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Volumetric Estimation of the Prostate Gland using Computed Tomography in Normal Beagle Dogs

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Abstract : The purpose of this study was to determine and compare prostate size using ultrasound and computed tomography (CT). The prostate gland was evaluated in eight normal Beagle dogs. Length, depth, and width of the prostate gland were measured by ultrasound and volume of the prostate was obtained from the two ellipsoid formula (US1, US2). Height, length, width, area, and volume of the prostate gland were measured by CT. Ratios of prostatic height, length, and width to the sixth lumbar vertebral body length were calculated. There was no significant difference between the US1 and US2 method, and between US2 and CT method, respectively. The prostatic volume calculated by US1 method was significantly lower than those with CT ($p = 0.029$). The Upper limits of ratios of prostate length, height, and width to the length of the sixth lumbar vertebra were 1.3, 1.1, and 1.7, respectively. Among these prostate dimensions, prostate length and height could be a useful index in estimating prostate size regardless of body weight.

Key words **:** prostate, ultrasonography, computed tomography, dog.

Introduction

Prostate disease is a common problem in older, intact male dogs (6). All common prostate gland diseases usually cause enlargement, which may be symmetric, asymmetric, or a combination of the two. Disorders associated with prostatomegaly are benign prostatic hypertrophy, prostatitis, prostatic cyst, abscess and neoplasia (10). Hypertrophy and prostatitis usually cause symmetric enlargement, whereas neoplasia and cysts cause asymmetric enlargement (10). Estimation of the canine prostate gland size would be useful for clinical evaluation of prostatic disorders and monitoring the response of therapy (1). The diagnostic tools used for evaluating prostate size in dogs include abdominal radiography and transabdominal ultrasonography (1,3). Radiography is a simple method of measuring prostate size, but the prostate boundaries may not be easy to identify because of interference of other organs such as urinary bladder and descending colon (9). Transabdominal and transrectal ultrasound have been used for the assessment of prostate size in dogs (3). Transrectal ultrasonography is reported as an accurate method of determining prostate size in human beings (9). However, it may not be convenient, because it requires a special transducer. In dogs, transrectal ultrasonography causes discomfort when the probe is introduced to the rectum, especially for dogs with prostate enlargement (9). Transabdomnial ultrasonography is an accurate, inexpensive and convenient method to measure prostate size in dogs (9). However, sonographically indistinct dorsal and ventral prostate margin has also been reported, likely because these margins have similar acoustic impedances to other tissues (1).

Computed tomography (CT) has become widely available in veterinary medicine for assessing disorders of the abdomen, including those of the gastrointestinal tract and reproductive system (11). CT generates tomographic images, avoiding superimposition of tissue and the confusing shadows which is inherent in conventional radiographs (11). Furthermore, minor changes in size and shape of the prostate gland are more easily detected with CT than with radiography or ultrasonography (10). However, there are currently few reports on CT-based evaluation of prostate gland in dogs (11). A previous study compared prostatic dimensions measured on radiography and ultrasonography in dogs (1). However, there are no reports about comparing prostatic sizes using ultrasonography and CT.

The purpose of this study was to evaluate for normal variation of prostate gland dimensions using ultrasonography and CT and determine a useful parameter for CT measurement of the prostate gland in normal Beagle dogs.

Materials & Methods

Eight healthy Beagle dogs with age ranging from 4 to 5

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years and body weight ranging from 7.9 to 10.6 kg (mean 9.35 kg) were used. None of the dogs had a history of urologic disorders and hormonal treatment. Physical examinations and clinical laboratory analysis including complete blood count and serum biochemistry and urinalysis were normal in all dogs. Thoracic and abdominal radiography and abdominal ultrasonography revealed no significant findings. Ultrasound-guided fine needle aspiration of the prostate gland was performed and cytologic features of prostate glands were normal in all dogs.

Ultrasonographic images were obtained with an ultrasound system (SonoAce8800®, Medison, South Korea) using 10.0 MHz linear transducer. The transducer was moved to obtain the maximum size of the gland in longitudinal section and the following dimensions were measured: cranial to caudal pole of the prostate length (L) and dorsal to ventral part of the prostate depth (DL) (Fig 1). A transverse image was obtained vertical to the maximal longitudinal section of the prostate gland. The maximum width (W) and depth (DT) were measured in the transverse image. Prostate volume was calculated using following formulas.

US1) Prostate volume = $1/2.6\ (L \times W \times DL) + 1.8$

US2) Prostate volume = $0.487 \times L \times W \times \{(DL+DT)/2\} + 6.38$

All dogs were fasted for approximately 12 hours before CT examination. For CT scanning, general anesthesia was performed. A 22 G intravenous indwelling catheter was placed in cephalic vein. Anesthesia was induced with propofol (5-6 mg/kg, IV, AnepolInj®, Hana, Korea) and maintained with isoflurane (1.5 MAC, inhalation, Ifran®, Hana, Korea). The dogs were positioned in dorsal recumbency and their heads were placed toward CT gantry. CT scanning was performed using multi-detector CT (Asteion 4, Toshiba, Japan) under the following conditions: 150 kVp, 120 mAs, 2 mm slice thickness.

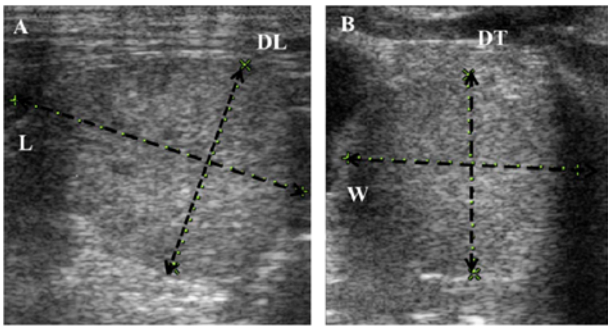

Fig 1. Longitudinal (A) and transverse (B) ultrasonographic scan of Beagle dogs illustrating where measurements were made. L: length, DL and DT: depth, W: Width.

All CT data were reconstructed with an image-processing workstation (Rapidia®, Infinitt, Korea) and evaluated with three cross-sectional images (transverse, sagittal and dorsal planes) and three-dimensional images. The length of the sixth lumbar vertebral body was measured on reconstructed sagittal images. A transverse image was obtained vertical to the urethral axis visualized on a sagittal image. On transverse images, the heights of the left and right lobes of the prostate gland were measured. Prostatic width was defined as maximum dimension perpendicular to prostatic height on the transverse image. On dorsal plane images, prostatic length was defined as the maximum distance parallel to the urethral axis on the left and right lobes of the prostate gland, respectively. Prostatic width on the dorsal plane image was defined as the maximum dimension perpendicular to the longitudinal axis. Prostatic area was determined on the transverse image with a freehand image tracing software tool. Prostatic volume was calculated by a volume rendering software tool (Fig 2A-D). Ratios of prostatic length (rL), width (rW) and height (rH) to the length of the sixth lumbar vertebral body were calculated.

Statistical analysis was performed using SPSS for window 17.0 (PASW® statistic 17.0, SPSS Inc., Chicago, USA). Mean and standard deviation were calculated for body weight, each prostatic dimensions (height, length, width) and rH, rL and rW, respectively. Wilcoxon signed-rank test was used to compare heights of the left and right lobes, the lengths of left and right lobes, widths on transverse images and dorsal plane images of the prostate gland. A Spearman correlation test was used to compare the relationship between height and volume, width and volume, and length and volume. A linear regression equation was obtained for each of the indexes. One-

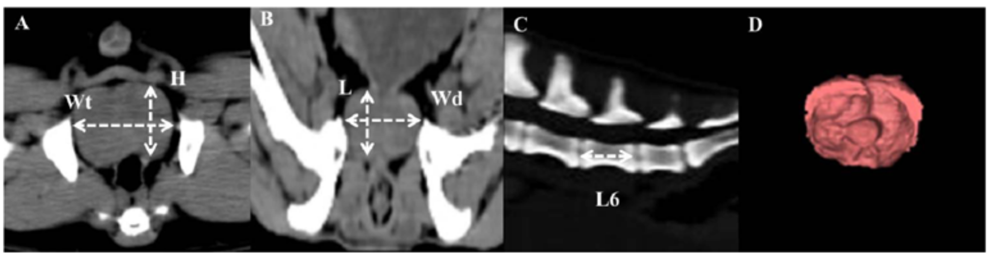

Fig 2. CT images of the prostate gland in a male dog illustrating where measurements were made. Transverse (A), dorsal (B) and Sagittal plane (C) CT images of the prostate in a male dog. Height was measured on the transverse image and prostatic length was measured on the dorsal plane image. Prostatic width was measured on transverse image and dorsal plane image, respectively. Length of the sixth lumbar vertebral body (C) and 3D volume of the prostate gland were calculated (D). L: length, H: height, Wt: width on transverse image, Wd: width on dorsal image, L6: length of the sixth lumbar vertebral body.

way ANOVA test was used to compare the volume between the ultrasonography and CT. A value of $P < 0.05$ was considered statistically significant.

Results

The results of the prostate volume in 8 Beagle dogs using ultrasound and CT were summarized in Table 1. The range of prostate volumes in 8 normal Beagle dogs was from 7.8 to 15.27 ml in US1, 8.33 to 23.33 ml in US2 and 8.52 to 29.63 ml in CT method. The calculated prostatic volume from both US1 and US2 methods were lower than those from CT method. There were no significant difference between the US1 method and US2 method. There was also no significant difference between US2 and CT method. The US1 method was significantly underestimated compared with CT method ($p = 0.029$). There was no significant relationship between body weight and volume.

All prostatic measurements and analyses for prostatic dimensions/L6 ratio using CT were summarized in Table 2 and 3. On transverse images of the prostate gland, range of height and width were from 16.80 to 26.07 mm and from 23.64 to 39.29 mm, respectively. On dorsal images, the range of length and width were from 11.38 to 29.51 mm and from 23.14 to 36.05 mm, respectively. A significant positive correlation was found between prostatic length ($r^2 = 0.69$) and width ($r^2 = 0.80$) and volume (Fig 3, 4). There was no significant relationship between height and volume (Fig 5). The ranges of rL, rH and rW were from 0.61 to 1.42, 0.83 to 1.18 and 1.25 to 1.86, respectively.

Table 1. Measurements of ultrasonographic and computed tomographic prostate gland volumes in the 8 Beagle dogs

*p < 0.05

No.	Ultrasonographic prostate volume (ml)		CT prostate volume (ml)
	US1	US2	CT
1	13.89	21.74	23.14
2	9.02	15.04	17.69
3	7.8	11.04	11.35
4	8.08	8.33	8.52
5	8.74	23.33	26.71
6	8.88	10.34	11.37
7	11.08	17.32	20.03
8	15.27	21.75	29.63
Mean ± SD	10.35 ± 2.81*	16.11 ± 5.83	18.56 ± 7.72*

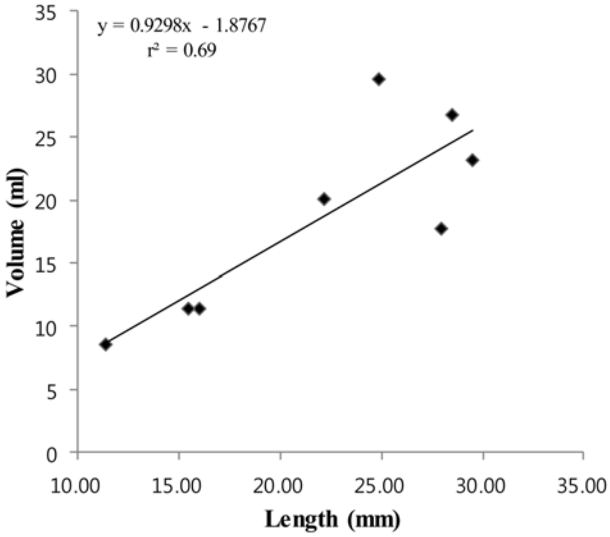

Fig 3. The correlation between prostate length and volume by CT method in the 8 Beagle dogs. There was statistical significant relationship between length and volume of the prostate gland.

Discussion

Canine prostate size has been used as a factor indicating prostate disorders. Previously, measurements of prostatic length, depth or height and width using radiography and ultrasonography have been used to estimate prostate size (1). On abdominal radiography, prostatic depth is difficult to estimate due to imprecise prostatic boundaries caused by interference of adjacent viscera, especially the colon which may obscure the

Table 2. Measurements of the computed tomographic prostate size in the 8 Beagle dogs

No.	L6 (mm)	Length (mm)			Height (mm)			Width (mm)		
		Left lobe	Right lobe	Mean length	Left lobe	Right lobe	Mean height	Wd	Wt	Mean width
1	23.51	27.66	31.35	29.51	23.97	24.9	24.44	35.96	35.04	35.50
2	20.17	28.51	27.44	27.98	16.22	17.38	16.80	36.05	35.63	35.84
3	20.39	16.67	15.29	15.98	20.84	21.3	21.07	28.25	27.78	28.02
4	18.72	9.82	12.93	11.38	18.76	17.64	18.20	23.14	23.64	23.39
5	20.11	26.94	30.07	28.51	20.75	17.98	19.37	35.32	39.29	37.31
6	18.22	15.07	15.8	15.44	17.45	16.7	17.08	28.7	27.49	28.10
7	19.94	23.41	20.92	22.17	22.37	23.67	23.02	32.01	33.46	32.74
8	22.12	23.54	26.15	24.85	25.97	26.16	26.07	35.56	35.8	35.68
Mean ± SD	20.40 ± 1.71	21.45 ± 6.82	22.49 ± 7.21	21.97 ± 6.91	20.79 ± 3.29	20.72 ± 3.79	20.75 ± 3.48	31.87 ± 4.77	32.27 ± 5.34	32.07 ± 4.99

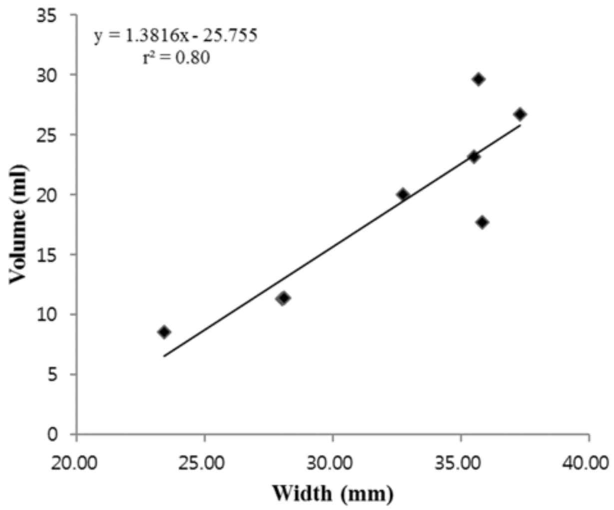

Fig 4. The correlation between prostate width and volume by CT method in the 8 Beagle dogs. There was statistical significant relationship between width and volume of the prostate gland.

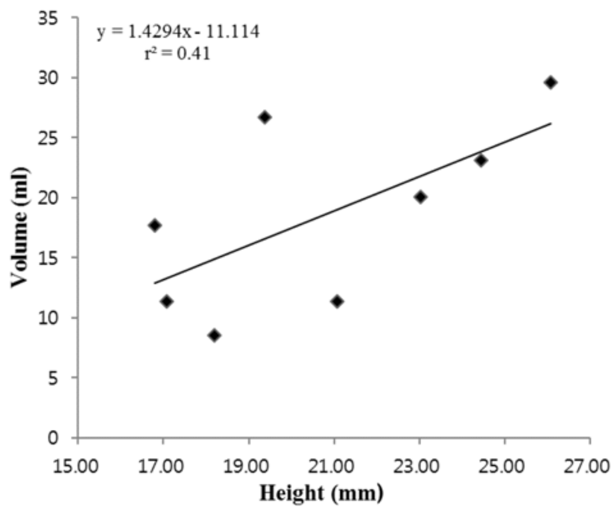

Fig 5. The correlation between prostate height and volume by CT method in the 8 Beagle dogs. There was no statistical significant relationship between height and volume of the prostate gland.

dorsal radiographic border of the prostate (1,8). Ultrasonographic meathods are non-invasive, simple and quick procedures for the assessment of prostate size (1,2). However, indistinct dorsal and ventral prostate margin has also been reported, likely because these margins have similar acoustic impedances to other tissues (1,4). CT which is widely used for assessing disorders of the abdomen in veterinary medicine is thought to be more accurate and valuable tool for evaluation of the prostate gland in dogs (11).

Using ultrasonographical method, the measurements of length and depth of prostate gland were satisfactory but width on transverse section was not as good. The transducer had to be angled caudally to obtain a proper transverse section. This is probably due to difficulty in the assessment of the transverse section when the prostate is located intrapelvically, a problem also encountered with another study (4). However, prostate height, length and width were easily measured in transverse and dorsal plane on CT images. The boundaries of the prostate gland on CT image were more distict than ultrasonography.

In this study, the volume of prostate gland obtained with ultrasonographic method was lower than those obtained by CT. This underestimation of the prostate volume occurred with ultrasonography, which shows that the inaccuracy is related to the use of the ellipsoid formula. In other words, the prostate is not a true ellipsoid (9). Besides, the problems associated with imaging the prostate gland have been reported previously as due to scanner configuration, the difficulty in the positioning of the transducer in the transverse plane due to the dog's penis, indistinct margins of the prostate dorsally and ventrally since these margins are adjacent to other tissues with acoustic impedances similar to that of the prostate (3). This study did not obtain the actual prostate volume to determine whether ultrasonography or CT was more accurate in volume. Transrectal ultrasonography has been shown to underestimate the prostate volume compared with CT in human study (6). Based on these results, we believed that CT was more accurate method than ultrasonographic methods. However, further study will be needed to compare the actual prostate gland volume with prostate volume estimation using CT. There was no significant relationship between body weight, age and volume. Possible reason could be the small numbers of the studied dogs and further study should be required.

In this study, prostate length and width correlated better with prostate volume than height. A previous study also showed similar results (1,11). This result may be caused by less resistance to longitudinal enlargement than that provided in the dorsoventral plane by adjacent structures such as the pubis and rectum (1).

There was no standard of definitive prostatomegaly evaluation with imaging modalities in dogs. Physical measurement is the only real gold standard. Therefore, normal range of prostate volume and a single parameter are very important for evaluating prostate disorders. On radiographic assessment, prostatomegaly is diagnosed when the prostatic dimension (length or width) exceed 70% of the pubic brim-sacral promontory dimension (1). However, this method is also subjective and inaccurate measurement with observer variability. Furthermore, surrounding tissues which influence the prostate gland may lead to indistinct prostate margins on radiography. Therefore, objective normal prostate gland dimension range will be needed.

In this study, we also evaluate ratios of prostate length, width and height to the length of the sixth lumbar vertebral body. A ratio of 1.3, 1.1 and 1.7 was suggested as the upper limit of the normal range in length, height and width, respectively. Ratio of prostate length and height to the length of the sixth lumbar vertebral body was about 1:1. Among these prostate dimensions, prostate length and height could be a useful index in estimating prostate size regardless of body weight and also applied to the radiography.

In order to establish normal range of prostate gland sizes, more studies required to variable breeds, age and body weight. There are no reports about comparison true prostate gland with estimated prostate gland volume using CT. Further studies are needed to more completely define the role for evaluating prostate volume by CT in dogs, especially dogs with prostate disease.

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정상 비글견에서 컴퓨터단층촬영술을 이용한 전립선의 부피 평가

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요 약 : 전립선의 크기를 측정하는 것은 전립선 이상을 임상학적으로 인지하고 치료에 대한 반응을 모니터링 하는데 유용하다. 전립선 질환에서 일반적으로 나타나는 전립선의 형태와 크기 변화는 방사선, 초음파 및 컴퓨터단층촬영 (CT)과 같은 영상학적 방법을 통해 평가한다. 본 연구에서는 전립선의 크기를 평가하는데 가장 많이 사용되는 초음파와 실질 장기의 평가에 높은 정확도를 보이는 CT를 이용하여, 중성화 하지 않은 정상 비글견에서 전립선 크기를 측정하고 비교하는데 목적이 있다. 또한 CT를 이용하여 전립선의 크기를 측정하여 체중과 관계없이 전립선의 크기를 평가할 수 있는 간단하고 실용적인 기준을 확인하고자 한다. 비뇨기계 및 내분비계에 이상이 없고 세포학적 검사로 정상 전립선으로 평가된 8 마리 정상 비글견에서 초음파와 CT 촬영을 실시하여 전립선의 크기를 비교 및 평가하였다. 초음파를 이용한 전립선의 부피를 측정하기 위해 서로 다른 2가지 단면에서 각 측정치를 구하고 타원체 공식 (US1, US2)에 대입하였다. CT의 경우 freehand tracing 방법을 이용해 전립선의 부피를 측정하였다. 초음파를 이용한 2가지 방법 모두 CT를 이용한 방법보다 낮은 측정치를 보였으며, 특히 US1 방법이 CT방법에 비해 통계적으로 유의성 있게 낮은 결과치를 보였다. CT를 통해 촬영된 이미지의 재구성을 통해 전립선의 길이, 높이, 너비를 측정하여 부피와의 상관관계를 평가하였다. 측정된 수치 중 길이와 너비가 부피와 가장 높은 상관관계를 나타냈다. 또한 촬영된 이미지에서 6번째 요추체의 길이를 측정하고 각 전립선 크기 (길이, 높이, 너비)와의 비율을 분석하였다. 실험에서 요추 6번과 전립선의 길이 및 높이는 약 1:1의 비율을 보였으며, 길이와 높이의 상한선은 1.3배, 너비의 상한선은 1.7배로 고려되었다. 이러한 비율에 대한 결과 중 길이와 높이에 대한 비율은 방사선 사진에서도 적용이 될 수 있을 것으로 생각되며, 전립선 크기를 체중과 상관없이 평가할 수 있는 간단하며 유용한 지표로 사용될 수 있을 것으로 생각된다.

주요어 : 전립선, 컴퓨터 단층촬영, 초음파, 개