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Original Article

Assessment of abdominal fat distribution by computed tomography in obese dogs

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Abstract

Obesity is a risk factor for canine health but there has been no study on the tendency of body fat accumulation naturally occurring in obese dogs. This retrospective observational study aims to evaluate the tendency to accumulate visceral and subcutaneous fat using computed tomography (CT) in naturally occurring obese dogs. The study included 15 dogs with a body condition score of 8 or 9 that underwent abdominal CT scans. Total fat area (TA), visceral fat area (VA), subcutaneous fat area (SA) and body area (BA) were measured by non-contrast transverse image at the third lumbar vertebra (L3) and the sixth lumbar vertebra (L6). TA, VA and SA were divided by the length of the L6 body to account for different body size. The ratio (rTA, rVA, and rSA) was then calculated. rTA and rVA were significantly higher at L3 and rSA was significantly higher at L6. TA/BA and VA/SA were analyzed at L3 and L6, respectively. No difference in TA/BA between L3 and L6 was shown while the VA/SA was significantly higher at L3 than at L6 (P = 0.001). There was no difference of visceral and subcutaneous fat distribution between the male and female groups. The findings of the present study suggested that visceral and subcutaneous fat are accumulated at L3 and L6, respectively, and obese dogs tend to accumulate more visceral than subcutaneous fat.

Keywords: canine, computed tomography, fat distribution, subcutaneous fat, visceral obesity

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Introduction

Obesity is divided into subcutaneous and visceral fat types according to the location of the accumulation. Visceral obesity is recognized as an important factor in an underlying metabolic disorder rather than subcutaneous fat accumulation in human medicine (Despres JP *et al*., 1989; Fujioka S *et al*., 1987). Visceral fat may also affect metabolic and cardiac disorders in dogs (Adolphe JL *et al*., 2014; Hua J *et al*., 2016; Kabir M *et al*., 2011; Müller L *et al*., 2014; Santarossa A *et al*., 2017; Thengchaisri N *et al*., 2014). However, the study of abdominal fat composition in dogs has been less reported than in humans.

Computed tomography (CT) for quantifying obesity is an objective method to separately evaluate visceral or subcutaneous fat. Previous studies have proved the accuracy of CT for measuring body composition in dogs which also suggests that CT is a useful methodology to evaluate body fat (Kim D *et al*., 2018; Purushothaman D *et al*., 2013; Turner RBS *et al*., 2019). Studies of abdominal fat accumulation tendency using CT in normal dogs and comparison before and after neutering have been reported (Kim D *et al*., 2018; Kobayashi T *et al*., 2014). A previous study using normal Beagle dogs reported that the third lumbar vertebra (L3) and the sixth lumbar vertebra (L6) are more suitable locations for evaluating visceral and subcutaneous fat, respectively (Kim D *et al*., 2018; Ishioka K *et al*., 2005). When compared before and after neutering in three dogs, the increase in visceral fat after neutering was not as remarkable as that of subcutaneous fat (Kobayashi T *et al*., 2014). However, there have been few studies on the tendency of body fat accumulation in obese dogs (Ishioka K *et al*., 2005). A study has reported that the body fat accumulation tendency in four obese dogs was caused by high-energy feeding showing that visceral fat accumulated faster than subcutaneous fat (Ishioka K *et al*., 2005). However, has been no no study on the tendency of body fat accumulation in dogs with naturally-occurring obesity. Thus, this paper questions that the tendency of body fat accumulation in dogs with naturally occurring obesity was the same in normal or obesity-induced dogs. The purpose of this study was to demonstrate the visceral and subcutaneous fat accumulation tendency by CT in naturally occurring obese dogs.

Materials and Methods

This retrospective observational study included obese dogs that had had an abdominal CT scan. This study defined obesity as a body condition score (BCS) of 8 or 9 on a nine-point scale based on the weight management guidelines for dogs and cats (Brooks D *et al*., 2014). The decisions of BCS were made by a consensus of at least two veterinarians. The database was screened for non-contrast CT scan of the abdomen performed at the Veterinary Teaching Hospital of Kyungpook National University between June 2016 and December 2020. Approval by the Animal Care and Use Committee of our institution was not required due to the retrospective nature of the study. Moreover, all clients had previously signed informed consent for the use of their dog's data in research. Patients with peritoneal effusion, large abdominal masses and abdominal herniation at the L3 or L6 levels were excluded. Similarly, patients with a recent history of abdominal surgery that could alter abdominal fat status were also excluded. The medical records were reviewed and the breed, age, sex, body weight and nine-point scale BCS were recorded.

Computed tomography scan techniques and image assessment: A 32-Multislice CT scanner (Alexion, Canon Medical Systems, Tokyo, Japan) was used for all CT scans performed in this study. All dogs had undergone general anesthesia and were positioned in dorsal recumbency on the CT table. The scanning parameters were 120 kV, 200 mA and 1.0 mm slice thickness. The CT images were acquired from the diaphragm to the coxofemoral joint in a craniocaudal direction.

All CT images were reviewed and analyzed on a soft-tissue window (window width, 450 Hounsfield units (HU); window level 40 HU) and sagittal images on a bone window (window width, 2,000 HU; window level, 600 HU) using a picture archiving and communication system (INFINITT PACS, INFINITT Healthcare, Seoul, Korea). Body area (BA), total fat area (TA), subcutaneous fat area (SA) and visceral fat area (VA) were assessed on transverse CT images with the most prominent spinous processes in L3 and L6 (Fig. 1). The region of interest (ROI) was manually drawn along the skin-air interface to assess BA and TA. Another ROI was manually drawn surrounding the peritoneal cavity to assess VA. The SA was calculated by subtracting VA from TA. The areas occupied by the fat attenuation range (-135 to -105 HU) were obtained in reference to a previous study (Ishioka K *et al*., 2005). To standardize the fat areas, TA, VA and SA were divided by the L6 length and described as a ratio for each criterion ($_r$TA, $_r$VA, and $_r$SA). The sagittal CT images with bone windows were used to measure the length of L6 (Fig. 2). The TA/BA and the VA/SA ratios were calculated to evaluate the tendency of abdominal fat accumulation based on previous studies (Fujioka S *et al*., 1987; Kamimura MA *et al*., 2013; Kvist H *et al*., 1988; Moon HG *et al*., 2008; Park HS and Lee K, 2005).

Statistical analysis: All statistical analyses were performed using commercial software (SPSS 25.0, IBM SPSS Statistics, Armonk, NY, USA). The Shapiro-Wilk test was used to evaluate the normality of rTA, rVA, rSA, TA, BA, VA and SA. The differences between rTA, rVA and rSA at L3 and L6 were analyzed using the Wilcoxon signed-rank test to identify the site of fat accumulation. Similarly, the differences between TA/BA and VA/SA at L3 and L6 were respectively analyzed using the Wilcoxon signed-rank test. The differences of TA/BA and VA/SA at L3 and L6 between the male and female groups were analyzed using the Mann-Whitney *U* test. *P*-values of < 0.05 were considered statistically significant.

Results

Fifteen dogs met the inclusion criteria: three Chihuahua, two Cocker Spaniel, two Shih-Tzu and one each of Yorkshire terrier, Bichon Fries, Poodle, Dachshund, Maltese, Beagle, Spitz and Welsh Corgi. The mean values ± standard deviation (SD) of age and body weight were 9.4 ± 3.6 years (range, 3–14.2 years) and 11.2 ± 5.7 kg (range, 3.3–23.2 kg), respectively. Nine females (one intact and eight spayed) and six males (one intact and five castrated) were included in the study. Ten and five dogs were assigned a BCS of 8 and 9, respectively.

The rTA and rVA were higher at L3 than at L6 ($P < 0.05$). The rSA was higher at L6 than at L3 ($P = 0.011$). No significant differences in the mean values of TA/BA between L3 and L6 were found. VA/SA was higher at L3 than L6 ($P = 0.001$). The mean values ± SD for $_r$TA, $_r$VA, $_r$SA, TA/BA and VA/SA at L3 and L6 levels are summarized in Table 1. In evaluating the tendency to abdominal fat distribution by sex, no difference was noticed in the TA/BA and VA/SA at L3 and L6 between males and females. The mean values ± SD of TA/BA and VA/SA depending on gender at L3 and L6 levels are summarized in Table 2.

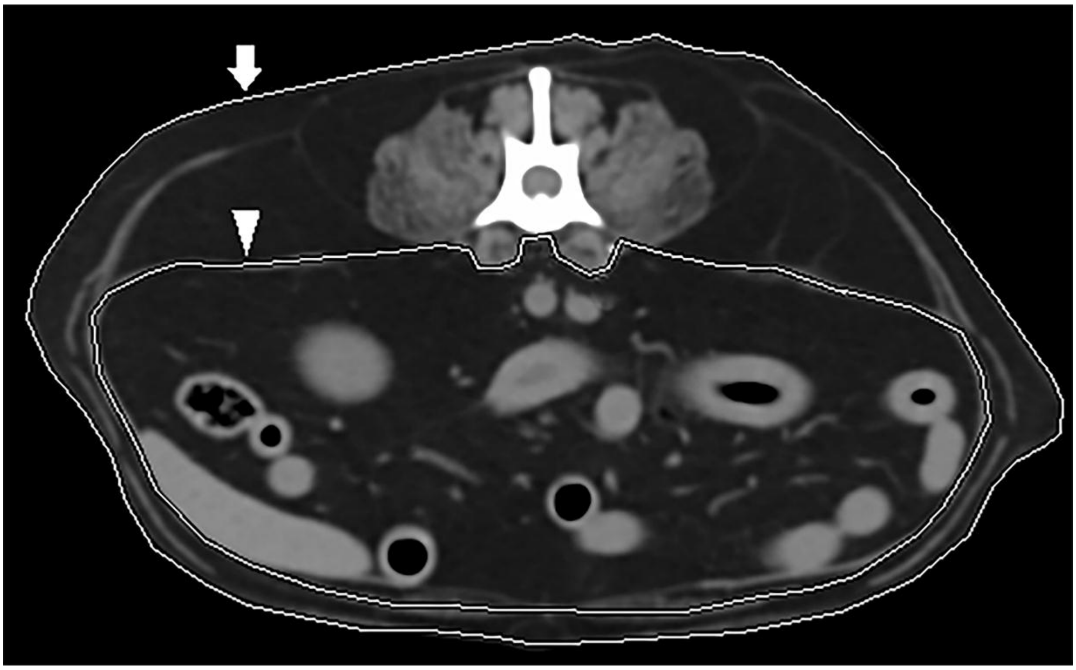

Figure 1 Measurement of body area (BA) and fat area using the transverse image of computed tomography at L3. The region of interest (ROI) is drawn around the body (arrow) to measure the BA and total fat area (TA). Another ROI is drawn surrounding the peritoneal cavity (arrowhead) to measure the visceral fat area (VA). The VA is subtracted from the TA to calculate the subcutaneous fat area (SA). The attenuation range of –135 to –105 Hounsfield units is used to measure the TA, VA and SA.

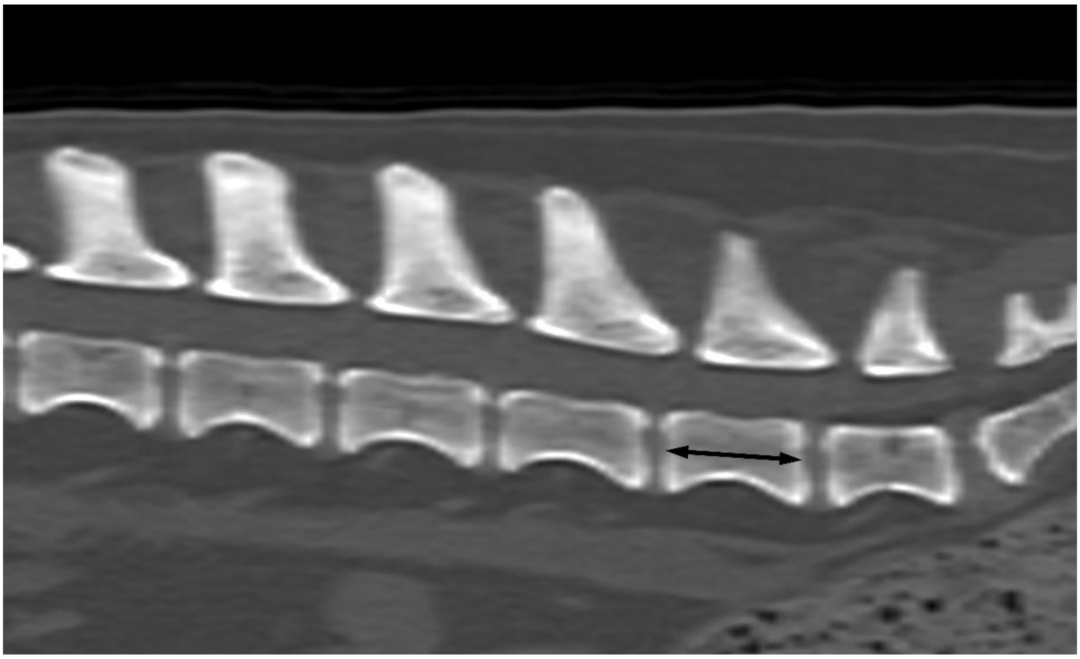

Figure 2 Measurement of L6 length using sagittal image of computed tomography. The distance parallel to the dorsal border of the L6 body and halfway between the dorsal and the ventral border of the L6 body is measured (arrow).

Table 1 The fat measurement and measuring criteria at L3 and L6 Level (n = 15)

Variable	Location (mean ± SD)		*P*-value[a]
	L3	L6	
rTA	470.0 ± 206.3	422.6 ± 251.4	0.028*
rVA	228.5 ± 96.3	97.1 ± 57.7	0.001*
rSA	241.4 ± 128.3	325.5 ± 204.4	0.011*
TA/BA	0.39 ± 0.08	0.39 ± 0.12	0.588
VA/SA	1.12 ± 0.71	0.32 ± 0.18	0.001*

[a]Wilcoxon signed-rank test
*Statistically significant
L3, third lumbar vertebra; L6, sixth lumbar vertebra; rSA, ratio of subcutaneous fat area; rTA, ratio of total fat area; rVA, ratio of visceral fat area; SD, standard deviation; TA/BA, total fat area to body area ratio; VA/SA, visceral fat area to subcutaneous fat area ratio

Table 2 TA/BA and VA/SA in the male and female groups

Location	TA/BA (mean ± SD)			VA/SA (mean ± SD)		
	Male	Female	*P*-value[a]	Male	Female	*P*-value[a]
L3	0.38 ± 0.05	0.40 ± 0.09	0.529	1.38 ± 1.05	0.95 ± 0.34	0.529
L6	0.40 ± 0.08	0.38 ± 0.15	0.776	0.40 ± 0.25	0.28 ± 0.10	0.388

[a]Mann-Whitney *U*-test
L3, third lumbar vertebra; L6, sixth lumbar vertebra; SD, standard deviation; TA/BA, total fat area to body area ratio; VA/SA, visceral fat area to subcutaneous fat area ratio

Discussion

This study evaluated whether obese dogs would have a different tendency to accumulate body fat compared with normal dogs. The present study found that obese dogs had a fat distribution that is consistent with the fat distribution of normal Beagle dogs, which was previously reported (Kim D *et al*., 2018). The tendency to body fat accumulation at the L3 and L6 levels was similar in both obese and normal dogs; rTA and rVA were significantly higher at the L3 level while rSA was significantly higher at the L6 level. However, VA/SA at the L3 level was reported to be 0.72 in normal dogs (Kim D *et al*., 2018) but it was 1.14 in obese dogs in the present study. Therefore, obese dogs tend to accumulate more visceral fat at the L3 level than normal dogs. Another study reported that VA/SA was 0.78 in four obesity-induced dogs and that three of the four dogs had increased VA/SA (Ishioka K *et al*., 2005). The reason for the difference in VA/SA between the previous study (Ishioka K *et al*., 2005) and the present study was thought to be that weight gain and the total fat mass increase was the criterion for obesity in the previous study, while BCS 8–9 was the criterion in this study. In addition, it may have been due to the cause of obesity (obesity caused by high-energy feeding in the previous study versus naturally occurring obesity in the present study), the number of animals and the duration of obesity induction. Furthermore, breeds should also be considered in evaluating the fat distribution based on a previous study on breed effect in body composition (Jeusette I *et al*., 2010).

The different effects of visceral and subcutaneous fat have been reported in human medicine. Visceral obesity is an important factor in metabolic disease and VA/SA is significantly correlated with metabolic diseases (Fujioka S *et al*., 1987). In addition, visceral fat may play an important role in hypertension, coronary heart disease and non-insulin dependent diabetes mellitus and dyslipidemia (Bergman RN *et al*., 2006; Kanai H *et al*., 1990; Nasir K *et al*., 2005; Rattarasarn C *et al*., 2003; Rexrode KM *et al*., 2001). Abdominal fat distribution in animals is also presumed to be associated with metabolic diseases based on previous studies (Adolphe JL *et al*., 2014; Kabir M *et al*., 2011; Müller L *et al*., 2014). However, another study reported the different effects of abdominal fat between dogs and humans. Leptin, an anti-obesity hormone that increases energy expenditure and suppresses appetite, is mainly synthesized in the adipocyte (Ettinger SJ and Feldman EC, 2017). The adipose tissue volume of visceral fat is the main determinant of leptin level in dogs, which is different from humans where the subcutaneous fat is the main determinant of leptin level (Müller L *et al*., 2014). Moreover, increasing visceral fat did not significantly increase insulin resistance in the canine model (Castro AV *et al*., 2015). This suggests that the effects of visceral and subcutaneous fat may differ between obese dogs and obese humans. Therefore, multiple factors of the metabolic mechanism could influence body fat distribution. Consequently, further studies are needed to identify fat distribution between different metabolic diseases in dogs.

Sex differences in abdominal fat distribution using CT were reported in human medicine (Kvist H *et al*., 1988; Dixon A, 1983; Lemieux S *et al*., 1993; Pouliot MC *et al*., 1992). Similar fat distribution tendency has been reported in normal Beagle dogs and visceral and subcutaneous fat is significantly accumulated in males and females, respectively (Kim D *et al*., 2018). This fat distribution tendency was also observed in obese dogs in the present study, although the measures were not significantly different at both L3 and L6. This may be due to the small number of obese dogs and neutralization in this study. Intact males and intact females were included in the previous study (Kim D *et al*., 2018). However, 11 of 13 dogs in this study were neutralized. It can be concluded that neutralization may influence fat distribution. Previous studies showed that men have continuously increasing visceral adipose tissue volume with increasing total fat while women have constant volumes of visceral adipose tissue until 30 L of total adipose tissue accumulation (Kvist H *et al*., 1988). However, the present study could not evaluate the process of abdominal fat accumulation tendency for each gender. Thus, further studies are needed to evaluate the different fat distribution in obese dogs among sexual status.

A limitation of this study was that gender distribution was unbalanced and the study population was small. Nevertheless, this study could be valuable in that it has studied naturally occurring obese dogs. Further studies are needed to clarify the relationship of fat accumulation site and sexual status in a larger population and intact or neutralization status should be especially taken into consideration. Another limitation was the absence of information on food or care routine that may affect obesity such as food or treats selection, composition, amounts of intake of dietary energy or exercise. However, based on a previous study describing no correlation in visceral and subcutaneous fat distribution with food (Adolphe JL *et al*., 2015), it was believed that food did not have a significant effect on the results in the present study.

In conclusion, naturally occurring obese dogs tend to accumulate more visceral and subcutaneous fat at L3 and L6, respectively. Moreover, obese dogs tend to accumulate more visceral fat at L3 than normal dogs. The result of the present study showed no significant differences in visceral and subcutaneous fat distribution between males and females. Further studies are needed on abdominal fat distribution between sexes, considering the neutralization, in a larger number of obese dogs.

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