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An evaluation of canine inguinal hernias containing the uterus: clinical experience of four cases (2017-2022) and literature review

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Abstract: The aim of this study is to identify and summarize the evidence and risk factors of canine inguinal hernia containing the uterus (Inguinal Hysterocele; IH) etiology by presenting our clinical experience with a literature review. A total of 18 canine IH cases were evaluated in the study. Of these, four have not yet been published anywhere, two have been published before, and 12 were obtained through a literature review. According to the findings, 81.3% of the cases were small/medium races, 83.3% were ≥5 years old, and 72.7% were multiparous. Totally 83.3% of the cases were chronic and 72.2% of the cases had a hernia on the left side of the body. In inguinal gravid hysterocele (IGH) cases, clinical symptoms started after >30 days of pregnancy. In addition to estrogen, repeated exposure to sex hormones and conception/birth status are also effective in etiology. Finally, the uterus herniates into the inguinal canal and conception/uterine pathologies occur in the already herniated uterus. Inguinal hysteroceles are causes life-threatening problems. In the clinic, inguinal swellings/masses can be confused with adipose tissue, so careful control and surgical intervention of swellings/masses can eliminate serious problems that may develop.

Key words: Abdominal hernias, bitch, hormonal etiology, hysterocele

1. Introduction

Inguinal hernia, which is described as the protrusion of an organ or a tissue into the inguinal canal [1], is classified among caudal abdominal hernias. This condition is most common in horses, boars and dogs, and rare in cattle [2] and feline [3]. Sex is an important factor in the development of inguinal hernias, which are categorized as either congenital or acquired and traumatic or nontraumatic [1]. Acquired and nontraumatic hernias are more common in females and congenital hernias are more common in males [4].

Clinically, inguinal hernias can be confused with malignant mammary gland tumors, mastitis, inguinal lymph node hypertrophy, lipomas, hematomas, granulomas or local abscesses [1]. Internal organs that may be involved in hernial protrusion include the small intestines, colon, urinary bladder, spleen and uterus [5]. In their retrospective study on 41 cases, Itoh et al. [6] reported that the uterus was more inclined to herniate (68%), when compared to the small intestines (41%) and colon (5%). In a study, reported the presence of the uterus in the hernial sac of 23.07% of the unneutered bitches they examined; and indicated to have observed the development of inguinal hysterocele (IH) in 7.69% of the unneutered bitches [4]. Furthermore, Itoh et al. [6] reported to have detected the inguinal normal/healthy hysterocele (INH), inguinal gravid hysterocele (IGH), and inguinal pathologic hysterocele (IPH) at rates of 62.5%, 12.5% and 18.75%, respectively.

As can be seen, the uterus is the most frequently herniated organ [4,6] and it has its own characteristics apart from other organ herniations. For example, as can be seen above, herniation of the uterus is called hysterocele [7] and there is no special nomenclature in inguinal hernias associated with other organ herniation. Since it is a reproductive organ, clinical findings can be seen in a wide range from asymptomatic to pyometra-associated symptoms. Moreover, in the case of IGH it is doubtful whether the pregnancy will continue. Finally, the etiology of canine IH has not been definitively revealed, yet [2,8–10]. Therefore, there is a need for specific evaluation of IH in dogs. At this point, due to the impossibility of planning a prospective study on canine IH, available information sources are limited to case reports and retrospective studies. Due to the paucity of information on the epidemiology and etiology of IH in dogs, research in this field has received considerable attention.

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In this paper, we report four cases of canine IH three of them include IGH, and one of them includes a pyometric hysterocele. We also performed a literature review of IH in bitches. Our aim was to identify and summarize the evidence and risk factors of canine IH by providing a comprehensive evaluation of the etiological and clinicopathological findings and treatment results.

2. Description of four cases

Having not been published elsewhere, data pertaining to the four cases of IGH and inguinal pyometric hysterocele, which were diagnosed and treated at our clinic, are presented in Table 1.

Case 1 was admitted twice to our clinic. The first admission was due to a swelling of the left inguinal mammary gland, which was indicated to have persisted by the fifth month postpartum. Ultrasonographic examination of the animal revealed the INH, and although surgical treatment was recommended, the animal owner rejected this. The patient was admitted to the clinic for a second time, two months after its first admission, with complaints of the enlargement of the swelling, anorexia and lethargy. In the examination, IGH was diagnosed, and this time surgical treatment was accepted by the animal owner.

All four cases were treated with herniorrhaphy and ovariohysterectomy. After the herniated uterus and hernial content were relocated to the abdominal cavity with herniorrhaphy, the uterus was surgically removed with ovariohysterectomy. The examination of the hernial content demonstrated that in all four cases the entire uterus had herniated into the inguinal canal. In Case 1, the intestines and omentum were observed to have herniated together with the uterus. Based on information gathered from the clinical follow-up of the cases during the first month after surgery and a phone survey ranging from two to four years, none of the cases were determined to have developed any short or long-term postoperative complication. Macroscopic examination showed that while the size of the fetal sac varied among the same uterus, some of the fetal sacs were tight, and others were soft. Either the uterine horns displayed bending or torsion or there was a narrowing between the fetal sacs, and these areas displayed pathologies ranging from ischemia to necrosis, which were associated with color changes. The examination of the uterine content/fetal sacs revealed that while animals in 30 days or 36–38 days of gestation (Cases 1 and 2) showed signs of fetal viability, in fact fetal resorption had started in some of the fetal sacs. In Case 3, which was in 52–54 days of gestation, fetal maceration was detected. In the case diagnosed with pyometra (it is stated as case 4 in Table 1 and case 10 in Table 2), the uterine lumen was observed to be filled with a putrid yellowish content.

3. Materials and methods

In total 18 cases were evaluated in this review. These included six cases that were diagnosed and treated at our clinic and 12 cases found by literature review. Four out of our six cases have been reported in this review, on the other hand, 2 out of them were published before in 2011 [11]. The cases evaluated in this review and their sources are presented in Table 2.

All cases were evaluated for the breed, size, age, body weight and parity of the animal, time of appearance and localization of the inguinal mass, clinical findings, hemogram and serum biochemical parameters, estrus/coitus, gestational age, signs of fetal viability, treatment procedure, hernial content, macroscopic and histopathological findings of the uterine tissue excised at surgery, and postoperative complications.

The selected criteria were evaluated for age groups of ≥5 years (middle-aged and senior animals) and <5 years (young animals) and case duration periods that were defined as acute (≤3 weeks) and chronic (>3 weeks).

Table 1. The cases diagnosed and treated at our clinic, the data of which has not been published elsewhere.

Our case number	Breed/size	Age (y)	BW (kg)	Parity	Duration/ localization of swelling	Estrus / coitus	Gestational age (d /fetal viability / uterine content
Our Case 1*	Crossbred/M	7	20	>1	6 m/L	+/45 d	36–38 /+/FR
Our Case 2	Terrier/S	11	8.5	>1	4 y/R	nd/nd	30/+
Our Case 3	Transylvanian hound/M	8	22	>1	2 w/L	+/60 d	52–54/-/FM
Our Case 4**	Rottweiler/M	9	36	>1	4 m/L	nd/nd	Pyometra

M: Medium, S: Small, L: Left, R: Right, nd: No data, FR: Fetal resorption, FM: Fetal maceration

*At the first admission, although the animal was diagnosed with inguinal hysterocele, the owner rejected surgical treatment. At the second admission, the animal was diagnosed with inguinal gravid hysterocele.

**This case was presented as case 10 in Table 2 because of the classification of the cases evaluated in this review.

Inguinal gravid hysterocele cases were evaluated under two groups that included animals in ≤30 days and >30 days of gestation.

Based on clinical diagnosis, uterine content and histopathological diagnosis, the cases with IH were assigned to three groups, including animals with IGH (n = 9), IPH (n = 6), and an INH (n = 3). Table 2 shows the study groups and their sources.

Although ultrasonographic and macroscopic examinations revealed no fetal tissue in the inguinal sac in Case 6 [12] and Case 7 [5], based on the histopathological detection of fetomaternal tissues, gestation was considered to have terminated and these two cases were included in the IGH group (Table 2).

4. Results

The results of all evaluated cases are summarized in Table 3.

Of the evaluated cases, 33.3% were terriers or breeds that carried terrier genes (Boston terrier, Maltese, West Highland, Doberman pinscher) and 16.7% were crossbreds. While the body size of two cases was not able to be determined from literature data, 81.3% (13/16) of the remaining cases were small- or medium-sized breeds. Of all cases, 83.3% (15/18) were aged ≥5 years and 16.7% (3/18) were aged < 5 years (Table 3).

Parity data was able to be obtained for only 11 animals from previous case reports. Accordingly, 72.7%, 18.2% and 9.1% of the cases were multiparous, primiparous and nulliparous animals, respectively (Table 3).

The inguinal mass was determined to have displayed a chronic course for a period ranging from several months to four years in 83.3% (15/18) of the cases, and to have developed acutely in only 16.7% (3/18) of the cases (Cases 3, 4, and 9) (Table 3). The inguinal mass was located on the left side of the body in 61.1% (11/18) of the cases and on the right side of the body in 16.7% (3/18) of the cases, and was located bilaterally in 22.2% (4/18) of the cases. However, based on the examination of the hernial content, it was determined that in two of the bilateral cases (Cases 17 and 18), while the uterus had herniated to the left, the omentum and fat tissue had herniated to the right. Thus, rates of IH to the left and right were determined to be 72.2% and 16.7%, respectively. For one of the bilateral cases (Case 9), information on the direction of IH was

Table 2. Classification of the cases evaluated in this review and their sources.

Diagnosis	Case no	Source	References
Gravid Hysterocele (n = 9)	Case 1	New cases	Present study*
	Case 2		
	Case 3		
	Case 4	Published by our team	[11]
	Case 5		
	Case 6	Found by literature review	[12]**
	Case 7		[5]**
	Case 8		[13]
	Case 9		[7]
Pathologic Hysterocele (n = 6)	Case 10	New case	Present study*, ‡
	Case 11	Found by literature review	[8]
	Case 12		[14]
	Case 13		[15]
	Case 14		[16]
	Case 15		[17]
Normal Hysterocele (n = 3)	Case 16	Found by literature review	[18]
	Case 17		[19]
	Case 18		[9]

*Cases treated at our clinic and the data of which have not been published elsewhere.

**Cases included in the gravid hysterocele group based on the detection of fetal structures in the uterus at histopathological examination.

‡This case was represented as our case 4 in Table 1.

Table 3. Individual data and clinical classification of all evaluated cases.

Parameters		Hysterocele			Total (n = 18)
		Gravid (n = 9)	Pathological (n = 6)	Normal (n = 3)	
Age, range, year		3.5–11	5–13	3–12	3–13
	≥5 years	7	6	2	15 (83.3%)
	<5 years	2	0	1	3 (16.7%)
BW, median (range), kg		15.9 (2.45–35)	16.1 (7–36)	8	15.4 (2.45–36)
Size (n = 16)					
	Small-Medium	8	4	1	13 (81.3%)
	M. Large-Large	1	1	1	3 (18.7%)
Parity (n = 11)					
	Multiparous	5	1	2	8 (72.7%)
	Primiparous	0	1	1	2 (18.2%)
	Nulliparous	0	1	0	1 (9.1%)
Onset (n = 18)					
	Acute (≤3 w)	3	0	0	3 (16.7%)
	Chronic (>3 w)	6	6	3	15 (83.3%)
Affected body side (n = 18)					
	Left	7	4	0	11 (61.1%)
	Right	1	2	0	3 (16.7%)
	Bilateral	1	0	3	4 (22.2%)
Herniated portion of the uterus (n = 18)					
	Left	3	0	0	3 (16.6%)
	Right	0	1	0	1 (5.6%)
	Bilateral	6	4	3	13 (72.2%)
	Uterine body	0	1	0	1 (5.6%)
Surgical treatment (n = 18)					
	H	1	0	1	2 (11.1%)
	H+OHE	8	6	2	16 (88.9%)

M. Large: medium-large; H: herniorrhaphy; OHE: ovariohysterectomy

not available. In another case (Case 16), the left uterine horn was reported to have herniated to the left and the right uterine horn was indicated to have herniated to the right (Table 3). Furthermore, while both uterine horns had herniated in 72.2% (13/18) of the cases, only the left uterine horn had herniated in 16.6% (3/18), only the right horn had herniated in 5.6% (1/18), and only the uterine body had herniated in 5.6% (1/18) of the cases.

Estrus/coitus information was available for only six of the cases and pointed out to the animals having shown estrus/coitus 30 to 60 days before the onset of the complaints.

Both our clinical experience and case evaluations suggest that the clinical manifestation of IH depends on gestational age and the condition of the uterus. The clinical findings detected in each group are summarized in Table 4. Accordingly, the treatment of 20 to 25-day-old hysterocele cases with herniorrhaphy alone in the acute period enables the completion of both gestation and parturition without any harm to the uterus and fetuses (Case 18). The clinical findings associated with IGH vary with gestational age, such that gestation continues with no significant clinical finding in animals in ≤30 days of gestation. In cases of IGH, it has been observed that while fetuses survive in the hernial sac up to day 35, thereafter, fetal death occurs. As of >50 days, fetal maceration occurs. On the other hand, while gestation terminates in the herniated uterine horn, it is possible to observe the normal continuation of gestation in the other uterine

Table 4. Findings accompanying clinically diagnosed inguinal hysterocele.

Diagnosis	Other clinical signs/ CBC and biochemistry	Fetal viability	Macroscopy/histopathology	References
Gravid hysterocele				
≤30 d	No significant changes	+	Start and end of resorption / no change	Present study* [7] [11] [13]
>30 d	Anorexia, lethargy, vomiting, lameness/no significant changes	+ < 35 d - > 35 d	Start and end of resorption/maceration (>50 d) Histopathological diagnosis without the macroscopic observation of fetal structures	Present study* [5] [11] [12] [13]
Pathological hysterocele				
CEH-pyometra	Anorexia-lethargy, vomiting/ hyperproteinemia, lymphocytosis, monocytic anemia, hemoglobinemia, increased WBC CRP		Findings consistent with the CEH-pyometra complex, metritis-pyometra complex, and leiomyosarcoma	Present study* [7] [8] [14] [15] [16]
Hydrometra/ mucometra	No significant changes		Clear yellow watery uterine contents/ diffuse hemorrhage, edema, and hyperemia in the lamina propria	[17]
Normal hysterocele				
Incarceration	Vomiting/no data		Ischemic right horn at macroscopic examination	[18]
	No significant changes		No macroscopic changes	[9] [19]

*Cases treated at our clinic and the data of which have not been published elsewhere.
CEH: Cystic endometrial hyperplasia; WBC: White blood count; CRP: C-reactive protein

horn located in its normal position in the abdominal cavity (Case 7). Clinical or macroscopic findings associated with pregnancy are no longer present in advanced IGH cases but can be confirmed by histopathologic evaluation. Cases 6 and 7 are consistent with these findings, clinical uterine pathologies replace the terminated pregnancies. In the group including animals with IPH, the clinical presentation, complete blood cell count (CBC) and serum biochemical parameters were consistent with those associated with the cystic endometrial hyperplasia (CEH)-pyometra complex (Cases 10, 11, 12, 13, and 14) and hydrometra/mucometra (Case 15). In one of the cases displaying the INH, the clinical finding observed was vomiting and resulted from the incarceration of the herniated uterine horn (Case 16) (Table 4).

All of the cases evaluated in this review were treated by surgery. While 88.9% of the cases were treated with a combined surgical treatment of herniorrhaphy and ovariohysterectomy, 11.1% (2/18) of the cases underwent herniorrhaphy alone. Of the cases treated with herniorrhaphy alone, one displayed INH (Case 18) and the other presented with a 23 to 25-day-old acute IH (Case 9). In Case 9, after being returned to the abdominal cavity by herniorrhaphy, the uterus was removed by ovariohysterectomy once the parturition process was completed. No postoperative complications were observed during the clinical follow-up of the cases and the subsequent phone survey.

5. Discussion

The exact etiology of inguinal hernias has been elucidated neither in human medicine nor in veterinary medicine [2,8–10]. Based on our evaluations and experience, we consider hernias to be polyetiological. However, as already indicated in the literature, several risk factors are influential on the development of inguinal hernias. The findings of the present review suggest that the etiology of IH in dogs could be related to not only estrogen (E2) [20], but also progesterone (P4) [21] and relaxin (RLN) [22] levels as well as the gestation and parturition processes.

To date, risk factors influential on inguinal hernias have been categorized as anatomical, hormonal and metabolic factors [23]. However, the results of recent human medical research have altered this input. The main underlying reason of hernias appears to be the quantitative and qualitative abnormalities of the cells and extracellular matrix (ECM) [24] of the fascial connective tissue as well as of the elastic and collagen fibers [25].

Another significant cause of hernias is trauma. Normally, traumatic inguinal hernias are expected to result from an anatomical weakness of the muscles in the inguinal region [23]. In fact, only 14.3% of inguinal hernias result from serious trauma such as hit by a car [4]. None of the cases included in this review were of traumatic origin, and traumatic inguinal hernias are not the subject of this study. Besides, it seems that neurohormonal and physioanatomical changes that are exposed during normal pregnancy and parturition, in which there is a severe physical stress situation though not as much as trauma may also play a role in the etiology. All of the indicated factors could lead to herniation by causing defects in the fibroelastic structure of the inguinal canal.

5.1. Risk factors for the development of inguinal hernias

Risk factors such as sex, age, breed and size influence the development of inguinal hernias [23]. In humans, a very low or a very high body mass index as well as high intraabdominal pressure are also listed among risk factors [10].

Cases of inguinal hernia are, to a very large extent (75%), observed in unneutered bitches [4], middle-aged dogs and small to medium-sized dog breeds [6,23]. Furthermore, predisposition has been determined for several dog breeds, including among others, the Basenji, Pekingese, Poodle, Basset hound, Cairn terrier, Chihuahua, Cocker spaniel, Dachshund, Pomeranian, Maltese and West highland terrier [23].

The findings obtained in this review agree with the literature reports referred to above. However, the evaluation for parity revealed that more than 90% of the cases were multiparous. This suggests that gestation or repeated exposure to sex hormones could also act as risk factors. We speculate that sex hormones alone do not account for the etiology of herniation and that clinical and molecular changes, which occur during parturition, could also be involved in the etiology of herniation.

5.2. Genetics

In human medicine, inguinal hernias are considered to be of a complex multifactorial and hereditary nature. Thus, this type of hernia is more frequently observed in the daughters of women with inguinal hernia [10]. Researches have pointed out four suspect loci, which are effective in developing of connective tissue homeostasis and are associated with familial mutations that are passed over several generations [26]. While genetics are reported not to be involved in the etiology of inguinal hernias in veterinary medicine, there are breeds described as being predisposed to this condition. In fact, 33.3% of the cases evaluated in this review are terriers or breeds carrying terrier genes suggests that polygenic factors could be involved in the etiology. However, this hypothesis needs to be further supported by genetic data.

5.3. Anatomy, structure of the vaginal process, and components of the extracellular matrix

The inguinal canal is a structure localized to the caudoventral abdominal wall, through which the genitofemoral nerve, artery, and vein as well as the external pudental artery, and the male spermatic cord and the female round ligament pass. Being composed of internal and external inguinal rings, the inguinal canal is made up of the internal abdominal oblique and rectus abdominis muscles, the inguinal ligament, and the aponeurosis of the external abdominal oblique muscle [1]. As it can be seen the canal has a fibroelastic structure, and a defect in this structure causes herniation [2]. Inguinal hernias having been observed more frequently in unneutered bitches [4] could be related to the inguinal canal being shorter and wider in females, when compared to males [23]. However, this explanation is not sufficient. The keyword here is "unneutered". Because the morphological structure of the inguinal canal does not change in spayed females. Besides, Waters et al., [4] reported that inguinal hernias in males are more common at a young age (<2 years), therefore, they suggested that male inguinal hernias are congenital rather than acquired in dogs. These data mean that there are other factors affecting the fibroelastic structure of inguinal canal in females.

In domestic animals of both sex, anatomically, an exposed vaginal process is the main underlying reason of inguinal hernias. The degeneration of this structure, which should also be covered in humans, is listed as one of the main causes of inguinal hernias [23]. The vaginal process is formed by the protrusion of the peritoneum during the descent of the testes, and should disappear over time [10].

The fibroelastic structure of the inguinal canal has an important place in the etiology of inguinal hernias. Matrix components including collagen fibers, proteoglycans/glycosaminoglycans, elastin, fibronectin and laminin, and some enzymes build connections through a complex and highly dynamic network, and thereby, regulate the functions of this structure. The structure and composition of the ECM define tissue behavior [27]. The composition is dynamic, such that the contributory rate of ECM in the composition, fascial architecture, and levels of enzymes involved in connective tissue hemostasis are altered by physiological processes, such as gestation, as well as by various connective tissue and metabolic diseases [27–30].

The reorganization of the ECM throughout gestation and parturition is fundamental to the maintenance of normal reproductive functions. Elevated hormone levels during gestation bring about an increased elasticity of the fascial tissue [27]. Compared to control patients, individuals with inguinal hernia have been reported to have 1:3 less collagen in the tissues of the abdominal wall [10]. Inguinal hernias are more common in patients with connective tissue disorders [28,29]. Metabolic diseases are also involved in the etiology of hernias, such that diabetes mellitus has been reported in 8.4% of patients with a hernia of the abdominal wall [30]. The level of collagen in the transversal fascia and rectus sheath decreases with ageing [31]. In fact, 83.3% of the cases evaluated in this review were animals aged ≥5 years. Matrix metalloproteinases (MMPs) and lysyl oxidase activity play an important role in the failure of tissue homeostasis. For the maintenance of tissue homeostasis, MMPs digest the proteins of the ECM and lysyl oxidase cross bonds collagen and elastin [32,33]. The transversal fascia contains high levels of MMP-1, -2, and -9 and a low level of lysyl oxidase [10].

5.4. The effect of sex hormones

In view of inguinal hernias being more common in unneutered females and observed during estrus or gestation [23], and sex hormones having been determined to be effective in the development of inguinal hernias in mice [34], previous studies have focused on the etiological role of sex hormones [1,7,23], particularly on that of E2 [5,7].

In female dogs, physiologically, E2 levels start to increase during pro-estrus and peak just before the onset of estrus. Progesterone is found at high levels during diestrus and gestation, and ensures the maintenance of gestation [35]. Relaxin, the only pregnancy-specific hormone in dogs, is secreted as of day 25 of gestation [35] and facilitates parturition [22].

Sex hormones also have extragonadal functions, which support gonadal/reproductive activity, and various metabolic effects. Estrogen is involved in the development, maturation and ageing of the bone, muscle, and connective tissues [27,36], and shows an inhibitory effect on collagen synthesis and fibroblast proliferation [27]. Progesterone may cause temporary or permanent diabetes mellitus in bitches [37]. Diabetes mellitus alters the structure and functions of connective tissue by its effects primarily on collagen type I [30]. Through its integral role in the redevelopment of the multiple tissues of the musculoskeletal system [20], RLN enables the reformation of the pelvic symphysis by means of collagen catabolism, and the relaxation of the pubic ligaments during parturition [22].

As can be seen, E2, P4, and RLN affect the elasticity of the inguinal canal and/or the surrounding pelvic tissues. These hormones show these effects by altering enzymatic activity, and thus, the composition of the ECM. While E2 and P4 increase the activity of MMP-2, P4 decreases the activity of MMP-9 [38]. Owing to its collagenolytic effect, RLN enables the discharge of the activators of MMPs, collagenase and plasminogen, and thereby, alters ligament mechanics [20]. The expression of MMPs can be also induced by cytokines, growth factors, stress, and inflammation [39]. Gestation has significant effects on all these factors. In fact, gestation is a proinflammatory condition, which requires the physiological adaptation of the immune system of the mother. It is considered that both E2 and P4 contribute to the interaction of endocrine and immune factors through their effects on immune cells [21,40].

5.5. Clinical manifestation

Inguinal hernias are generally observed as painless swellings and do not present with incarceration or clinical findings [23]. Anamnesis reveals no finding other than the enlargement of an egg-sized mass [9,11]. Of the cases evaluated in this review, 83.3% involved chronic swellings and the patients were admitted to the veterinary clinic for the sudden or slow enlargement of the swelling. The tendency determined in this review for the herniation of the uterus into the left inguinal canal (72.2%) agrees with previous literature reports 57.14% and 94.12% reported by [4] and [6], respectively. The exact cause of this tendency has not been determined, yet. However, Itoh et al. [6] suggested that this tendency could not be explained by the anatomy of the inguinal canal or systemic factors. These researchers indicated that the ventrolateral mechanical effect of the descending colon on the left uterine horn would be greater on a physiologically and pathologically enlarged uterus. Nevertheless, they also stated that this proposition did not explain the cases encountered in male animals.

The most serious complication in hernia is incarceration/strangulation of the herniated organ [41]. However, as the inguinal canal is a natural anatomical structure, unless traumatic cicatrization occurs, there is no possibility of the canal being obliterated and the herniated organ being strangulated. Uterine incarceration appears to develop mostly due to the uterus itself. Indeed, in the cases evaluated in this review, clinical symptoms were observed upon the gradual enlargement of the inguinal swellings. The incarceration/strangulation of an enlarged uterus, due to either gestation or a pathological condition, in the hernia sac causes fetal death and circulatory disorder, and results in clinical symptoms. In the cases evaluated in this review, fetal deaths occurred as of the 30th day of gestation, fetal viability was not detected as of day 35, and terminated gestations presented with the risk of developing into uterine pathologies. As a result of the resorption of the fetus/

fetal structures and uterine circulatory disorders, IGH cases presented with clinical symptoms such as anorexia and lethargy. Cases of the CEH-pyometra complex also presented with clinical symptoms relevant to the disease. As of day >30 of gestation and in the event of IPH, clinical symptoms are accompanied by alterations in the CBC and serum biochemical parameters.

Fetal deaths and the clinical symptoms observed can be explained by ischemia-reperfusion (IR) damage, and this damage resulting from the incarceration and strangulation of the enlarged uterus in the hernial sac [14] triggers a rather complex pathophysiological process leading to cell damage and death, increased vascular permeability, tissue necrosis and multiple organ dysfunction [42]. It is well known that uteroplacental circulation is critical to the health and development of the fetus [43]. The incarceration of the placenta would cause local ischemic necrosis [44] and alterations in the regional blood flow of the placenta [45], which would eventually exacerbate the already poor condition. Indeed, as gestation advances, the risk of fetal death caused by acute placental failure-induced hypoxia increases [7,46]. It has been reported that, in the event of the IPH, IR damage would worsen the situation [14]. In the cases we treated, the macroscopic findings we observed in the incarcerated/strangulated regions of the uterus, such as color changes associated with pathologies ranging from ischemia to necrosis, are in support of the reports referred to above, despite laboratory/molecular tests not having been conducted.

While cases of inguinal hernia are treated by surgery, the treatment method applied should be tailored according to the specific health condition of the animal, the case being acute or chronic, the uterine content and the owner of the animal showing consent or nonconsent to the neutering of the animal. For example, as reported by Peinado et al. [7], in acute cases, in which the fetus, uterus and general condition of the pregnant animal are not yet adversely affected, it could be attempted to perform herniorrhaphy, return the uterus to its normal position in the abdominal cavity and allow gestation to progress. However, in cases of inguinal hernia, it is generally preferred to perform herniorrhaphy together with ovariohysterectomy with an aim to prevent possible recurrences and the hereditary transfer of polygenic factors [11]. Of the cases evaluated in this review, only one underwent herniorrhaphy alone [9], and another first underwent herniorrhaphy for the relocation of the uterus, and after the completion of the birth process, was neutered by ovariohysterectomy [7]. Herniorrhaphy and ovariohysterectomy were performed together in 88.9% of the cases.

Although laparoscopic repair may occur in cases of inguinal hernia, veterinary practitioners generally prefer standard surgery for treatment. The surgical treatment approach is based on performing a midline dissection, which enables the concurrent treatment of bilateral cases, and requires expanding the incision line [47]. This invasive method and similar approaches bear the risk of hemorrhage, infection of the incised area, wound dehiscence, hematoma, seroma, postoperative excessive swelling, recurrence, sepsis/peritonitis and death as postoperative complications [9]. Despite a postoperative complication rate of 17% [4, 48] and a death rate of 3% having been reported for inguinal herniorrhaphy, complications are rarely encountered [6] and long-term postoperative results are described as being excellent [17]. None of the cases we selected from literature reports and those we treated presented with postoperative complications or the recurrence of inguinal hernia.

5.6. Clinical interpretation

Based on the literature review, case evaluations and our clinical experience we consider three possible scenarios for the IH: 1) conception/uterine pathologies may occur while the uterus is located in its normal abdominal position, and uterine herniation may develop thereafter, 2) the entirety or part of the uterus may be displaced prior to conception/uterine pathologies occurred, enter the inguinal canal, but not complete its herniation, and 3) the uterus may complete its herniation prior to conception/uterine pathologies occurred, but this may go unnoticed by the owner of the animal.

Although there is a publication suggested that the ligamentum teres pulls the uterus into the inguinal canal [49,50], due to most cases following a chronic course and the possibility of the gravid or pathological uterus herniating into the inguinal canal without any trauma being low, we consider the first scenario to be less likely than the second or third scenarios. Indeed, a uterus that partly enters the inguinal canal before pregnancy may easily herniate in its entirety because of an increased weight due to the developing fetus(es) or uterine pathologies. However, we consider the most likely scenario to be the third. Firstly, in agreement with the literature reports evaluated in this review [6,23] most of the cases being chronic (83.3%), having developed in middle-aged to senior animals (83.3%), having appeared and increased after estrus/coitus, displaying a parity of ≥1 (>90%), and the acute cases having occurred in animals aged 5–8 years, two of which were multiparous, as well as the most commonly herniated hollow organ being the uterus and the herniation of the normal uterus being observed at a high rate [6] have led us to this conclusion. On the other hand, it is also possible for inguinal hernias to be rather small and go unnoticed [23]. In such cases, lipoidosis of the mammary glands caused by advanced age and repeating lactations, and the inguinal mammary lobes having a more secluded anatomical position may result in

the hernial swelling being confused with fat deposition. The indifference of the animal owner may also result in the hernia going unnoticed. In view of this information, we speculate that the uterus herniates into the inguinal canal after parturition, and that subsequent conception/uterine pathologies develop in the already herniated uterus. Thus, we consider the gestation and parturition processes to have an important etiological role in inguinal hernias.

6. Summary and conclusion

The etiology of the IH is multifactorial. Clinical evaluation can provide only limited data on cases of inguinal hernia and comments on the etiology are not more than speculation. Furthermore, as performing a prospective study on inguinal hernias in dogs is almost impossible, case reports are highly important in understanding canine inguinal hernias. However, case reports should not be limited to describing the clinical process, but rather provide complementary data on factors such as tissue elasticity, the ECM and MMPs, as well as molecular findings. Molecular findings could provide supplementary data for determining the etiology and may even alter the prevailing opinion.

Unfortunately, we were not able to make a molecular evaluation of the cases we treated at our clinic. Therefore, although our propositions are highly speculative, they draw attention to three factors that, to date, have not been assessed in detail for cases of inguinal hernia.

Our major findings can be summarized as follows: IH generally develop in middle-aged to senior and multiparous dogs, follow a chronic course, and manifest clinical symptoms after conception/uterine pathologies occurred. Based on the assessment of these findings together with available data and our clinical experience, we speculate that: 1) repetitive exposure to sex hormones and conception/parturition has an important etiological role in canine IH, 2) thus, not only E2, but also P4, RLN and the parturition process contribute to the etiology, 3) the uterus herniates into the inguinal canal as a result of these processes and conception/uterine pathologies occur in the herniated uterus.

Cases of IGH and IPH can be treated only by surgical intervention. Once the uterus has been determined to have herniated, herniorrhaphy should be performed regardless of the uterus being gravid, pathological or normal, and the animal should be neutered in view of the risks/effects of polygenetic factors. The method to be applied in the event of gestation should be decided according to the state of the uterus. If the uterus is not incarcerated/strangulated, ischemic/necrotic areas have not developed, and fetal viability is confirmed, the herniated uterus can be relocated to allow for parturition to occur under monitoring. This option seems viable for cases into 25 days of gestation. In cases with greater gestational age, performing ovariohysterectomy would be more reasonable. It is recommended to perform laparoscopic interventions rather than standard surgical interventions with a view to ensure better animal welfare conditions.

To avoid their underestimation, inguinal swellings should be examined cautiously by palpation and ultrasonography, and closely monitored. Thereby, inguinal hernias can be diagnosed early, and the appropriate treatment options can be determined without delay, preventing further deterioration of the condition. In view of the uterus being the most commonly involved organ in inguinal hernias, we assume that our speculations may also apply to nontraumatic and noncongenital inguinal hernias in general.

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