Computed tomography and magnetic resonance imaging findings in dogs with vaginal leiomyoma and leiomyosarcoma

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Abstract

Background: In humans, magnetic resonance imaging (MRI) is preferred over computed tomography (CT) for the assessment of pelvic lesions. Although CT findings of several pelvic tumours have been reported in veterinary medicine, MRI findings are limited.

Objectives: The purpose of this study was to retrospectively compare the CT and MRI findings in dogs with vaginal leiomyoma and leiomyosarcoma.

Methods: This retrospective study of five dogs compared the CT and MRI findings of intrapelvic lesions, including vaginal leiomyoma (n = 4) and leiomyosarcoma (n = 1). No invasion of the surrounding tissue was detected on histopathological examination. In this retrospective study, the following parameters of CT and MRI were recorded for each dog: the border between the lesion and the adjacent pelvic organs, including the prostate, rectum or urethra; signal intensity (SI) of the lesion; enhancement pattern; presence of haemorrhage; necrosis or cystic areas and lymphadenopathy. Because SI on MRI is affected by cell density, tumour cell density was analysed using a microscope slide.

Results: In vaginal leiomyoma, the border between the lesion and the surrounding pelvic organ tends to be clearer on MRI than on CT. In vaginal leiomyosarcoma, the border was comparable between MRI and CT. Each lesion showed heterogeneous enhancement on CT and MRI scans. In each lesion, the assessment of haemorrhage, necrosis, cystic areas and lymphadenopathy was comparable between MRI and CT. The SI of the lesion on T2WI of the vaginal leiomyoma and leiomyosarcoma were hyperintense in four cases (4/4; 100%) and mixed intense in one case (1/1; 100%), respectively. The cell density of leiomyosarcoma is higher than that of leiomyomas.
INTRODUCTION

In veterinary medicine, computed tomography (CT) is performed for the purpose of several tumour diagnoses and staging (Forrest, 2016). Magnetic resonance imaging (MRI) is performed for pelvic tumours, including prostate adenocarcinoma, although in limited numbers (Tanaka et al., 2020). MRI examinations are expensive compared to CT, require more extended anaesthesia, and have limited facilities. Therefore, it may be necessary to compare the findings of CT and MRI to understand their characteristics and select the appropriate examination modality.

In humans, various modalities have been used to assess pelvic lesions. MRI is preferred over CT for pelvic lesions because of superior soft tissue contrast compared to CT (Laval-Jeantet et al., 1985; Ng et al., 1997; Park, 2014). Because signal intensity (SI) on MRI is affected by cell density in the lesion, MRI is useful in differentiating benign from malignant lesion (Som & Biller, 1989). MRI allows visualization of the rectum, urinary bladder, and internal genitalia with high soft-tissue contrast (Blomqvist et al., 2002). Pelvic tumours arise from the rectum, nerves, blood vessels, glands and adipose tissue (Spector et al., 2011). In veterinary medicine, CT findings of several pelvic tumours have been reported (Spector et al., 2011; Tanaka et al., 2021). Full-body CT is a suitable imaging modality when pelvic tumours are suspected (Ferraris et al., 2021). Because of the limited volume of the pelvic cavity, large masses compress the adjacent organs. To the best of our knowledge, information regarding pelvic lesions using MRI is limited. Therefore, we hypothesized that MRI would be more useful than CT for assessing pelvic lesions. Therefore, we aimed to compare the CT and MRI findings in dogs with pelvic lesions, including vaginal leiomyoma and vaginal leiomyosarcoma.

MATERIALS AND METHODS

This study was a retrospective case study. The owners of the dogs included in this study provided informed consent for the diagnostic procedures, treatment and use of clinical data such as medical history, imaging studies and histopathological findings for research and publication purposes. As all diagnostic studies and initiated treatments were part of daily clinical activities, this study did not require submission to the local ethics and welfare committee. All dogs with suspected pelvic lesions on radiography and ultrasound that had undergone both CT and MRI at our institution between 2015 and 2021 were enrolled in the current study. MRI was additionally performed after CT for a detailed evaluation of the lesions. The inclusion criterion was the presence of histopathologically diagnosed primary pelvic lesions.

All dogs were induced with 7 mg/kg propofol (Propofol 1%; MSD Animal Health K.K., Tokyo, Japan) and maintained with isoflurane (2%) and oxygen with an endotracheal tube. CT and MRI examinations were performed under general anaesthesia and standardized according to our previous protocol (Tanaka et al., 2020; Tanaka et al., 2021). CT examinations were performed using a SOMATOM Scope (Siemens AG, Munich, Germany) multidetector 16-slice CT scanner in the helical scan mode following the usual protocol. The dogs were placed in dorsal recumbency before undergoing the CT. Apnoea was induced during the acquisition by discontinuing the ventilator. A full-body scan was performed on all dogs to evaluate distant metastases. CT was performed with a pitch of 0.65, with a scan thickness of 1.2 mm, 100 mAs, 120 kV and patient size-adjusted display field of view (FOV), and was reconstructed at 2-mm slice thickness using abdominal and pulmonary filters. For contrast-enhanced imaging, 2 ml/kg of nonionic contrast medium (300 mgI/ml) of iohexol (Ioverin 300; Teva Pharma Japan, Inc., Aichi, Japan) was administered to all dogs via an indwelling intravenous cannula placed in the cephalic vein using a pressure injector. The injection time was 20 s. Contrast-enhanced studies were performed in the arterial (20 s after contrast injection), portal (60 s after contrast injection) and equilibrium (180 s after contrast injection) phases.

MRI was performed immediately after the CT scan. MRI was performed using a 1.5 Tesla system (Brivo MR355; GE Healthcare Japan, Tokyo, Japan). All dogs were positioned in dorsal recumbency and ventilated during MRI. The MRI scanning protocol included transverse fast-spin echo T2-weighted imaging (T2WI) and transverse spin-echo (SE) T1-weighted imaging (T1WI). T2WI was performed using repetition time (TR)/echo time (TE) 4600/120 ms; thickness 3.5 mm; spacing 0.7 mm; the number of excitations (NEX) 3; FOV 140 mm; matrix 480 × 480. T1WI was performed using the following parameters: TR/TE 350/13 ms; thickness 3.5 mm; spacing 0.7 mm; NEX 4; FOV 140 mm; matrix 320 × 320; flip angle 90°. SE post-contrast T1WI was performed after administering gadolinium-DTPA 0.2 ml/kg (Magnevist; Bayer, Tokyo, Japan).

Observers were unaware of the final diagnoses at the CT and MRI image review time. CT and MRI images were assessed in the transverse plane using digital imaging and communications in medicine image viewing software (Horos software ver. 2.4.1; Horos Project, Minneapolis, MA). Two experienced veterinary radiologists reviewed all CT and MRI images, and CT and MRI features were recorded by consensus.

Conclusions: The SI on T2WI may be useful for differentiating leiomyoma from leiomyosarcoma. MRI may be useful to differentiate vaginal leiomyomas from leiomyosarcomas and evaluate margins.

KEYWORDS

cell density; computed tomography; magnetic resonance imaging, pelvic

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FIGURE 1  Interpretation of the procedure. The source microscopic image (a; H&E stain) was divided into three primary colour images (red, green, and blue) (b). Then, the threshold was defined for tumour cell nuclei, and the nuclear area was extracted (c).

Various qualitative parameters were recorded during image analysis: the border between the lesion and the adjacent pelvic organs, including the prostate, rectum or urethra on CT and MRI (clear or unclear); the SI of the lesion on MRI, including T2WI and pre-contrast T1WI (hyper-, iso-, hypo-, mixed-); enhancement pattern of the lesion on CT and MRI (homogeneous or heterogeneous); haemorrhage in the lesion on CT and MRI (present or absent); necrosis or cystic areas in the lesion on CT and MRI (present or absent); lymphadenopathy on CT and MRI (present or absent) and pulmonary metastasis on CT (present or absent).

The border was defined as the boundary between the lesion and the adjacent pelvic organ. It was classified as clear if the organ structures and boundaries bordering the tumour were clear. On MRI, the border was evaluated using T2WI and post-contrast T1WI. The SI of the lesion was assessed, excluding the cystic and necrotic areas. The SI on T2WI and pre-contrast T1WI was subjectively compared between the lesion and skeletal muscle. If several degrees of SI were detected, the SI was defined as mixed intensity. For the enhancement pattern (homogeneous or heterogeneous) on CT, the enhancement pattern of lesions in the equilibrium phase was considered homogeneous or heterogeneous depending on whether there was less or more than 10 HU difference in enhancement present in the lesions (Zhu et al., 2012). On MRI, the enhancement pattern was considered subjectively depending on homogeneous or heterogeneous SI change compared between pre- and post-contrast T1WI (Sadohara et al., 2006). Haemorrhage was defined as an unenhanced area and/or area containing high attenuation value within the lesion seen on pre-contrast-enhanced CT (Sadohara et al., 2006). On MRI, haemorrhage was defined as an unenhanced area and an area that contained high-signal intensity on both T2WI and T1WI, although haemorrhage showed various signal intensities due to bleeding within the tumour (Griffin et al., 2008; Kalisz et al., 2021; Sadohara et al., 2006). Necrosis or cystic areas was defined as an unenhanced area and/or an area of decreased attenuation seen within the lesion on CT, and an unenhanced area and/or an area of low-signal intensity observed on T1WI and high-signal intensity on T2WI on MRI (Sadohara et al., 2006). Lymphadenopathy was defined as when greater than reported normal lymph nodes (Beukers et al., 2013). Lymphadenopathy was assessed for the medial iliac, internal iliac and sacral lymph nodes.

Tumour cell density was analysed based on a previous report (Tasaki et al., 2015). Cell density was analysed by excluding necrotic areas using ImageJ software (NIH, Bethesda, MD, USA). Microscopic images were randomly obtained from different regions of each tumour section (Figure 1a). Red, green and blue colour spreads were processed for each image, and the red image in which the cell nucleus was most marked was selected (Figure 1b). A threshold was defined to extract tumour cell nuclei (Figure 1c). Based on this threshold, cell density was calculated by dividing the total area of the tumour cell nuclei by the entire area of the microscopic image.
FIGURE 2 Representative images of vaginal leiomyoma. CT images in pre-contrast (a), arterial phase post-contrast (b), portal phase post-contrast (c), and equilibrium phase post-contrast (d) images; MR images in T2WI (e), pre-contrast T1WI (f), and post-contrast T1WI (g) images. Leiomyoma indicated heterogeneous enhancement on CT and MRI and hyperintense signal on T2WI. CT, computed tomography; MRI, magnetic resonance imaging; T2WI, T2-weighted imaging; T1WI, T1-weighted imaging.

3 | RESULTS

A total of 22 dogs satisfied our initial criteria; of these, five met the final conditions for analysis. This study included vaginal leiomyomas \((n = 4)\) and vaginal leiomyosarcomas \((n = 1)\). For all lesions, the presumed organ on CT and MRI matched the actual organ of origin. In addition, all lesions were surgically removed, and no invasion of the surrounding tissue was detected histopathologically.

The vaginal leiomyoma group consisted of one spayed and three intact female dogs. The mean \((\pm\ SD)\) age of the dogs was \(11 \pm 1.3\) years. The dog breeds included two Chihuahua, one Miniature Dachshund and one Shetland Sheepdog. The vaginal leiomyosarcoma case was from an intact 9-year-old female Toy Poodle.

Vaginal leiomyoma showed heterogeneous enhancement on CT and MRI. On CT, there were no differences in enhancement between the post-contrast phases. SI of the vaginal leiomyoma indicated hyperintense on T2WI and isointense on T1WI. Representative images of vaginal leiomyomas on CT and MRI are shown in Figure 2. In addition, the vaginal leiomyosarcoma showed heterogeneous enhancement on CT and MRI. On CT, there were no differences in enhancement among each post-contrast phase. SI of the vaginal leiomyosarcoma indicated mixed intensity (hypo- to isointense) on T2WI and isointense on T1WI. Representative images of vaginal leiomyosarcomas on CT and MRI are shown in Figure 3. The CT and MRI findings are summarized in Tables 1 and 2, respectively. In the vaginal leiomyoma group, the border between the lesion and the surrounding pelvic organ was clearer on MRI than on CT. On CT, the border of the vaginal leiomyoma was unclear at the rectum in three cases \((3/4; 75\%)\) and urethra in one case \((1/4; 25\%)\). In each lesion, the assessment of haemorrhage, necrosis, cystic areas and lymphadenopathy was comparable between MRI and CT. Representative images of the border between the lesion and adjacent pelvic organs on CT and MRI are shown in Figure 4.

### TABLE 1 Computed tomography features of leiomyoma and leiomyosarcoma

| Number and frequency of the pelvic lesions | Leiomyoma | Leiomyosarcoma |
|-------------------------------------------|-----------|---------------|
| **Border**                                |           |               |
| Clear                                    | 0/4 (0%)  | 1/1 (100%)    |
| Unclear                                  | 4/4 (100%)| 0/1 (0%)      |
| **Enhancement pattern**                  |           |               |
| Homogeneous                               | 0/4 (0%)  | 0/1 (0%)      |
| Heterogeneous                            | 4/4 (100%)| 1/1 (100%)    |
| **Haemorrhage**                           |           |               |
| Present                                  | 0/4 (0%)  | 0/1 (0%)      |
| Absent                                   | 4/4 (100%)| 1/1 (100%)    |
| **Necrosis or cystic areas**              |           |               |
| Present                                  | 4/4 (100%)| 1/1 (100%)    |
| Absent                                   | 0/4 (0%)  | 0/1 (0%)      |
| **Lymphadenopathy**                      |           |               |
| Present                                  | 0/4 (0%)  | 0/1 (0%)      |
| Absent                                   | 4/4 (100%)| 1/1 (100%)    |
| **Pulmonary metastasis**                 |           |               |
| Present                                  | 0/4 (0%)  | 0/1 (0%)      |
| Absent                                   | 4/4 (100%)| 1/1 (100%)    |

Tumour cell density was analysed in three dogs with leiomyoma \((75\%)\) and in one dog with leiomyosarcoma \((100\%)\). It was not assessed in one dog with leiomyoma, as no microscope slides were available. The
mean tumour cell densities in leiomyoma and leiomyosarcoma were 12.3 ± 1.36% and 22.6%, respectively.

4 | DISCUSSION

In this study, MRI was superior to CT in assessing clear boundary between the tumour and adjacent organs. This may be due to the loss of contrast caused by the absence of fat between the tumour and the adjacent organs on CT. In humans with low anterior rectal tumours, CT cannot assess tumour infiltration as accurately as MRI because the lack of a fatty layer between the tumour and the surrounding mesentery makes the poor differentiation of rectal wall (Dar et al., 2014; Maizlin et al., 2010). On CT, the limiting factor is tissue differentiation (Follen et al., 2003). In humans, T2WI provides excellent detail of normal tissue anatomy and detects the internal structure of tumour (Follen et al., 2003). Our results indicated clear, detailed tissue anatomy and the relationship between tumour and adjacent tissue on T2WI. Therefore, T2WI may be used to evaluate the margins of the primary tumour. Unfortunately, this study did not include cases of tumour invasion into adjacent organs. Further investigation of the invasion of pelvic lesions into adjacent organs in a large population of dogs is required. In this study, there was no difference in the detection of haemorrhage, necrosis, cystic areas or lymphadenopathy between CT and MRI. In this study, T2*WI was not performed to assess haemorrhage on MRI. T2*WI may improve the detection rate of haemorrhage, because T2*WI detects even small haemorrhages as low-signal foci and is the most sensitive sequence for detecting haemorrhagic debris.
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leiomyosarcoma tumour extension and lymphadenopathy (Laval-Jeantet et al., 1985). Structural evaluation. In humans, MRI is superior to CT in evaluating (Sadohara et al., 2006). Therefore, MRI may be useful for a detailed in depicting the capsule, septum and haemorrhage within the tumour (Atlas, 2009; Cordonnier et al., 2007). In humans, MRI is superior to CT in assessing clear boundary between the tumour and skeletal muscle. In addition, T2WI may be useful for differentiating leiomyomas from leiomyosarcomas. However, the enhancement pattern may not differentiate leiomyomas from leiomyosarcomas. Therefore, the SI findings could differentiate leiomyomas from leiomyosarcomas. However, the MRI findings showed the possibility of differentiation. Therefore, MRI may be useful in differentiating leiomyomas from leiomyosarcomas.

In this study, the SI of leiomyosarcoma on T2WI was mixed, including hypointense areas, compared to that of leiomyomas. Decreased SI on T2WI in malignant tumours is caused by a high cell density, which causes a reduction in mobile protons (Som & Biller, 1989). Therefore, the SI of leiomyosarcoma may be lower than that of leiomyoma. On CT and MRI, leiomyomas and leiomyosarcomas showed heterogeneous enhancement. A previous report indicated that leiomyomas show internal homogeneity on CT, which is useful in differentiating benign from malignant tumours (Spector et al., 2011). However, our results differed from those of previous reports. In humans, heterogeneous enhancement is caused by haemorrhage, necrosis and calcification (Agah et al., 2017). In this study, necrosis or cystic areas were present in leiomyoma, which may have affected the enhancement pattern. However, the enhancement pattern may not differentiate leiomyomas from leiomyosarcomas. Therefore, the SI on T2WI may be useful for differentiating leiomyoma from leiomyosarcoma. In this study, no CT findings could differentiate leiomyomas from leiomyosarcomas. However, the MRI findings showed the possibility of differentiation. Therefore, MRI may be useful in differentiating leiomyomas from leiomyosarcomas.

This study had some limitations. First, this study included a small number of dogs with a limited distribution of tumour types. In particular, malignant tumours that invaded the adjacent organs were not assessed. Second, this study was performed with a limited sequence type of MRI. The structural evaluation may be more accurate using several sequences, including fat-suppressed, thin-sliced 3D, and T2* sequences. Further studies are needed to determine the appropriate MRI sequence that would be the most useful for structural evaluation.

In conclusion, MRI, including T2WI and post-contrast T1WI, was superior to CT in assessing clear boundary between the tumour and adjacent organs. Therefore, MRI may be used to evaluate the margins of the primary tumour without a contrast agent. In addition, T2WI may be useful for differentiating vaginal leiomyoma from leiomyosarcoma.

### Table 2

| Magnetic resonance imaging features of leiomyoma and leiomyosarcoma |
|--------------------------|--------------------------|
| **Number and frequency of the pelvic lesions** | | |
| **Leiomyoma** | **Leiomyosarcoma** |
| N = 4 | N = 1 |
| **Border** | | |
| Clear | 4/4 (100%) | 1/1 (100%) |
| Unclear | 0/4 (0%) | 0/1 (0%) |
| **Signal intensity** | | |
| T2WI | | |
| Hyper- | 4/4 (100%) | 0/1 (0%) |
| Iso- | 0/4 (0%) | 0/1 (0%) |
| Hypo- | 0/4 (0%) | 0/1 (0%) |
| Mixed- | 0/4 (0%) | 1/1 (100%) |
| T1WI | | |
| Hyper- | 0/4 (0%) | 0/1 (0%) |
| Iso- | 4/4 (100%) | 1/1 (100%) |
| Hypo- | 0/4 (0%) | 0/1 (0%) |
| **Enhancement pattern** | | |
| Homogeneous | 0/4 (0%) | 0/1 (0%) |
| Heterogeneous | 4/4 (100%) | 1/1 (100%) |
| **Haemorrhage** | | |
| Present | 0/4 (0%) | 0/1 (0%) |
| Absent | 4/4 (100%) | 1/1 (100%) |
| **Necrosis or cystic areas** | | |
| Present | 4/4 (100%) | 1/1 (100%) |
| Absent | 0/4 (0%) | 0/1 (0%) |
| **Lymphadenopathy** | | |
| Present | 0/4 (0%) | 0/1 (0%) |
| Absent | 4/4 (100%) | 1/1 (100%) |

T2WI, T2-weighted imaging; T1WI, T1-weighted imaging.

(Atlas, 2009; Cordonnier et al., 2007). In humans, MRI is superior to CT in depicting the capsule, septum and haemorrhage within the tumour (Sadahara et al., 2006). Therefore, MRI may be useful for a detailed structural evaluation. In humans, MRI is superior to CT in evaluating tumour extension and lymphadenopathy (Laval-Jeantet et al., 1985). Conversely, CT is more useful in detecting distant metastases (Horvat et al., 2019). In this study, no metastases were observed in all dogs. Unfortunately, this study included a limited number of patients with pelvic lesions. Further studies are needed to determine the selection criteria for CT and MRI scans.

MRI is currently considered the gold standard for imaging in humans, as leiomyomas can be differentiated from malignant vaginal tumours, such as leiomyosarcomas, based solely on their MRI characteristics (Demulder & Ascher, 2018). In humans, vaginal leiomyomas appear as hypointense lesions on T2WI compared to the skeletal mus-
AUTHOR CONTRIBUTIONS
Toshiyuki Tanaka: Conceptualization, data curation, formal analysis, investigation, project administration, validation, visualization and writing-original draft.
Shunsuke Noguchi: writing-review and editing.
Yusuke Wada: formal analysis, writing-review and editing.
Hiroki Yamazaki: writing-review and editing.
Hidetaka Nishida: writing-review and editing.
Hideo Akiyoshi: Supervision, writing-review and editing.

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CONFLICT OF INTEREST
The authors declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the first author (T.T.), upon reasonable request.

ETHICAL STATEMENT
The owners of the dogs included in this study provided their informed consent for the diagnostic procedures, treatment and use of clinical data, such as medical history, imaging studies and histopathological findings for research and publication purposes. As all the diagnostic studies and initiated treatments were part of daily clinical activities, this study did not require the submission to the local ethics and welfare committee.

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REFERENCES
Agah, J., Karimzadeh, S., & Moharrer Ahmadi, F. (2017). Misdiagnosis of a giant uterine leiomyosarcoma: Clinic and image challenges. Case Reports in Oncological Medicine, 2017, 3568328.
Atlas, S. W. (2009). Intracranial hemorrhage. In S.W. Atlas (Ed.), Magnetic resonance imaging of the brain and spine (4th edn., pp. 644–694). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.
Beukers, M., Grosso, F. V., & Voorhout, G. (2013). Computed tomographic characteristics of presumed normal canine abdominal lymph nodes. Veterinary Radiology & Ultrasound: The Official Journal of the American College of Veterinary Radiology and the International Veterinary Radiology Association, 54(6), 610–617.
Blomqvist, L., Holm, T., Nyén, S., Svanström, R., Ulskog, Y., & Iselius, L. (2002). MR imaging and computed tomography in patients with rectal tumours clinically judged as locally advanced. Clinical Radiology, 57(3), 211–218.
Cordonnier, C., Al-Shahi Salman, R., & Wardlaw, J. (2007). Spontaneous brain microbleeds: Systematic review, subgroup analyses and standards for study design and reporting. Brain, 130(8), 1988–2003.
Dar, R., Chowdri, N., Parray, F., Shaheen, F., Wani, S., & Mushtaque, M. (2014). Pre-operative staging of rectal cancer using multi-detector row computed tomography with multiplanar reformation: Single center experience. Indian Journal of Cancer, 51(2), 170–175.
Demulder, D., & Ascher, S. M. (2018). Uterine leiomyosarcoma: Can MRI differentiate leiomyosarcoma from benign leiomyoma before treatment? American Journal of Roentgenology, 211(6), 1405–1415.
Ferraris, E. I., Giacobino, D., Lussich, S., Olippo, M., Valazza, A., Martano, M., Buracco, P., & Morello, E. M. (2021). Benign or low-grade malignant masses occupying the pelvic canal space in 11 dogs. Animals (Basel), 11(5), 1361.
Follen, M., Levenback, C. F., Iyer, R. B., Grigsby, P. W., Boss, E. A., Delpassand, E. S., Fornage, B. D., & Fishman, E. K. (2003). Imaging in cervical cancer. Cancer, 98(9), 2028–2038.
Forrest, L. J. (2016). Computed tomography imaging in oncology. The Veterinary Clinics of North America. Small Animal Practice, 46(3), 499–513.
Griffin, N., Grant, L. A., & Sala, E. (2008). Magnetic resonance imaging of vaginal and vulval pathology. European Radiology, 18(6), 1269–1280.
Horvat, N., Carlos Tavares Rocha, C., Clemente Oliveira, B., Petkovska, I., & Gollub, M. J. (2019). MRI of rectal cancer: Tumor staging, imaging techniques, and management. Radiographics, 39(2), 367–387.
Kalisz, K., Enzerra, M., & Mansoori, B. (2021). Overview of spontaneous intraabdominal tumor hemorrhage: Etiologies, imaging findings, and management. Abdominal Radiology, 46(2), 427–440.
Laval-Jeantet, M., Vadrot, D., Arrive, L., & Buy, J. N. (1985). MRI of the pelvis in comparison with CT scan. Archives Internationales De Physiologie Et De Biochimie, 93(5), 61–66.
Maizlin, Z. V., Brown, J. A., So, G., Brown, C., Phang, T. P., Walker, M. L., Kirby, J. M., Vora, P., & Tiwari, P. (2010). Can CT replace MRI in preoperative assessment of the circumferential resection margin in rectal cancer? Diseases of the Colon and Rectum, 53(3), 308–314.
Marinelli, M., Lupetti, E., Gigante, A., Mandolesi, A., Bearzi, I., & De Palma, L. (2007). Collagenous fibroma of the deltoid muscle: Clinical, surgical and histopathological aspects. Journal of Orthopaedics and Traumatology, 8(2), 91–94.
Namimoto, T., Yamashita, Y., Awai, K., Nakaura, T., Yanaga, Y., Hirai, T., Saito, T., & Katabuchi, H. (2009). Combined use of T2-weighted and diffusion-weighted 3-T MR imaging for differentiating uterine sarcomas from benign leiomyomas. European Radiology, 19(11), 2756–2764.
Ng, S. H., Chang, T. C., Ko, S. F., Yen, P. S., Wan, Y. L., Tang, L. M., & Tsai, M. H. (1997). Nasopharyngeal carcinoma: MRI and CT assessment. Neuroradiology, 39(10), 741–746.
Park, S. B. (2014). Features of the hypointense solid lesions in the female pelvis on T2-weighted MRI. Journal of Magnetic Resonance Imaging, 39(3), 493–503.
Russo, M., England, G. C. W., Catone, G., & Marino, G. (2021). Imaging of canine neoplastic reproductive disorders. Animals (Basel), 11(5), 1213.
Sadohara, J., Fujimoto, K., Müller, N. L., Kato, S., Takamori, S., Ohkuma, K., Terasaki, H., & Hayabuchi, N. (2006). Thymic epithelial tumors: Comparison of CT and MR imaging findings of low-risk thymomas, high-risk thymomas, and thymic carcinomas. European Journal of Radiology, 60(1), 70–79.
Shadbolt, C. L., Coakley, F. V., Qayyum, A., & Donat, S. M. (2003). MRI of vaginal leiomyomas. Journal of Computer Assisted Tomography, 25(3), 355–357.
Shuto, R., Kiyosue, H., Horii, Y., Miyake, H., Kawano, K., & Mori, H. (2002). CT and MR imaging of desmoplastic fibroblastoma. European Radiology, 12(10), 2474–2476.
Siegelman, E. S., & Outwater, E. K. (1999). Tissue characterization in the female pelvis by means of MR imaging. Radiology, 212(1), 5–18.
Som, P. M., & Biller, H. F. (1989). High-grade malignancies of the parotid gland: Identification with MR imaging. Radiology, 173(3), 823–826.
Spector, D. I., Fischetti, A. J., & Kovak-McClaran, J. R. (2011). Computed tomographic characteristics of intrapelvic masses in dogs. Veterinary Radiology & Ultrasound: The Official Journal of the American College of
Tanaka, T., Ashida, K., Iimori, Y., Yamazaki, H., Mie, K., Nishida, H., & Akiyoshi, H. (2020). Less enhancement and low apparent diffusion coefficient value on magnetic resonance imaging may be helpful to detect canine prostate adenocarcinoma in case series. *Veterinary and Comparative Oncology, 18*(4), 861–865.

Tanaka, T., Iimori, Y., Yamazaki, H., Hidetaka, N., & Hideo, A. (2021). Contrast-enhanced computed tomography characterization of canine rectal neoplasms. *Japanese Journal of Veterinary Research, 69*(3), 163–173.

Tasaki, A., Asatani, M. O., Umezu, H., Kashima, K., Enomoto, T., Yoshimura, N., & Aoyama, H. (2015). Differential diagnosis of uterine smooth muscle tumors using diffusion-weighted imaging: Correlations with the apparent diffusion coefficient and cell density. *Abdominal imaging, 40*(6), 1742–1752.

Thomassin-Naggara, I., Daraë, E., Cuenod, C. A., Rouzier, R., Callard, P., & Bazot, M. (2008). Dynamic contrast-enhanced magnetic resonance imaging: A useful tool for characterizing ovarian epithelial tumors. *Journal of Magnetic Resonance Imaging, 28*(1), 111–120.

Togashi, K., Ozasa, H., Konishi, I., Itoh, H., Nishimura, K., Fujisawa, I., Noma, S., Sagoh, T., Minami, S., & Yamashita, K. (1989). Enlarged uterus: Differentiation between adenomyosis and leiomyoma with MR imaging. *Radiology, 171*(2), 531–534.

Yamashita, Y., Torashima, M., Takahashi, M., Tanaka, N., Katabuchi, H., Miyazaki, K., Ito, M., & Okamura, H. (1993). Hyperintense uterine leiomyoma at T2-weighted MR imaging: Differentiation with dynamic enhanced MR imaging and clinical implications. *Radiology, 189*(3), 721–725.

Zhu, L., Wu, G., Ghimire, P., & Xu, L. (2012). CT features of peripheral T-cell lymphoma in the gastrointestinal tract in the Chinese population and literature review. *Journal of Medical Imaging and Radiation Oncology, 56*(2), 143–150.

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