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Sonographic features of the uncomplicated postoperative abdomen in dogs treated for pyometra by ovariohysterectomy

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Abstract

Pyometra is a prevalent disease in intact bitches and the standard treatment is ovariohysterectomy (OHE). Published descriptions of normal sonographic findings after OHE are currently lacking. The aims of this prospective observational study were to describe and compare postoperative abdominal sonographic features for three time-points following OHE in a group of dogs with pyometra and an uneventful recovery. A total of 22 dogs had sequential focused abdominal ultrasound examinations on days 1, 4–6, and 10–15 postsurgery. Recorded sonographic features for each examination time point and characteristics of the cervical stump and the mesovarium, size, and echogenicity of medial iliac lymph nodes (MILNs), presence of free peritoneal fluid, and pneumoperitoneum. The cervical stump appeared as a heterogenous area with a hypoechoic center surrounded by hyperechogenic tissue in all dogs. The cervical stump transverse-sectional area was larger on day 4–6 compared with day 1 and day 10–15 ($P = .0009$). Mesovarium ligature reactions were identified as heterogeneous and hyperechoic areas with central and/or edge shadowing in all dogs. The size and echogenicity of MILNs and the mesovarium reactions did not significantly differ among time points. Free peritoneal fluid was detected in 45%, 41%, and 9% and pneumoperitoneum in 95%, 82%, and 14% of dogs at sequential time points. Findings from this sample of dogs with an uneventful recovery following OHE due to pyometra can be used to assist veterinarians in interpreting postoperative abdominal ultrasonographic characteristics in future dogs treated surgically for pyometra.

KEYWORDS
canine, case series, genital tract, postsurgery, ultrasonography

1 | INTRODUCTION

Pyometra is a common disease in intact bitches.[1,2] About 20%–25% of intact bitches are affected before 10 years of age. The recommended treatment is an ovariohysterectomy (OHE).[3] Complications, such as peritonitis, urinary tract infections (UTI), wound infections, and even death after surgery, have been reported in about 25% of the cases.[4,5] When signs of complications occur, an ultrasonographic examination

of the abdomen is commonly performed to rule out peritonitis, cervical abscessation, hemorrhage, and/or UTI. However, the sonographic characteristics of the normal postoperative abdomen may overlap with potential pathologic findings. Normal surgical reactions such as hyperechoic fat, pneumoperitoneum, peritoneal effusion, and postoperative ligature resorption can be difficult to distinguish from postoperative peritonitis and cervical abscessation.

Following a comprehensive literature review, no published studies describing the abdominal sonographic features after treatment for pyometra by OHE in dogs were found. There were only a few studies available to date that describe the normal sonographic appearance of the abdomen in dogs after any surgical procedure.[6-9] Hence, it can be difficult for veterinarians to decide whether reactions seen at the sonographic examination are part of a normal postoperative process or if a postoperative complication has occurred.

Aims of this study were to describe the postoperative sonographic features of the cervix, mesovarium ligatures, medial iliac lymph nodes (MILNs), and surrounding abdominal tissues at three different time points following OHE in a group of dogs with pyometra and an uneventful recovery. Our hypotheses were that the cervical stump, the mesovarium area, and the MILNs would differ in size and other characteristics among the three examination time points.

2 | MATERIALS AND METHODS

2.1 | Selection and description of subjects

This prospective observational study was approved by the ethical committee of the Swedish Board of Agriculture (DNR C 31/16). All examinations were performed at Evidensia Specialist Animal Hospital Helsingborg. All dogs were privately owned and treated according to the discretion of the clinician and followed national antibiotic guidelines.[10,11]

The inclusion period went from March 2018 to November 2019. A convenience sample of privately owned dogs with clinical signs consistent with pyometra including; vaginal discharge, polyuria, polydipsia, inappetence, vomiting, lethargy, fever, and visually confirmed purulent content at incision of uterus after OHE, were included after informed owner consent.[12,13] Exclusion criteria were treatment with immunosuppressive drugs, sonographic signs of peritonitis before surgery, signs of leakage from the uterus during surgery and clinical signs of postoperative complications. Clinical signs of postoperative complications included fever (rectal temperature > 39.5°C) at the time of the second or third sonographic examination, postoperative intraabdominal bleeding, surgical wound infection, UTI requiring treatment, or abnormal vaginal discharge after discharge from the hospital. Furthermore, dogs with an increased serum concentration of C-reactive protein (CRP), at the day of the 2nd or 3rd postoperative sonographic examination, compared with baseline, were excluded, as this was interpreted as a sign of abnormal recovery.[14-16]

2.2 | Data recording and analysis

All included dogs had three sequential, standardized sonographic examinations of the abdomen. These were performed the day after surgery, 4–6 days after surgery, and on the day of suture removal day 10–15. The sonographic examinations were performed by five different veterinarians, all with several years of practical experience in ultrasonographic imaging. All examinations followed a standard protocol and were performed in B-mode using a GE ultrasound machine (Logiq E9) and a linear transducer (9–11 MHz). All dogs were positioned in dorsal recumbency during the sonographic examination.

The standardized ultrasound protocol started with an A-FAST (abdominal focused assessment with sonography for trauma) examination to look for free fluid.[17] An abdominal fluid score (AFS), if found, was entered into the patient record. After the A-FAST, the highest level of the abdomen was checked for pneumoperitoneum. A video loop of the cervical area, in longitudinal and transverse plane, was recorded in a left to right and a caudal to cranial direction, respectively. Still images of the maximum longitudinal cross sectional area size of the MILNs, which had been acquired with the probe placed ventrolateral on the dog and directed roughly 45° to the midsagittal plane, were saved. A video loop in sagittal plane over the left and right mesovarium area was recorded in a lateral to medial direction.

All images and videos were reviewed by one of the authors (M.N.), a veterinarian with a national specialist degree in diseases of dogs and cats, and with 15 years of experience in diagnostic ultrasonography. Measurements were done in the image review platform of the hospital's Picture Archiving and Communication System (SECTRA IDS7, v22.2, SECTRA AB). The recorded video loops were scrolled to assess the margins of the cervical stump and mesovarium ligature reaction. The frames with maximum cross-sectional area, later referred to as size, were chosen for measurements. The maximal length of the cervical stump was measured in longitudinal plane by placing the caliper at the level of the ligature and at the outer cranial margin of the hyperechoic area identified as the cervix. The maximal height of the cervix in longitudinal view was measured at two locations, cranial and caudal to the ligature, by placing the caliper at its most ventral and dorsal outer margins (Figure 1A). In the transverse plane, the image location containing the cervical stump at its maximal size was located. At that location, both the maximum diameter (referred to as width) and the orthogonal diameter (referred to as height) were measured. The transverse area of the cervix stump was calculated by marking the outer hyperechoic margin with pointers at eight different sites to get a ROI area (Figure 1B). The maximal length of the mesovarium reaction was measured parallel to the long axis of the scan plane of the transducer, by placing the calipers, at its outer hyperechoic margins. The point of its maximum height was identified and measured orthogonal to the length (Figure 1C). The maximum height and length of the MILNs were measured on the still images (Figure 1D). The characteristics of the cervical stump, mesovarium reaction, and the MILNs were documented.

The included dogs underwent a preoperative clinical examination and blood sampling. Clinical examination and blood sampling were
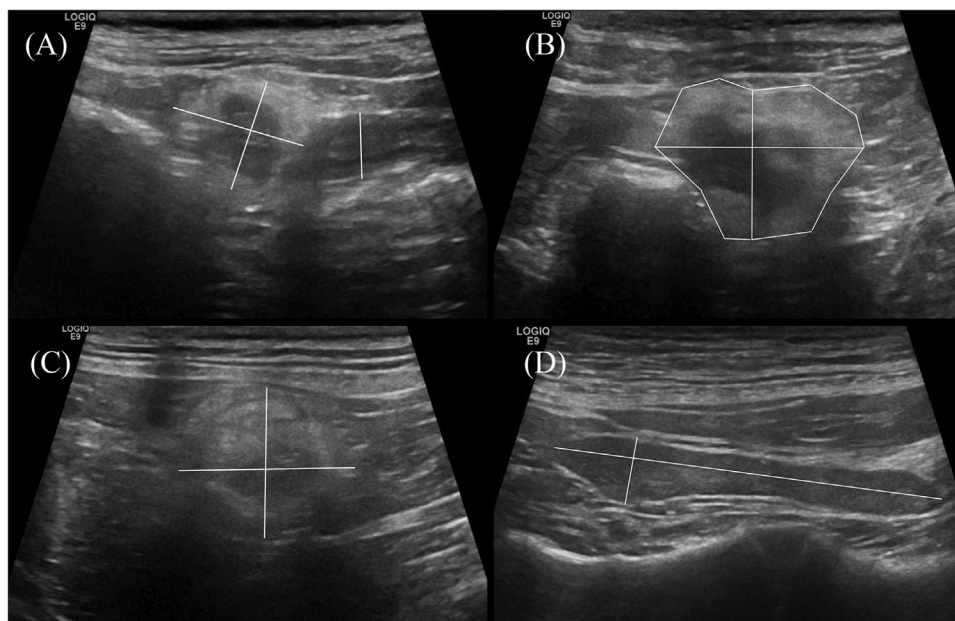
FIGURE 1 B-mode ultrasound images, with calipers, to illustrate method of measurements of A, Longitudinal view of cervix. B, Transverse view of cervix. C, Sagittal plane of mesovarium. D, Longitudinal view of medial iliac lymph node.

repeated the day after surgery, 4–6 days after surgery, and at the day of suture removal day 10–15. At each examination the following information was recorded by the attending Licensed veterinarian: body weight, general condition, color, and hydration of mucous membrane, capillary refill time, skin turgor, body condition score (BCS), arrythmia, heart murmur, heart beats per minute, signs of abdominal tension, signs of abdominal pain, signs of infection in the surgical incision, body temperature, and signs of vaginal discharge. The BCS was rated 1–9, according to WSAVA guidelines, and further divided into underweight ≤3, normal weight 4–5, and overweight ≥6, in the statistical analysis. As only one dog was found to be underweight, it was excluded from the statistical analysis of body weight. The pre-operative minimum database included CRP, hematocrit, leukogram, total serum protein, alanine aminotransferase, creatinine, urea and potassium. Serum CRP concentration and a leukogram were analyzed at day 1, 4—6, and 10–15 postsurgery.

The dog owners filled in a short questionnaire on entry into the study and at the follow-up visits on day 4–6 and day 10–15. In the questionnaire, the owner was asked to grade their dog's general condition from 1 to 10 and to state which, if any, medications the dog was given. They were also asked several questions regarding whether their dog had any vaginal discharge, vomiting, signs of hematuria, polyuria, polydipsia, and pollakiuria. A follow-up questionnaire was sent out by regular mail 2 months postsurgery. The dog owners were again asked to grade their dog's general condition from 1 to 10 and to state if the dog had vaginal discharge. They were additionally asked if they had identified any complications to the surgery if the surgical wound had healed satisfactorily, and whether they felt that their dog had a better general condition than in the time period before the signs of pyometra.

Immediately following surgery, the surgeon concerned filled in a form with questions regarding surgical approach including suture and ligature technique, omental wrapping of cervical stump, and cauterizing of stump. The ligature material, time from incision to closure and if any bleeding was noted from the ligatures during surgery were documented. The surgeon also recorded if signs of uterine rupture were detected during the surgery and if purulent content was present after incision into the excised uterus. Finally, the surgeon's name and experience (years in the veterinary profession) were recorded.

2.3 | Statistics

Statistical analyses were completed by a veterinarian with a PhD level training in statistics (IL), using a commercially available software program (JMP Pro 16.0.0). Data were presented as median with inter quartile range (IQR) and as mean with standard deviation. A value of $P < .05$ was considered statistically significant for the analyses, if not otherwise indicated. Area measurements of ultrasonographic variables were corrected for body surface area (BSA) and length measurements were corrected for body weight (BW). For continuous outcome variables, overall differences between time-points of examination were investigated using a mixed linear model including dog identity as a random variable and time-point of examination as a fixed variable. The normality of the distributions of model residuals was ensured by subjective evaluation. The Tukey HSD test was used as post hoc test for pairwise comparison of examination points. For ordinal outcome variables, differences between time points, for each individual, were investigated using the Wilcoxon sign-rank test with Bonferroni corrected P-values for multiple comparisons.

TABLE 1 Baseline data at inclusion for 22 dogs with pyometra.

Parameters at inclusion	Variable	Range (median) or number of dogs (%)
Age (y)		0.7–11.2 (7.9)
Body weight (kg)		7.1–36.6 (19.8)
Body condition score (1–9)		3–8 (6)
Breed	Mixed breed	3 (14)
	Golden retriever	2 (9)
	Cavalier King Charles Spaniel	2 (9)
	Miscellaneous	15 (68)
Major clinical signs	Polyuria	12 (52)
	Polydipsia	13 (56)
	Fever (>39.5°)	1 (4)
	Vaginal discharge	18 (78)
	Decreased general condition	14 (60)
Medication	Glucocorticoid opthalmic ointment	1 (4)
	Ciclosporin opthalmic ointment	1 (4)

TABLE 2 Serum C-reactive protein concentration and selected leukogram parameters, at the day of ovariohysterectomy and at three time points postoperatively in 22 dogs with pyometra diagnosis.

Parameter	Reference interval	Day of OHE Median (IQR)	Day 1 Median (IQR)	Day 4–6 Median (IQR)	Day10–15 Median (IQR)
C-reactive protein (mg/L)	0–30	175 (66–264)	135 (102–168)	42 (31–72)	<10 (<10–25)
Total leukocyte count (10^9/L)	5.1–16.8	21.2 (16.0–32.3)	35.0 (26.4–45.4)	16.0 (11.5–21.2)	10.7 (8.7–13.5)
Total neutrophil count (10^9/L)	3.0–11.5	14.5 (10.4–19.4)	28.7 (21.2–36.8)	11.7 (9.0–17.8)	8.2 (6.8–9.6)
Total neutrophil band cell count (10^9/L)	0–0.3	1.2 (0.4–3.6)	1.3 (0–2.5)	0 (0–0.6)	0 (0–0.03)

Abbreviation: OHE, ovariohysterectomy.

3 | RESULTS

3.1 | Baseline data

Twenty-two client-owned dogs that underwent OHE following a pyometra diagnosis were included in the study. The study population consisted of a variety of dog breeds, ages, and sizes (Table 1). One of 22 dogs was sedated during one examination, otherwise all dogs were scanned without sedation. Inflammatory parameters including serum CRP, blood leukocyte, neutrophil, and neutrophilic band cell counts, at the three occasions are shown in Table 2. None of the dogs were treated with antibiotics. Selected clinical data, at the day of OHE are outlined in Table 3.

3.2 | Surgical procedure

Ten different surgeons with varying levels of experience in the veterinary profession (1–15 years) performed the surgery on these dogs. The time from incision to closure ranged from 15 to 130 min. All but one dog had the cervix and the ovarian vessels ligated with polyglactin 910

(Vicryl). One dog had ligations with poliglecaprone 25 (Monocryl). Different techniques for ligation were used including simple, anchored, and modified Miller's knot. One or two ligatures were placed around the cervix and ovarian vessels. The cervical stump was cauterized in seven cases and the omentum was wrapped around the cervical stump in 15 cases. There was no difference in the cross-sectional cervical area between dogs that had their cervical stump wrapped by the omentum ($P = .93$). Neither was there any difference between the cauterized and noncauterized group ($P = .70$). No signs of uterus rupture were seen in the 22 dogs. On postoperative incision of the uterus, macroscopic purulent material was detected in all cases.

3.3 | Ultrasound features

The abdominal fluid score was reduced at day 10–15 compared with day 1 ($P = .0011$), and day 4–6 ($P = .0016$) after surgery. At day 1 and day 4–6, free fluid was detected in almost half of the dogs (45% and 41%, respectively), whereas after 10–15 days fluid was detected in only 9% of the dogs. Pneumoperitoneum was seen in 14% of the dogs on day 10–15, compared with 95% and 82% at the earlier checkpoints

TABLE 3 Selected clinical data, at the day of ovariohysterectomy and at three time points postsurgery, in 22 dogs with pyometra diagnosis.

Parameter	Day of OHE Median (range) or % of dogs (number)	Day 1 Median (range) or % of dogs (number)	Day 4–6 Median (range) or % of dogs (number)	Day 10–15 Median (range) or % of dogs (number)	2–6 months Median (range)
Temperature (°C)	38.6 (37.7–40.3)	37.9 (37.1–39.3)	38.5 (37.8–39.4)	38.6 (37.8–39.3)	
Vaginal discharge	77% (17)	41% (9)	36% (8)	32% (7)	
General Condition (1–10)[a]	5 (1–10)		3 (1–8)	1 (1–3)	1 (1–3)
Medication					
NSAID	0	70% (16)	45% (10)	0% (0)	0% (0)
Opiod	0	100% (22)	9% (2)	0% (0)	0% (0)

[a]Estimated by dog owners, where 1 is good general condition and 10 is severely decreased general condition.

TABLE 4 Abdominal fluid score and number of dogs with free fluid and pneumoperitoneum at three time points after ovariohysterectomy, in 22 dogs with pyometra diagnosis.

Parameter	Day 1 Number (%)	Day 4–6 Number (%)	Day 10–15 Number (%)
Free fluid	10 (45)*	9 (41)*	2 (9)†
Pneumoperitoneum	21 (95)*	18 (82)*	3 (14)†
AFS 0–4[a]	*	*	†
0	12 (55)	13 (59)	20 (91)
1	7 (32)	9 (41)	2 (9)
2	2 (9)	0 (0)	0 (0)
3	1 (5)	0 (0)	0 (0)
4	0 (0)	0 (0)	0 (0)

Note: a: AFS, Abdominal Fluid Score 0 = no fluid, 1 = in one quadrant of the abdomen, 2 = in two quadrants of the abdomen, 3 = in three quadrants of the abdomen, 4 = in four quadrants of the abdomen. *,†.: levels not connected by the same symbol are significantly different. Within each row, values with the same superscript symbol did not differ significantly (Bonferroni corrected $P < .017$ was considered significant).

($P = .0001$). A-FAST score results and the number of dogs with free fluid and pneumoperitoneum at the three examination points are presented in Table 4.

The cervical stump was detected in all 22 dogs at all the selected examination time points. The cervical stump had a mixed echogenicity with a hypoechoic central region and a hyperechoic margin of varying degree of thickness (Figure 2). There was a correlation between body weight and the cross-sectional cervical area ($P = .026$, adjusted $R^2 = 0.18$), but no correlation was seen with body condition score ($P = .92$). The cervical stump area varied from 73–736 mm^3 on day 1, 153–895 mm^3 day 4–6 and 104–565 mm^3 on day 10–15. Measurements of the area, length, width, and height of the cervical stump are illustrated in a box diagram (Figure 3).

The mesovarium areas were recognized in all 22 dogs at the three examination points. These appeared as hyperechoic, heterogenic areas with edge shadowing and/or central shadowing artefacts (Figure 4).

The cervical stump was larger in all dimensions on day 4–6 compared with the day after surgery and at day 10–15. The size of the mesovarium ligature reaction did not differ between the selected time-points of examination. Body weight and body surface area corrected data, including correlation P-values, of the cervical stump and mesovarium reaction are reported in Table 5.

The right MILN was detected in all 22 dogs on day 1 and day 4–6 and in 19 dogs (86%) on day 10–15. The left MILN was detected in 21 dogs (95%) on day 1 and day 4–6; and in 18 dogs (82%) day 10–15. The mean lymph node height was 8.1 mm for the left MILN and 8.0 mm for the right MILN on day 1 with a standard deviation of 3.6 vs. 3.5 mm. The height of the lymph nodes did not differ between the selected examination dates ($P = .077$ (left MILN), $P = .056$ (right MILN)). Body weight corrected data of the lymph nodes is reported in Table 5. The majority (>93%) of MILNs had an oval/fusiform shape, which did not differ between the examination points ($P = .53$). 97% of the MILNs were hypoechoic and 7% were isoechoic compared with the surrounding tissues. No difference was seen between the examination points ($P = .34$).

4 | DISCUSSION

The findings that the cervical stump was significantly larger on day 4–6 compared with the other two examination time points support our hypothesis that the cervical stump would differ in size among time points. The study did not provide evidence to support the other hypotheses mentioned, namely that the mesovarium area, the MILNs size, and other characteristics would differ among time points during the first 15 days post-OHE.

This is the first published study to describe normal postoperative sonographic findings after OHE in dogs with pyometra. Based on our study, the cervical stump, the reaction around the mesovarium ligatures, and the medial iliac lymph nodes could be readily visualized by sonography after ovariohysterectomy. The detail and the size of the cervical stump varied widely between individuals. The reaction around the mesovarium ligatures was subjectively harder to define than the cervical stump. This indicates that measurements of this reaction are likely unreliable. While the cervical stump was more well-defined, a
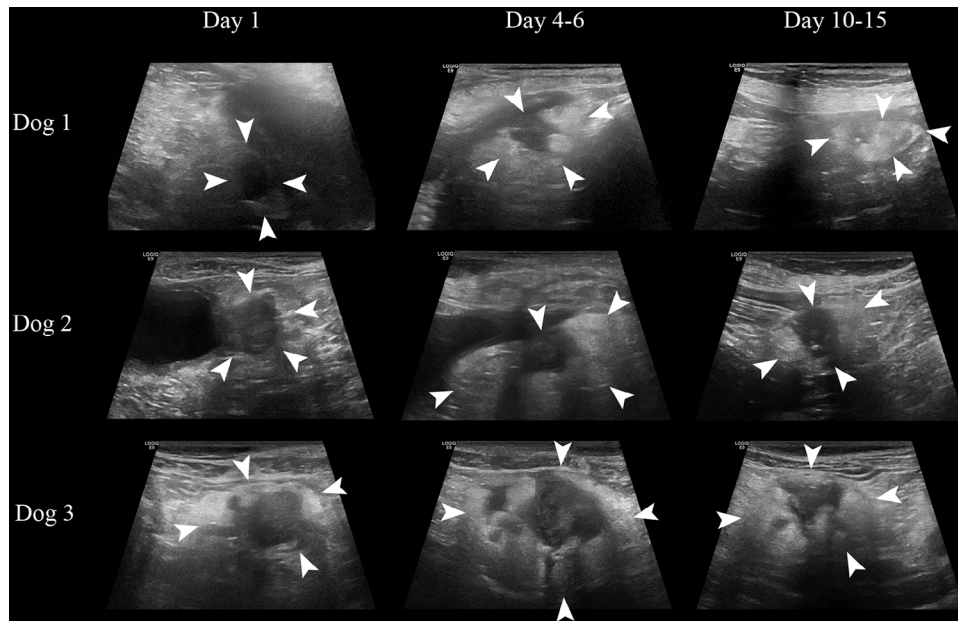
FIGURE 2 B-mode ultrasound images of the cervical stump in transverse view, in three different representative patients, at the three exam points (day 1, day 4–6, and day 10–15 postsurgery). All images are in the same scale. The arrow heads outline the outer margin of the hyperechoic reaction around the cervical stump. This figure illustrates the somewhat diffuse reaction and the wide range of variations between patients.
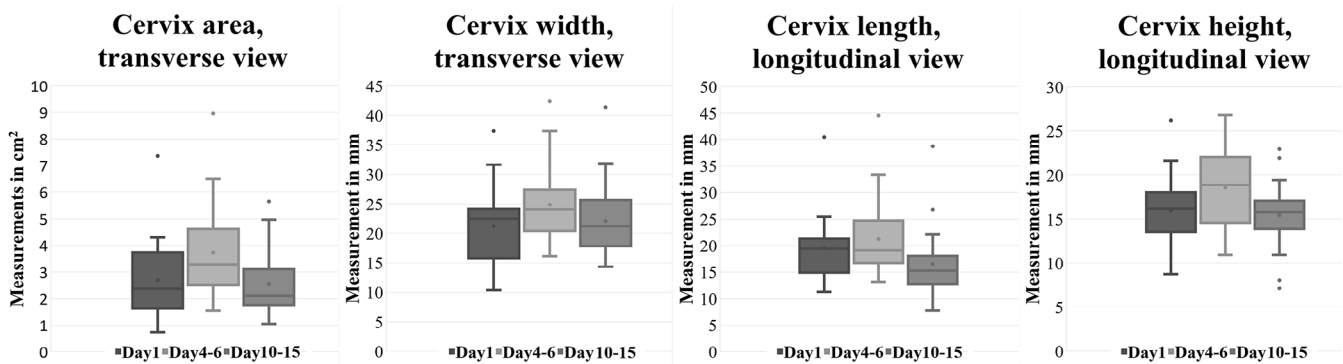

FIGURE 3 A box plot of 22 dogs, treated for pyometra, showing the range of the cervical size after ovariohysterectomy, at the three time points used for follow-up examination. The box illustrates the first, second and third quartile. The dot in the box represents the mean. The whiskers identify the smallest and largest measurement, and the outer dots represent the outliers (defined as 1.5 times the IQR larger than the third quartile or 1.5 times the IQR smaller than the first quartile).

video-loop of the area, instead of a still image, is in the authors' opinion essential to determine the borders. Furthermore, the cervical stump was larger on day 4–6 compared with both the day after surgery and the day of suture removal (day 10–15), even though individual variations were seen.

The larger cervical stump on day 4–6 is thought to reflect the normal stages of wound healing. In wound healing, the inflammatory phase dominates the first 3 days after surgery, followed by the proliferative phase, which starts about 3 days after surgery and continues for 2–4 weeks, whereafter the remodeling phase takes over.[18] This finding in our study is similar to that found in a study about the postoperative appearance of enterectomy, where the maximal wall thickness occurred between day 3 and 6, postoperatively.[6]

A resolution of free fluid and pneumoperitoneum was seen over a 4—15-day period. This is compatible with what has been described in previous reports on the postoperative abdomen after enterotomy.[6,19] However, free fluid was seen in all dogs on the day after laparotomy in one of the studies,[6] compared with 45% in our study. A possible explanation for this is that peritoneal lavage of the abdomen is more commonly performed after enterotomy than after OHE.[20] In our study none of the dogs had a peritoneal lavage.

The MILNs did not significantly differ in height between the selected time-points of examination, but there was a tendency toward a continuously decreasing height from day 1 to the day of suture removal. The height of the MILNs in this study were slightly greater the day after surgery (mean 7.5 mm) than preliminary normal reference values
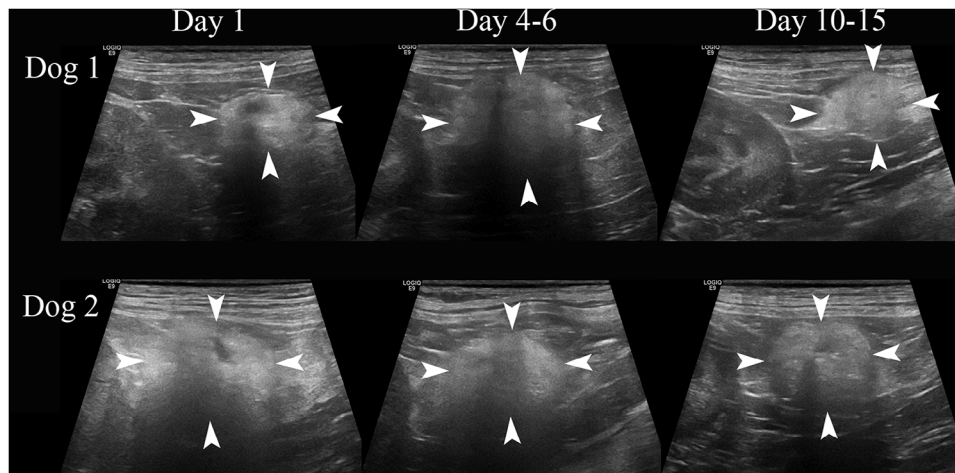
FIGURE 4 B-mode ultrasound images of the mesovarium area in transverse view, in two different representative patients, at the three exam points (day 1, day 4–6, and day 10–15 postsurgery). All images are on the same scale. The arrow heads outline the outer margin of the hyperechoic reaction around the mesovarium ligature.

TABLE 5 Sonographic measurements in 22 client-owned dogs with pyometra, at three time points after ovariohysterectomy.

Parameter (unit)	Day 1 Mean (SD)	Day 4–6 Mean (SD)	Day 10–15 Mean (SD)	P-value
Cervix in longitudinal view				
Length (mm/kg$^{1/3}$)	7.34 (2.29)*	8.05 (2.71)*	6.19 (2.25)†	<.0001
Height cranial to ligature (mm/kg$^{1/3}$)	5.99 (1.48)†	6.99 (1.87)*	5.86 (1.58)†	.0018
Height caudal to ligature (mm/kg$^{1/3}$)	4.54 (1.34)	4.48 (1.33)	4.13 (1.26)	.1357
Cervix in transverse view				
Area (mm2/0.101×kg$^{2/3}$)	363 (169)†	520 (235)*	360 (158)†	.0009
Height (mm/kg$^{1/3}$)	5.92 (1.39)†	7.16 (1.85)*	5.76 (1.42)†	.001
Width (mm/kg$^{1/3}$)	7.92 (2.30)†	9.35 (2.15)*	8.35 (2.24) *†	.0407
Left lymph node longitudinal view				
Length (mm/kg$^{1/3}$)	9.31 (2.98)*	9.06 (2.48)*†	7.74 (2.86)†	.02
Height (mm/kg$^{1/3}$)	2.95 (1.11)	2.85 (0.89)	2.44 (0.93)	.0774
Ratio height/length	0.32 (0.11)	0.33 (0.10)	0.34 (0.15)	.571
Right lymph node longitudinal view				
Length (mm/kg$^{1/3}$)	8.35 (2.08)	8.79 (2.47)	7.94 (81.93)	.1356
Height (mm/kg$^{1/3}$)	2.95 (1.03)	2.66 (0.81)	2.46 (0.81)	.0557
Ratio height/length	0.35 (0.11)	0.31 (0.08)	0.32 (0.11)	.297
Left mesovary sagital view				
Length (mm/kg$^{1/3}$)	9.07 (2.36)	8.98 (1.74)	8.04 (2.98)	.0848
Height (mm/kg$^{1/3}$)	5.69 (1.52)	5.98 (1.06)	5.45 (1.53)	.0631
Right mesovary sagital view				
Length (mm/kg$^{1/3}$)	9.72 (2.60)	9.61 (2.58)	8.33 (2.45)	.1302
Height (mm/kg$^{1/3}$)	5.97 (1.37)*†	6.73 (1.36)*	5.87 (1.52)†	.0225

Note: Area measurement is body surface area (BSA)[b] corrected and length measurements are body weight (BW)[a] corrected.
[a]BW corrected = length/BW$^{1/3}$.
[b]BSA corrected = area/0,101×BW$^{2/3}$.
,†,†: levels not connected by the same symbol are significantly different.

previously reported in normal dogs (mean 4.8 mm).[21] This difference in height may potentially be due to reactive lymphadenopathy secondary to inflammation. All lymph nodes in our study were hypo- or isoechoic to surrounding tissue and had a predominantly oval/fusiform shape, which is consistent with previous descriptions of normal and reactive medial iliac lymph nodes.[21–24]

The selected time points for follow-up examinations (day 1, day 4–6, and day 10–15 postsurgery) were chosen to be likely to provide the most useful information and to be convenient for the dog owner. The day after surgery the dogs were still in hospital and could be examined before release. The 4–6-day examination was chosen on the basis of an unpublished data search of medical records, of 100 dogs with pyometra, performed at the study center (Evidensia Specialist Animal Hospital Helsingborg). The search revealed that 20 dog owners sought medical care for suspected post-surgical complications, within the first 14 days postsurgery, with a median at day 5 (IQR 3–8). On day 10–15 after surgery, a routine appointment was booked, to check the surgical incision site and to have potential skin sutures removed. This allowed a final time point for a sonographic examination.

There are several limitations in this study. The sample size is small, which gives less power to the statistics and may have contributed to an underestimation of some associations. The population has a wide range of characteristics at inclusion, including age, size, breed, inflammatory response, size of uterus, size of cervix, different surgeons, and slightly different surgical techniques. All these parameters could potentially affect the body weight corrected size of the cervical stump and contribute to the large variation in the obtained data. Sonography is a subjective modality that is operator-dependent. This, in combination with diffuse reactions in the abdominal fat after laparotomy, could make measurements hard to reproduce between observers. In this study, it is both a strength and a weakness that while all the sonographic examinations were performed by five veterinarians, all measurements were made by the same observer. That is to say, the measurement results were not influenced by interobserver variability, but we do, on the other hand, not know the extent of such variability. All examinations in this study were performed by experienced sonographers. Structures found and evaluated might be harder for less experienced sonographers to identify and evaluate.

In conclusion, our study findings indicated that, in uncomplicated recoveries, the cervical stump was at its largest at day 4–6, and that there was a marked reduction of the size by day 10–15. Further case-control studies are needed to investigate potential sonographic differences between normal and abnormal healing. The result of this study may increase veterinarians' ability to interpret the complex post-operative state of abdominal tissues in dogs treated surgically for pyometra.

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Category 1

a. Conception and design: Nilsson, McEvoy, Toresson, Ljungvall, Nyman
b. Data aquisition: Nilsson
c. Analysis and interpretation of data: Ljungvall, Nilsson, McEvoy, Toresson

Category 2

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Category 3

a. Final approval of the completed article: Nilsson, Mc Evoy, Toresson, Ljungvall, Nyman

Category 4

a. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: Nilsson, Mc Evoy, Toresson, Ljungvall, Nyman

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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The Process 2020 checklist was used.

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Data are available from the corresponding author upon reasonable request due to restrictions, e.g., privacy or ethical reasons.

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