The Journal of Veterinary Medical Science

FULL PAPER

Internal Medicine

Usefulness of computed tomography for cryptorchidism in bulls

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ABSTRACT. Cryptorchidism is defined as the failure of the testis to descend into the scrotal position. Bulls with cryptorchidism have problems in both meat quality and husbandry management; thus, it is greatly important to accurately identify the retained testis and remove it during the early stage. Abdominal computed tomography (CT) was performed under general anesthesia in 34 bulls aged 3–9 months with cryptorchidism. All bulls underwent laparoscopic or incision approach for cryptorchidectomy, and 40 testes were dissected. The detection rates of retained testes were 64.5% in the abdominal cavity and 100% in the subcutaneous inguinal region, and the total detection rate was 72.5%. Furthermore, all cases in this study were suspected to have intra-abdominal cryptorchidism in primary care, but CT revealed that 22.5% of cases had cryptorchidism in the subcutaneous inguinal region. The CT value (mean ± standard deviation) of the retained testes was 20.96 ± 7.54 Hounsfield Unit, and the CT value and size of the retained testes showed a positive weak correlation with bovine age. Therefore, there is the demerit that general anesthesia and a huge device are necessary; nevertheless, CT is suggested to be useful in identifying the location of retained testes and selecting an appropriate surgical approach in bulls with cryptorchidism. Moreover, CT findings suggested that the maturation of the retained testes might depend not on the descending process but on age.

KEYWORDS: bull, computed tomography, cryptorchidism, diagnosis

J. Vet. Med. Sci.
84(10): 1430–1436, 2022
doi: 10.1292/jvms.22-0124

Received: 17 March 2022
Accepted: 23 August 2022
Advanced Epub:
2 September 2022

Cryptorchidism is the failure of one or both testes to descend into the scrotal position [9]. In most cases, the undescended testis remains in the extrascrotal region, abdominal cavity, or inguinal region [17]. Cryptorchidism can develop unilaterally or bilaterally, and its incidence has been relatively high in horses and pigs [14] and low (0.2%) in bulls [17]. If a testis (or testes) remains intact, cryptorchid bulls may develop heavy musculature and aggressive male behavior in the fattening phase and present problems in terms of both meat quality and husbandry management [10, 15]. Moreover, retained testes may increase the risk of tumors, and a case of young bull with cryptorchidism and testicular tumor has been reported [12]. Hence, it is extremely important to accurately identify the retained testis and remove it during the early stage.

The human chorionic gonadotrophin stimulation test has been used to determine interstitial cell function and detect functional retained testes by measurement of plasma testosterone levels following stimulation [4]. However, the test cannot elucidate the position of the retained testes. Although the retained testes were attempted to detect by palpation or ultrasonography, we had encountered cases where a definitive diagnosis is difficult to make using any diagnostic method, regardless of the location of the undescended testis. Although there is almost no report on diagnostic imaging for bovine cryptorchidism, in humans, two studies reported the sensitivity of ultrasonography in correctly identifying a non-palpable testis to be 33% and 45% [6, 19]. Recently, the usefulness of CT in the

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(Supplementary material: refer to PMC https://www.ncbi.nlm.nih.gov/pmc/journals/2350/)

detection of bovine abdominal diseases has been reported [3, 11, 13]. Conversely, most reports present only one case, so the detailed CT findings in each disease were not provided. However, we reviewed CT images of 40 retained testes in 34 cases in this study.

In bulls, especially in cases of intra-abdominal cryptorchidism, it is difficult to determine the location of the retained testes even if the paramedian or flank incision approach and palpation are used [16, 20]. Furthermore, we have also encountered some cases of inguinal cryptorchidism that could not be diagnosed by palpation of the inguinal area. Recently, the effectiveness of laparoscopic cryptorchidectomy has been reported in bulls with intra-abdominal cryptorchidism [3]. However, this technique requires special surgical instruments and the operator's high proficiency. Moreover, it is impossible to explore and/or visually recognize the retained testes in the abdominal cavity and inguinal region simultaneously using either surgical method. Therefore, it is extremely important to identify accurately the position of the retained testes as the abdominal cavity or inguinal region for both accurate diagnosis and appropriate choice of surgical approach. However, there is no detailed report on the possible specific locations of the retained testes in bulls with cryptorchidism, and the new tool to visualize the retained testes in living bulls has been desired.

This study aimed to evaluate effectiveness of CT in the diagnosis of cryptorchidism in bulls by summarizing the CT findings of 40 retained testes.

MATERIALS AND METHODS

Animals

Thirty-four bulls were referred to Miyazaki University Veterinary Teaching Hospital with suspicion of primary intra-abdominal cryptorchidism, and CT was performed between May 2012 and March 2018. Of these cases, 30 were Japanese Black cattle and two were Holstein, and two were F1 Japanese Black cattle-Holstein, weighing 98–322 kg (n=27) and aged 3–9 months (n=34). For 34 bulls suspected with cryptorchidism by ultrasonography and/or palpation in primary care, this study resulted in discovery of unilateral (n=28) and bilateral (n=6) retained testes. Of the total 40 testes, 30 were located on the left side (unilateral, 24 cases; bilateral, 6 cases) and 10 were located on the right side (unilateral, 4 cases; bilateral, 6 cases). Furthermore, the normal descended testes in bulls with unilateral cryptorchidism have been removed or confirmed in primary care. We considered the contralateral testes as affected by cryptorchidism, and the normal descended testes were not analyzed in this study.

Examinations and treatments for these animals were performed in accordance with the ethical standards of the Act on Welfare and Management of Animals 1973, Japan.

Computed tomography

We used a 16-slice multidetector helical CT scanner (Aquilion LB, Canon Medical Systems, Otawara, Japan). The scanning parameters were as follows: X-ray tube potential, 120 kV; X-ray tube current, 300 mA; gantry rotation time, 0.5 sec; and slice thickness, 2.0–8.0 mm. These parameters were used based on our pilot study. All bulls were premedicated with xylazine (Selactar; Bayer Yakuhin Ltd., Tokyo, Japan; 0.2 mg/kg IV) and general anesthesia was maintained with isoflurane (Isoflurane; Pfizer Inc., Tokyo, Japan.) through the endotracheal tube. The lateral recumbent position with the affected side up was employed during CT. If the bulls were suspected to have bilateral cryptorchidism, the right lateral recumbent position was employed.

Image analysis

All CT images were independently observed by four image diagnosticians (YG, YM, RS, and HS). If all four diagnosticians identified the same structure as the testis on CT images, it was concluded to be a retained testis. When even one person recognized a different structure as the testis on CT images, it was classified as undetected. The detection rate on the left and right sides of the abdominal cavity and subcutaneous inguinal region and the retention rate in three sites (around the rumen, around the urinary bladder, and subcutaneous inguinal region) were calculated. Furthermore, for each cryptorchidism determined on CT images, the CT values of the retained testis were measured at three locations on the same slice using the DICOM image analysis software (OsiriX®, Pixmeo, Bernex, Switzerland), and the average value was used as the CT value. Three arbitrary region of interests (ROIs) (ROI size was fixed; 15.46 mm^2) were set on the structures identified as retained testis on CT, and the calculated average value was used as CT value of the retained testis. Simultaneously, the major axis of retained testes was measured on CT images using multiplanar reconstruction. These parameters were measured by a person (KW) independently, and the average value was used.

Procedure of laparoscopic surgery and laparotomy

All bulls underwent cryptorchidectomy using abdominal laparoscopic or inguinal incision approach after CT based on the CT evaluation on that day. Laparoscopic surgery was performed in the standing position for all abdominal region cases after awakening from general anesthesia. Cryptorchidectomy by inguinal incision was performed in all subcutaneous inguinal region cases in the lateral recumbent position under general anesthesia immediately after CT. We recorded the actual major axis measurement and weight of the removed testes (n=29).

Statistical analysis

The collected data were analyzed on a personal computer using commercial software (Statcel-the Useful Addin Forms on Excel 2nd ed. OMS Ltd., Tokyo, Japan) with dependent Student's *t*-test and Pearson linear correlation coefficient to compare the measured length of testes by two methods (actual major axis measurement and major axis measurement on CT images), with χ^2 for independence test to compare the detection rates of retained testis in cases with right- or left-sided abdominal cryptorchidism, with simple regression

analysis to compare the correlation between the CT values of the retained testis and each parameter (major axis measurement on CT images, actual major axis measurement, weight of the removed testis, and age) related to the removed testes, simple regression analysis to compare the correlation between age and each parameter (CT values of the retained testis, major axis measurement on CT images, actual major axis measurement, and weight of the removed testis) related to the removed testes, and Bartlett test, Kruskal-Wallis test, Tukey-Kramer method as multiple comparison test, Scheffe's *F* test, and Bonferroni/Dunn method to compare the CT values of retained testis and actual major axis measurement to the retention site. The significance level was set at a *P*-value <0.05.

RESULTS

The detection rates on CT for left-sided and right-sided cryptorchidism were 86.7% (26/30) and 30% (3/10), respectively. The total detection rate was 72.5% (29/40) (Table 1). Of the 40 testes of 34 cases with cryptorchidism, 31 testes of 27 cases showed cryptorchidism in the abdominal cavity. The CT detection rates of abdominal cryptorchidism were 82.6% (19/23) and 12.5% (1/8) for the left-sided and right-sided involvements, respectively. The total detection rate was 64.5% (20/31). All nine undescended testicles of nine cryptorchidism cases involving the subcutaneous of inguinal region could be detected on CT, regardless of the left- and right-sided involvements.

The locations of 29 cryptorchidisms found by CT image were roughly divided into three areas: around the rumen, around the bladder, and at the subcutaneous inguinal region (Fig. 1). The percentage of cryptorchidism retention sites observed on CT images was calculated: around the rumen, 51.7% (15/29) (14, left side; 1, right side); around the bladder, 17.2% (5/29) (5, left side; 0, right side); and subcutaneous inguinal region, 31.0% (9/29) (7, left side; 2, right side) (Table 2).

The measured values (mean ± standard deviation) for each parameter used in the analysis were as follows: the CT value of the retained testis was 20.96 ± 7.54 Hounsfield Unit (HU) (range, 6.6–41.82 HU), major axis measurement on CT images was 53.59 ± 11.82 mm (range, 26.83–79.22 mm), actual major axis measurement was 52.03 ± 12.28 mm (range, 27–88 mm), weight of the removed testis was 31.29 ± 15.57 g (range, 3.41–69.9 g), and age was 6.43 ± 1.35 months (range, 3–9 months). A weak to modest

Table 1. The detection rate of cryptorchidism on the CT images

Retenion location	Side of cryptorchidism		Total (n=40)
	Left side (n=30)	Right side (n=10)	
In the abdominal cavity	82.6% (19/23)	12.5% (1/8)	64.5% (20/31)
Subcutaneous inguinal region	100% (7/7)	100% (2/2)	100% (9/9)
Total	86.7% (26/30)	30% (3/10)	72.5% (29/40)

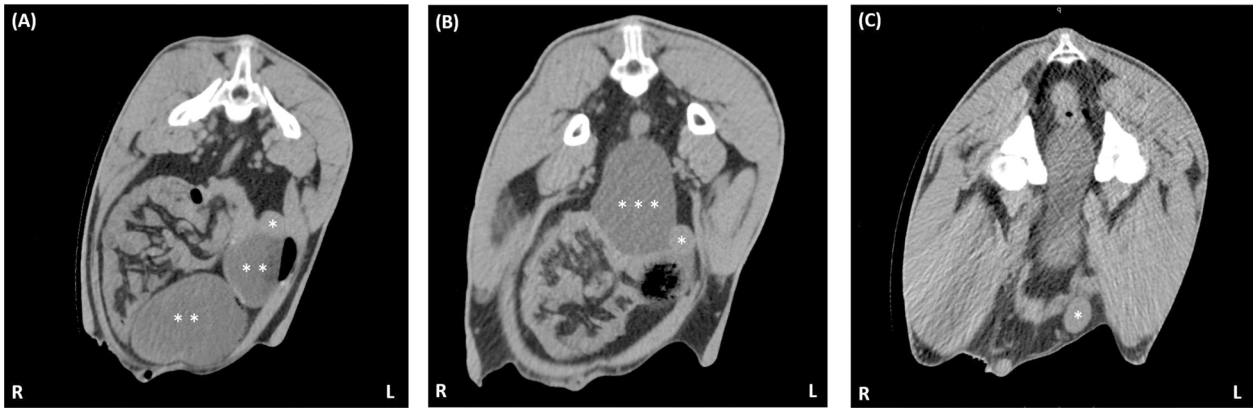

Fig. 1. Representative computed tomography (CT) findings of cryptorchidism in bulls. All images are transversal. **A** and **B** are CT images of cryptorchidism in the abdominal cavity. **C** is CT images of cryptorchidism at the subcutaneous inguinal region. *Testis, **Rumen, ***Bladder.

Table 2. Percentage of site of cryptorchid testis detected on CT images

Detection sites	Side of cryptorchidism		Total (n=29)
	Left side (n=26)	Right side (n=3)	
Rumen	53.9% (14/26)	33.3% (1/3)	51.7% (15/29)
Bladder	19.2% (5/26)	0% (0/3)	17.2% (5/29)
Subcutaneous inguinal region	26.9% (7/26)	66.7% (2/3)	31.0% (9/29)

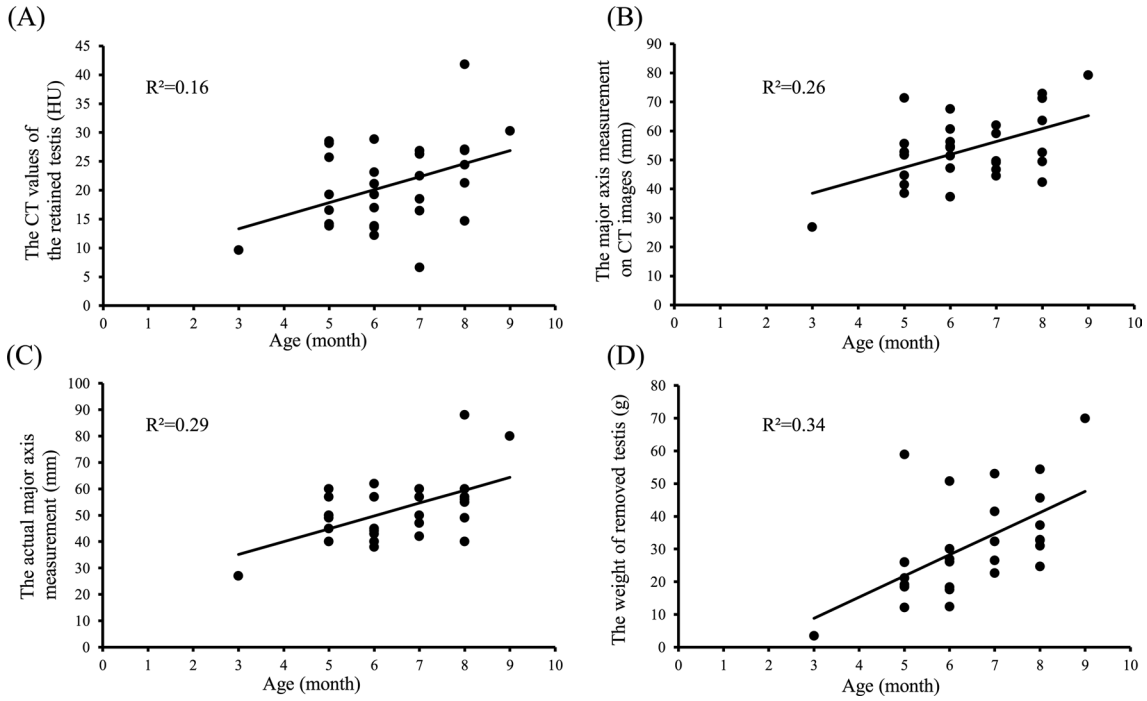

Fig. 2. The scatter diagrams and regression curves for the age and each parameter are shown in A–D. **A**. The relationship between the age and the CT values of the retained testis. **B**. The relationship between the age and major axis measurement on CT images. **C**. The relationship between the age and actual major axis measurement. **D**. The relationship between the age and weight of removed testis. There was a positive correlation between the age to all parameters (A–D).

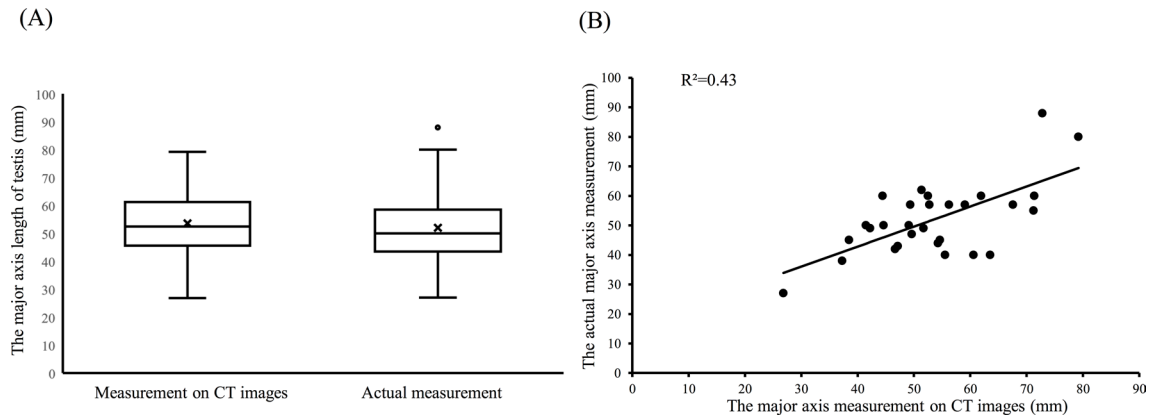

Fig. 3. We compared the major axis measurement on CT images to the actual major axis measurement. **A** is the box-and-whisker plot comparing the major axis measurement on CT images and the actual major axis measurement with Student's *t*-test. **B** is the scatter diagrams and regression curves for the major axis measurement on CT images and actual major axis measurement. There was no significant difference and a positive correlation between the major axis measurement on CT images to the actual major axis measurement.

positive correlation was found between CT values and all other parameters (R^2=0.16–0.42) (data not shown / Supplementary Fig. 1). Furthermore, age was weak positively correlated with all other parameters (R^2=0.16–0.34) (Fig. 2). The major axis measurement on CT images was not significantly different from the actual major axis measurement (P>0.05) (Fig. 3A), but positively correlated (R^2=0.43) (Fig. 3B). The CT values and actual major axis measurement showed no significant difference in the relationship between the retention site identified on CT (Fig. 4). There was not a large difference between the major axis measurement on CT images of left sided retained testes and right sided retained testis detected on CT in the abdominal cavity (Fig. 5A), and between the actual major axis measurement of the detected retained testes and undetected retained testes in each side (Fig. 5B).

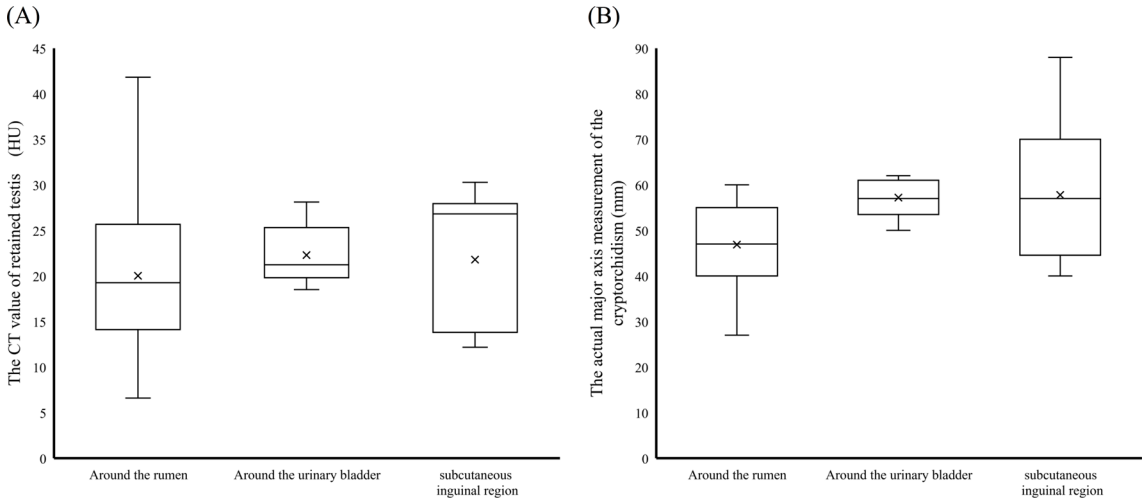

Fig. 4. We compared the CT values of the retained testis (**A**) and actual major axis measurement (**B**) with the site of retention identified on CT images, respectively with *post-hoc* test. A is the box-and-whisker plot comparing the CT values of the retained testis and site of retention with *post-hoc* test. B is the box-and-whisker plot comparing the actual major axis measurement and site of retention with *post-hoc* test. There was no significant difference between the site of retention and CT values of the retained testis or actual major axis measurement ($P>0.05$).

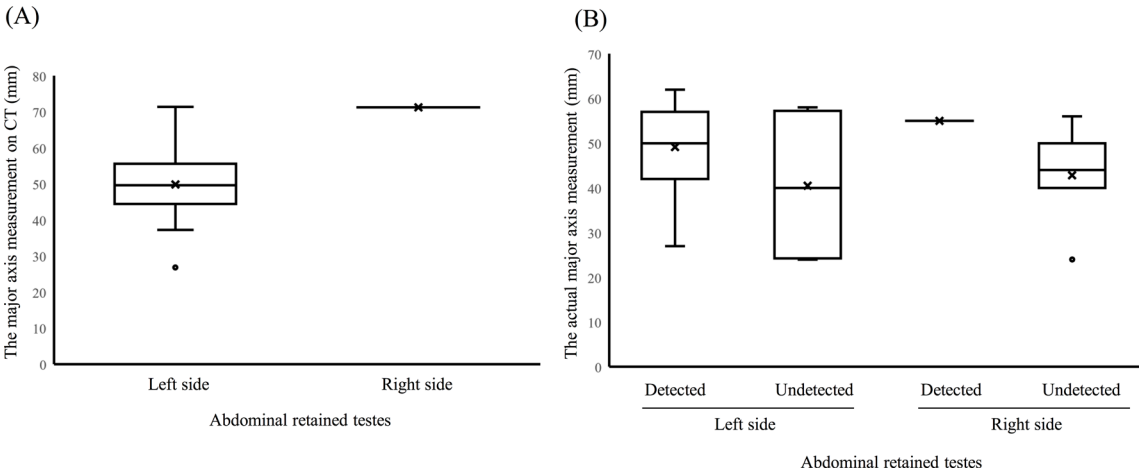

Fig. 5. **A**. There was not a large difference in the major axis measurement on CT images of retained testes in each side in the abdominal cavity. **B**. There was not a large difference between the actual major axis measurement of the detected retained testis and undetected retained testis in each side. Statistical analysis was not performed due to insufficient number of data in A and B.

DISCUSSION

A previous report on cryptorchidism in bulls found that the retained testis was present in the abdominal cavity in 34% of cases and in the inguinal region in 66% of cases [17]. These findings are inconsistent with those of the present study, which found that the retained testis was more often located in the abdominal cavity. The reasons for this may be that the breeds of cattle were different between the two studies and that all cases were referred from the primary care facility in the present study.

In recent years, the usefulness of ultrasonography in the diagnosis of cryptorchidism in the region between the bladder neck and subcutaneous inguinal region has been reported [5]. However, the site where the retained testis was most often found in this study was around the rumen, regardless of whether they were unilateral or bilateral and located on the left or right (total percentage of the testes around the rumen was 51.7%). Therefore, it is highly possible that the retained testis might be not detected by ultrasonography in the majority of cases. In dogs, ultrasonography is known to be a highly sensitive method for the diagnosis of cryptorchidism [1], and CT has been useful in cases of cryptorchidism associated with testicular tumors [18]. In humans, the diagnostic yield of ultrasonography is low [6, 19], with that of CT reported to be 100% [8] and magnetic resonance imaging (MRI) 76–100% [7, 21]. However, in cattle, ultrasonographic exploration of the cryptorchidism is limited [5], and MRI is difficult to use due to the tangible barriers. Therefore, in cattle, CT is a reasonable test for cryptorchidism, even if they are not neoplastic. Thus, we retrospectively analyzed CT findings

on 40 retained testes to evaluate the utility of CT testing for cryptorchidism in bovine.

The CT parameters in this study were based on the optimal conditions determined in our previous studies of CT imaging of intra-abdomen in bovine (unpublished).

The abdominal cryptorchidism detection rate observed in this study was high (total detection rate, 64.5%), particularly for left-sided cryptorchidism (82.6%) compared with right-sided cryptorchidism (12.5%) ($P<0.05$). Cryptorchidism in bulls was more often be unilateral and located on the left side [17]. Thus, CT may be useful in the detection of many cryptorchidism cases in bulls. At first, we hypothesized that the reason for the higher detection rate of left-sided cryptorchidism was due to the larger size of the left-sided retained testis or anatomical differences. However, there was not a large difference between the major axis measurement on CT images of left sided retained testes and right sided retained testis detected on CT in the abdominal cavity (Fig. 5A). In addition, there was not a large difference between the actual major axis measurement of the detected retained testes and undetected retained testes in each side (Fig. 5B). Thus, the reason for the higher incidence on the left side is unknown, but we attributed the difference in detection rate between the left and right sides to anatomical differences. Particularly, the rumen occupies most structures on the descending path of the testis on the left side, whereas the complex intestinal structures occupy the right side. Likewise, the 100% detection rate for both left and right inguinal cryptorchidism might be caused by few structures in that region. The patient positioning could affect the detection rate of retained testes. However, it is unlikely that the structure in abdominal tissues were widely changed by positioning. So, we assume that patient positioning in CT examination would not significantly affect the overall detection rate, although we have no objective evidence or experience.

CT can also be useful in selecting the incision site for cryptorchidectomy because all inguinal cryptorchidism cases were distinguished from abdominal cryptorchidism on CT images in this study. In this study, when CT detected the retained testes, the time from incision to detection of retained testes in laparoscopic surgery (limited to cases in which full clinical operative information was gained) was about 6 min shorter than when undetected. Although the difference was small, the severity of injury by laparoscopic exploration should be considerably reduced. The contribution of that might be bigger in surgical cryptorchidectomy by the paramedian or flank incision approach.

We confirmed that there was little coefficient of variation in the CT values of the retained testes in our pilot study (Supplementary Table 1). Therefore, we consider the CT values of the retained testis in this study to be reliable. The CT values and major axis measurement on CT images, actual major axis measurement, and weight of the retained testis showed a positive correlation with age. As growing Japanese Black cattle age, the testicular weight, major axis, seminiferous tubule diameter, and percentage of seminiferous tubules increase [2]. This suggested that the increase in CT values may be due to testicular development as the bulls grow. Meanwhile, the CT values and actual major axis measurement showed no significant association with the retention site. This suggested that the retained testis does not grow with descent but grows with the growth of the individual, similar to the normal testis. Furthermore, the present results showed a significant correlation between the major axis measurement of the retained testis on CT images and actual major axis measurement, suggesting that the major axis measurement of the retained testis by CT examination may be useful in estimating the actual size of the retained testis.

CT examination in bulls is limited to extremely high-value bulls because of the requirement of expensive equipment, general anesthesia, and off-label drugs. However, it can contribute to accurate detection of the retained testes and selection of the appropriate surgical approach. All present cases were suspected to have intra-abdominal cryptorchidism in primary care. However, when CT was performed, we found that cryptorchidism in the subcutaneous inguinal region was present in some cases. This suggests that some inguinal cryptorchidisms may not be palpable. Conversely, the detection rate of inguinal cryptorchidism by CT is 100%. We consider that CT can confirm whether there is cryptorchidism in the subcutaneous inguinal region and allows selection of an appropriate surgical method (laparoscopic surgery, laparotomy) and reduces the burden on the bulls. Moreover, we described the CT values and sizes of the retained testes. These showed a weak correlation with age, so it was considered that the maturation of retained testes might depend not on the descending process but on age.

The present study suggested that CT may be useful in the diagnosis and treatment of bulls with cryptorchidism.

CONFLICT OF INTEREST. All authors have no conflict of interest.

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