fig 4).

UMPS

UMPS was scored by assigning a maximal score of 27 and a minimal score of 0. All dogs had scores of 0 preoperatively. The mean UMPS for HALO, at each of the 7 time intervals, ranged from 1.1 to 4.8, and from 3.2 to 7.5 for OVH. UMPS scores were significantly higher

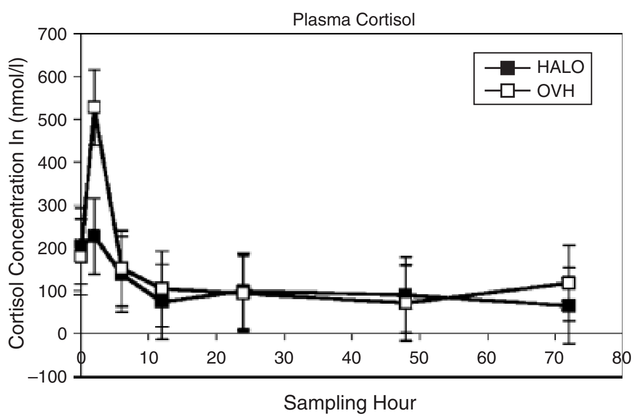

Fig 3. Mean plasma cortisol values and their corresponding 95% confidence intervals taken from female beagles at 0, 2, 6, 12, 24, 48, and 72 hours postoperatively. There is a significantly higher plasma cortisol level in the ovariohysterectomy (OVH) group at hour 2 when compared with the harmonic scalpel-assisted laparoscopy (HALO) group.

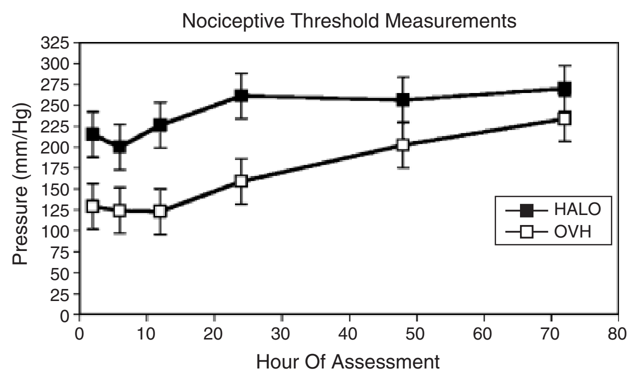

Fig 4. Mean abdominal nociceptive pressures and their corresponding 95% confidence intervals taken from female beagles at 2, 6, 12, 24, 48, and 72 hours postoperatively. The harmonic scalpel-assisted laparoscopy (HALO) group tolerated significantly higher palpation pressures than the ovariohysterectomy (OVH) group at all recorded times, with the exception of hour 72.

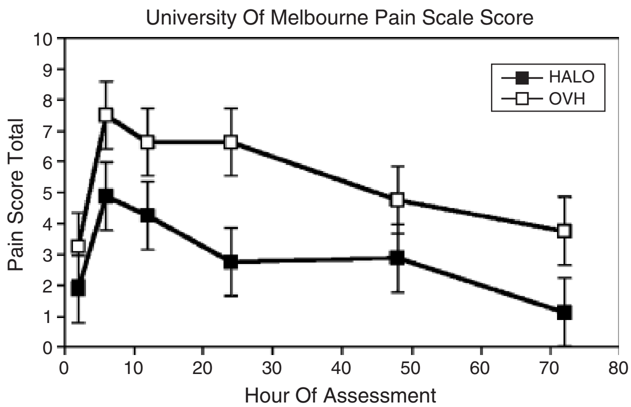

Fig 5. Mean University of Melbourne pain scores (UMPS) and their corresponding 95% confidence intervals taken from female beagles at 2, 6, 12, 24, 48, and 72 hours postoperatively. The ovariohysterectomy (OVH) group had significantly higher mean UMPS pain scores than the harmonic scalpel-assisted laparoscopy (HALO) group at all postoperative times.

($P = .0001$) for OVH compared with HALO at all times after surgery (Fig 5). No dogs in either group had a pain score of ≥ 10; none of the dogs were administered additional pain medication at any time during the study.

Complications

No major surgical complications occurred in either group. In the HALO group, 1 dog had a $<$1-cm puncture of the spleen from injury with Babcock forceps. Hemorrhage obscured visualization of the left ovary and increased surgery time to 98 minutes, which was significantly longer than any of the other 7 HALO procedures. No intervention was required to resolve the hemorrhage. All OVH dogs had mild incisional site redness and swelling; however, this resolved within 72 hours without treatment.

Operative Time

The mean OVH surgical time (31.7 minutes) was significantly less than the mean HALO surgical time (55.7 minutes; $P = .0001$). Surgical time had no significant nuisance effects on any of the measured objective or subjective pain variables at any recorded time.

Histopathology

Reproductive organs 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 μm in thickness. Soft tissues containing large muscular veins and arteries within 300 μm of the excisional margin lacked any evidence of extravasated hemorrhage (Fig 6).

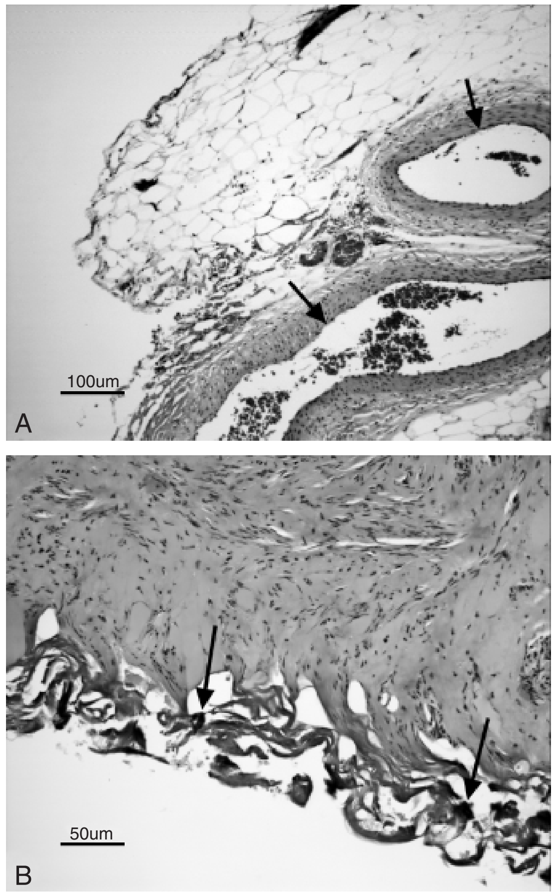

Fig 6. (A) Excisional margin of an ovarian pedicle from the harmonic scalpel-assisted laparoscopy (HALO) group. Large muscular veins and arteries (arrows) are present within 300 μm of the excisional margins. (B) Excisional margin of the uterine body from the HALO group. Note the protein coagulum along the cut surface (arrows) of this tissue.

DISCUSSION

Despite a significantly longer operative time, we found that HALO dogs seemingly experienced less postoperative pain and stress than OVH dogs. This conclusion was based on higher UMPS scores in OVH dogs at all postoperative time intervals, higher plasma cortisol concentrations at postoperative hour 2, and consistently more reaction to lower abdominal palpation pressures (nociceptive threshold) at all intervals up to postoperative hour 72. Significant differences in physiologic variables, CPK, and blood glucose concentrations were not detected between HALO and OVH dogs. Interestingly, both groups showed significant increases in CPK concentrations for 24 hours after surgery, but this was not useful for differentiating pain between groups.

Laparoscopic surgery is presumably less painful because of smaller incisional size, decreased muscular trauma, and earlier return to function.[22] We chose to study OVH because it is a commonly practiced surgical procedure in North America. We undertook a comprehensive approach to evaluate pain including objective and subjective methods, in order to increase sensitivity and decrease bias in our evaluations. Numerous pain assessment scoring systems have been used in veterinary medicine, including the visual analog scale, numerical rating scales, simple descriptive scales, and behavioral and physiologic response scales.[11] Unfortunately, as has been reported with pediatric human patients, none of these scoring systems are all-inclusive. Sensitivity of certain variables and minute changes in behavior may be overlooked with incorrect use of these evaluation systems.

UMPS

We found higher UMPS scores at all postoperative times in the OVH group, suggesting that HALO was less painful when evaluating both behavioral and physiologic responses. In a previous study, dogs that had OVH had higher UMPS scores than dogs that were only anesthetized, and excellent agreement was observed between the 2 blinded assessors, demonstrating the repeatability of UMPS scoring.[16] Our study yielded similar results; however, dogs were assessed by only 1 blinded observer.

Plasma Cortisol Concentration

Biochemical markers, like plasma cortisol concentrations, have been used as markers of pain and stress in veterinary medicine.[13,14] Although cortisol is possibly an insensitive marker of stress, it has been reported to increase significantly in response to surgical stress in dogs and cats.[12–14] We found significantly higher mean cortisol concentrations 2 hours after surgery in the OVH group compared with the HALO group; however, no significant differences were identified between the 2 groups at other times, and concentrations in both groups were considered normal by postoperative hour 6. Because all dogs had the same anesthesia protocol, anesthesia alone seemingly would not explain the difference in cortisol concentrations at hour 2. Although increased plasma cortisol concentrations have been reported in cats that have undergone longer surgical procedures,[14] the OVH dogs in our study had significantly lower surgical times than HALO dogs. Thus, it is possible that the elevated cortisol concentrations at hour 2 in the OVH group may truly reflect an increased stress response.

Blood Glucose Concentration

Glucose has been used to measure stress and pain in cats and human neonates.[13,23] Catecholamines released during stressful events lead to increased glucose levels to cope with increasing metabolic demands. However, glucose can be inconsistently reliable as a marker of stress and does not always correlate with other pain assessment methods.[13,22] We found increased glucose concentrations between hours 2 and 6 in both groups, and then a return to more normal concentrations. Despite these changes, we did not detect significant differences between groups at any time. In our study, glucose concentrations were not useful to discriminate differences in pain or stress.

CPK Concentration

Although, well known as a marker of muscle damage, CPK is not usually used as an indicator of pain in animals.[24] Recently, a study in human neonates used CPK as a useful variable for assessing pain after laparoscopic fundoplications and extramucosal pyloromyotomy procedures.[25] Because muscle trauma can be related to inflammation and pain, it may also prove to be a useful marker in veterinary patients.[26] In dogs, CPK concentrations increased in response to anesthesia with halothane and propofol, and after intramuscular injections.[27,28] We administered premedications and analgesics subcutaneously or IV, and anesthesia in all dogs was induced with thiopental IV and maintained with isoflurane in oxygen, thus presumably eliminating anesthesia as a likely source of error in interpreting CPK concentrations. CPK was increased above normal limits at 6, 12, and 24 hours in both groups; however, CPK concentrations were unable to discriminate differences in pain between groups. Thus, our findings corroborate similar previous results suggesting that CPK concentrations may not be a good indicator of pain in dogs.[20]

Physiologic and Behavioral Responses

We found no significant differences between HALO and OVH groups for the physiologic variables heart rate, respiratory rate, and temperature. These results are not surprising, as many of these variables have been shown to be unreliable measurements of pain when used alone. However, physiologic variables can provide useful information in assessing responses to noxious stimuli,[11] and have been used in several pain assessment studies.[15,29] However, when used as the sole means of assessing pain, these variables may not correlate well with painful behaviors exhibited by the patient.[15] Physiologic responses are affected by interactions with humans or inherent cardiopulmonary reflexes.[10] Thus, we conclude that whereas physiologic variables can offer valuable information, they should be used in conjunction with other measurement techniques when assessing pain. Others have reported that physiologic variables did not often correlate with behavioral or algometric scoring.[13,15] An inherent limitation in our study was an inability to measure these variables without human interaction. We housed the dogs in kennels of 2, in an attempt to limit environmental stresses. However, many dogs became excited when the handler entered the kennel for measurement recordings. Differences in heart rate and respiratory rate may have been falsely affected and directly attributable to the excitement of dog–human interaction.[30]

Abdominal Palpation Pressure

Nociceptive threshold readings have been used in previous animal pain studies.[15,31] The use of algometric scoring allows for more sensitive and objective measurements of pain in animals than categorical measures.[15] All abdominal palpations in our study were recorded as a pressure (mm Hg) when there was a conscious reaction to palpation. The same handler performed all palpations and recordings, to eliminate some bias. The HALO group tolerated significantly higher palpation pressure at all times except hour 72. OVH dogs were consistently more responsive and were sensitive to lower palpation pressures than HALO dogs, indicating more abdominal discomfort. This observation was consistent with a previous report where, based on subjective abdominal palpation scores, palpation was significantly more tolerated in laparoscopically treated OVH patients.[3] Another inherent limitation in our study was the abdominal bandage that was applied to blind the observer to the operative procedure performed. Every attempt was made to place the bandage on each dog as consistently as possible and to avoid differences in bandage thickness.

A limitation of our study design is an inability to differentiate pain effects directly attributable to surgical approach and those associated with use of the harmonic scalpel. The difference in surgical approach (laparoscopy versus celiotomy) has intuitive and measurable influences on pain scores. HALO dogs had smaller incisions and less soft-tissue injury than OVH dogs, and thus would be expected to have lower pain scores. Potential differences in pain scores attributable to use of the harmonic scalpel for hemostasis and transection in HALO versus ligation and transection in OVH cannot be established with our study design and was not a primary objective of our study.

Operative Time

Laparoscopic surgery requires experience with equipment and operative skills for MIS to maximize efficiency. Lack of depth perception, decreased tactile sensibility, and operating in a 2-dimensional surgical field can be delaying factors for inexperienced surgeons, leading to increased surgical times. The mean surgical time for HALO (55 minutes; range, 25–98 minutes) was significantly longer than for OVH. The 3 participating surgeons had varying degrees of experience with laparoscopic surgery, and procedure duration decreased with increasing surgical experience. Despite differing expertise, surgical time had no significant effect on pain variables.

The laparoscopic technique that we used had been developed earlier with a mean surgical time of 60 minutes (range, 35–100 minutes).[20] The mean surgical time for laparoscopic OVH has been reported as 120 minutes (range, 47–175 minutes) when using 4-0 metric, intracoporeal wire ligatures and bipolar cautery.[3] Laparoscopic intracorporeal sutures can be difficult to handle and often require substantial training to use effectively. Use of bipolar cautery during laparoscopy results in smoke, impairing observation, whereas the harmonic scalpel produces no smoke and minimal vapor. Thus, it is likely that both of these factors would have contributed to longer operative times than we found with HALO. The harmonic device has the benefit of coagulating vessels ≤ 5 mm with minimal collateral thermal damage to surrounding tissues.[19] Not surprisingly, shorter operative times (mean, 47 minutes) have been reported for laparoscopic ovariectomy.[32]

Complications

Complications of traditional OVH include incisional dehiscence, ovarian pedicle and uterine vessel hemorrhage, draining tracts, stump pyometra, seroma formation, and skin incision problems.[33,34] No major complications were associated with either HALO or OVH procedures in our study. Accidental puncture of the spleen with laparoscopic Babcock forceps occurred in 1 HALO dog and likely reflected operator inexperience. Hemorrhage was minimal and resolved without intervention; however, bleeding did lengthen surgical time to 98 minutes, which was significantly longer than other HALO surgical times. No incisional complications occurred in the HALO group. In the OVH group, mild cutaneous incisional erythema and swelling occurred; however, these changes resolved without need for further treatment.

Our complication rate was lower than a previous study, where minor complications occurred in 9 of 16 laparoscopic OVH (splenic laceration [3], vaginal discharge [1], and fever [1]).[3] Four dogs in that study required additional bipolar cauterization of the uterine stump because of residual bleeding.[3] A 2nd study evaluated use of monopolar and bipolar cautery techniques for laparoscopic ovariectomy.[32] Mesovarial arterial bleeding occurred in 8% of dogs in which bipolar cautery was used and in 13% of dogs where monopolar cautery was used. Additional ligatures were required to prevent recurrent hemorrhage in 20 of 103 reported cases.[32] We inspected each transected ovarian and uterine site for hemorrhage before abdominal closure and did not observe hemorrhage after use of the harmonic scalpel.

Histopathology

The harmonic scalpel has been used for hemostasis during hysterectomy in humans,[8,17] and OVH in horses,[18] and dogs.[20,35] The harmonic scalpel cuts, coagulates, and seals vessels simultaneously at much lower temperatures (50–100°C) than electrosurgery or laser surgery (150–400°C).[19] Vessel sealing at low temperatures with a protein coagulum is referred to as coaptive coagulation. Histologic examination of ovarian pedicle and uterine body in HALO tissues revealed that margins of transected areas had primary coagulation of vessels with no hemorrhage.

We concluded that HALO was a MIS technique for a commonly performed procedure in North America. HALO can be safely performed in 10–12 kg dogs; however, further studies are needed to determine whether HALO is safe for use in larger dogs. Potential benefits of HALO include decreased pain and fewer incisional complications. Dogs appeared to be in less pain after HALO, and the harmonic scalpel offers a safe, reliable means of hemostasis for OVH.

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