J Vet Clin 28(1) : 7-12 (2011)

Journal of Veterinary Clinics
www.ksvc.or.kr

Comparative Evaluation of the Lateral Ventricles with Computed Tomography in Yorkshire Terrier, Maltese, and Shih-Tzu Dogs

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(Accepted: December 08, 2010)

Abstract : This study was performed to evaluate the size and asymmetry of the lateral ventricles in CT images of three different small breed dogs. CT examinations were performed on thirty Yorkshire terriers, malteses, and shih-tzu dogs, respectively. The size and asymmetry of their lateral ventricles were evaluated at three different levels of brain, and dogs were categorized on the basis of the percentage of their ventricular height (Vh) to brain height (Bh). Degree of asymmetry was also categorized based on the rVh (ratio of right and left ventricular heights) as normal (rVh < 1.5), mild (1.5 < rVh < 2.0), or severe (2.0 < rVh). Clinically insignificant ventricular dilation was common in these breed dogs. However, severe asymmetry was not presented in clinically normal dogs. We suggested 11 mm as an upper limit of ventricular size in normal small breed dogs.

***Key words* :** ventriculomegaly, CT, dog.

Introduction

Hydrocephalus is a pathological condition in which there is an accumulation of cerebrospinal fluid (CSF) within the cranium and is a multifactorial disorder with a variety of pathophysiological mechanisms (2,17). Congenital hydrocephalus is the most common in toy breed dogs (17), and various diseases such as neoplasia and inflammatory diseases of brain can cause acquired hydrocephalus in small animals (12,16,21). Although all dogs with ventriculomegaly do not present neurologic signs, it is important to detect ventriculomegaly by neuroimaging methods for diagnosing of hydrocephalus and associated diseases. Unfortunately, the estimation of ventriculomegaly has been challenging due to marked breed variation of dogs. Brachycephalic, mesaticephalic and dolichocephalic breed dogs have different shaped skull and brain. In the current studies, variations in the appearance of the lateral ventricles were noted in some dogs (4,5,8,13,18,19). For example, the mean ventricular height at the level of the interventricular foramen in Beagle dogs was 4. 63 mm (8,19) In other reports, lateral ventricles of Bulldogs, Yorkshire terriers, and Boxers were relatively larger compared to that of Beagles, German shepherd dogs, Dachshunds, Labrador Retrievers, and Toy poodles (5,13). However, interbreed variation complicates ventricular size assessment, because the information about ventricular size and normal variations with respect to breed is still insufficient.

The purpose of this study is to design the method of measuring the size of lateral ventricles and to evaluate the size and asymmetry of the lateral ventricles in CT images of three different small breeds; Yorkshire terrier, maltese, and shih-tzu dogs.

Materials and Methods

Experimental Animals

Thirty Yorkshire terriers, maltese dogs, and shih-tzu dogs were included in this study. The signalments of experimental animals were summarized in Table 1. Physical and neurologic examinations were performed on all dogs. They had no clinically abnormal signs related to the central nervous system. Complete blood count, serum biochemical analysis, and thoracic and skull radiography were taken to evaluate the health condition of each dog. The procedures were approved by the Institute of Laboratory Animal Resources at Chungnam National University, and informed owner consents were obtained prior to the study enrollment.

Anesthesia

For taking CT, the dogs were premedicated with atropine (0.04 mg/kg, SC, Atropine sulfate inj.®, Jeil, Korea) and sedated with medetomidine (0.01-0.03 mg/kg, IV, Domitor®, Orion, Finland) and midazolam (0.1-0.3 mg/kg, IM, Dormicum®, Roche, Switzerland). The medetomidine was reversed using atipame-

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Table 1. Signalments of the experimental animals

	Age		Body Weight		Sex			
	Range (year)	Mean (year)	Range (kg)	Mean (kg)	Female		Male	
					Intact	Spayed	Intact	Castrated
YT	0.6-12	5.2	1.4-5.1	2.7	14	2	8	6
Mal	0.6-8	3.5	1.5-4.5	3.1	16	1	4	9
ST	0.3-8	3.1	2.9-9	4.6	18	0	2	10

YT: Yorkshire Terrier, Mal: maltese, ST; shih-tzu

zol after CT examination (0.04-0.12 mg/kg, IV, Antisedan®, Orion, Finland).

Computed Tomography

The CT images were obtained with a third-generation whole body scanner (CTmax®, GE, U.S.A). The dog was positioned in ventral recumbency. Contiguous 2 mm of the skull were obtained beginning immediately rostral to the optic canal and continuing caudally to a level of tympanic cavity.

Measurements of Lateral Ventricles

The size of the lateral ventricle and corresponding hemisphere were evaluated at the level of optic canal, interventricular foramen and temporomandibular joint with soft tissue window (WL: + 25, WW: 100) in all dogs. Brain height (Bh), ventricular height (Vh), Brain width (Bw) and venticular width (Vw) were measured on transverse images that were found vertically to the hard palate and were categorized on the basis of the percentage of their Vh to Bh (normal; $0 \leq Vh/Hh < 15\%$, moderate; $15 \leq Vh/Hh < 25\%$, severe; $Vh/Hh \geq 25\%$).

The Bh was measured in the longitudinal fissure at the level of optic canal, interventricular foramen and temporomandibular joint, respectively. The Vh was measured as the maximum length parallel to Bh in the lateral ventricle, and Hw as the maximum length vertical to Bh. The Vw parallel to the Bw and was found the largest distance (Fig 1). Each distance was measured as millimeter unit using caliper of CT scanner.

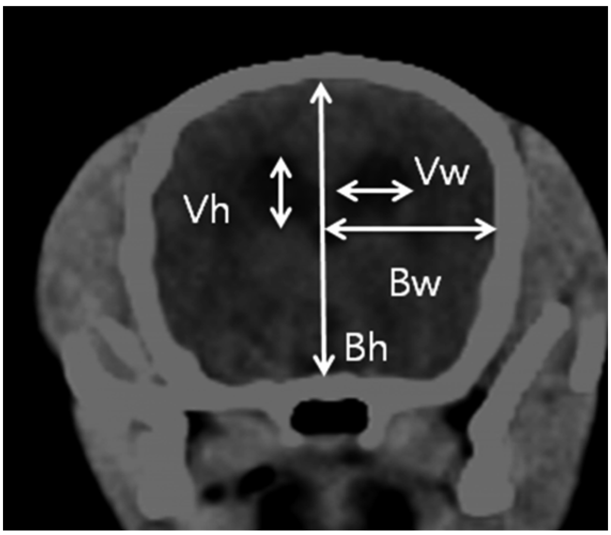

Fig 1. Transverse CT image with brain window in a Yorkshire terrier dog. The measurements used in the quantification of ventriculomegaly are shown: Bh, brain height; Bw, Brain width; Vh, ventricular height; Vw, ventricular width.

Degree of asymmetry was categorized on the basis of ratio (rVh) between left and right Vh as a mild ($rVh < 1.5$), moderate ($1.5 \leq rVh < 2$), or severe ($rVh \geq 2$).

Statistical analysis

A paired t-test was used to compare left and right ventricular height in each breed. Oneway ANOVA was performed among the three breeds to determine whether a significant difference existed between the means of each parameter measured. Pearson correlation was used to evaluate the relationship between the body weight and hemispheric height, ventricular height, and ventricular height to hemispheric height, respectively.

Results

For transverse scans of CT images, the mean sizes of lateral ventricles at the level of optic canal (OC), interventricular foramen (IVF) and temporomandibular joint (TMJ) were summarized in Table 2. The mean ratios of lateral ventricles to brain hemisphere and standard deviation (SD) in three breeds were summarized in Table 3.

Body weight had no statistical relationship to Vh, Vw, Vh/Bh, and Vw/Bw at the level of optic canal, interventricular foramen and temporomandibular joint in three breed dogs. Only one exception was right Vh at IVF of malteses showing mild correlation to body weight (Fig 2A). Also, the body weight had mild correlation to Bh at the level of interventricular foramen in Yorkshire terrier dogs (Fig 2B).

The mean value of the Vh was maximum at the level of interventricular foramen level in shih-tzu and maltese dogs. There were significantly differences between heights of the left and right lateral ventricls at the level of the temporomandibular joint in shih-tzu dogs ($p = 0.0414$), and the level of optic canal in Yorkshire terriers ($p = 0.0262$). Left and right ventricular heights significantly differ at all levels in maltese dogs (OC $p = 0.0043$, IVF $p = 0.0007$, TMJ $p = 0.0140$). Inter-breed difference of Vh was found in both left and right val-

Table 2. The results of ventricular heights and ventricular widths measured at the three different levels in Shih-tzu, maltese, and Yorkshire terrier dogs (mm).

		ST		MAL		YT	
		LT	RT	LT	RT	LT	RT
Vh	OC	4.15 ± 2.80	3.93 ± 2.44	4.46 ± 2.91	3.73 ± 2.01	4.45 ± 1.90	4.06 ± 1.88
	IVF	5.12 ± 2.21	4.86 ± 2.28	5.72 ± 2.86	4.85 ± 2.3	5.9 ± 2.33	5.55 ± 2.4
	TMJ	4.46 ± 2.35	3.86 ± 1.99	5.40 ± 3.33	4.72 ± 2.64	6.3 ± 2.25	6.06 ± 2.35
Vw	OC	4.57 ± 2.81	4.25 ± 2.56	5.16 ± 3.17	4.57 ± 2.74	4.96 ± 2.32	4.31 ± 0.77
	IVF	5.92 ± 2.53	5.6 ± 2.2	6.62 ± 3.22	5.99 ± 2.6	6.91 ± 2.57	6.78 ± 2.18
	TMJ	5.07 ± 2.65	4.7 ± 2.03	7.06 ± 3.91	5.98 ± 2.94	7.21 ± 2.15	7.23 ± 2.31

Vh; ventricular height, Vw; Ventricular width, ST; shih-tzu, MAL; maltese, YT; Yorkshire terrier, LT; left, RT; right, OC; optic canal level, IVF; interventricular foramen level, TMJ; temporomandibular joint level

Table 3. Relative ventricular heights and ventricular widths to brain heights and brain widths measured three different levels in shih-tzu, maltese, and Yorkshire terrier dogs (%).

		ST		MAL		YT	
		LT	RT	LT	RT	LT	RT
Vh/Bh	OC	11.7 ± 7.54	11.13 ± 6.53	12.89 ± 8.14	10.8 ± 5.9	13.45 ± 5.56	12.28 ± 5.57
	IVF	14.07 ± 5.71	13.31 ± 5.75	15.64 ± 7.66	13.29 ± 6.22	16.67 ± 6.43	15.68 ± 6.69
	TMJ	12.57 ± 6.44	10.87 ± 5.33	14.72 ± 9.04	12.93 ± 7.24	17.85 ± 6.35	17.17 ± 6.62
Vw/Bw	OC	22.3 ± 12.85	20.89 ± 11.89	26.96 ± 16.29	23.87 ± 13.85	26.06 ± 11.68	23.03 ± 4.47
	IVF	28.27 ± 10.87	27.02 ± 10.43	33.05 ± 16.14	29.84 ± 12.71	34.76 ± 12.75	34.03 ± 10.64
	TMJ	23.62 ± 12.06	22.06 ± 9.94	34.27 ± 18.96	28.94 ± 14	34.92 ± 10.42	34.96 ± 10.91

Vh; ventricular height, Bh; brain height, Vw; Ventricular width, Bw; brain width, ST; shih-tzu, MAL; maltese, YT; Yorkshire terrier, LT; left, RT; right, OC; optic canal level, IVF; interventricular foramen level, TMJ; temporomandibular joint level

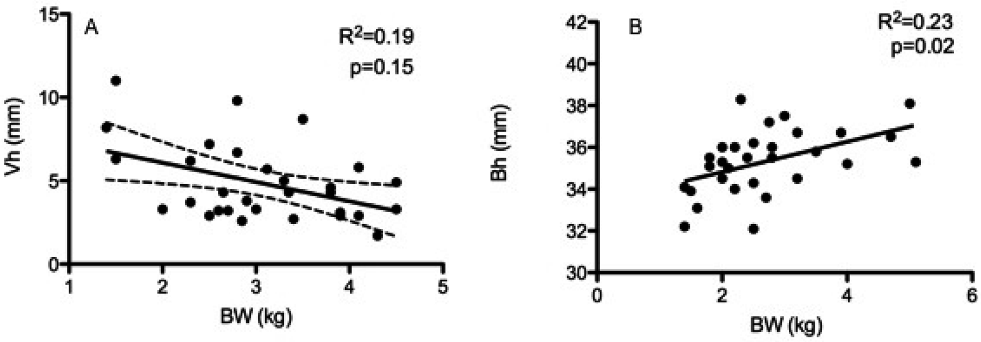

Fig 2. There are correlation between body weight (BW) and right ventricular heights (Vh) at IVF in maltese dogs, and body weight (BW) and brain height (Bh) in Yorkshire terriers.

ues at the level of temporomandibular joint between shih-tzu and Yorkshire terriers (Lt. p = 0.0341, Rt. p = 0.0002). For ventricular widths, no significant difference was observed between left and right values measured all three levels in shih-tzu and Yorkshire terriers, and at the level of interventricular foramen in maltese. Vws of maltese dogs showed significantly different values between left and right at the level of OC (p = 0.0039) and TMJ (p = 0.0060).

Distribution of the relative size of ventricles to brain height and asymmetry between the left and right ventricular size were summarized in Table 4. Most ST and Mal dogs were within normal group as 60% and 50% respectively, but 53% YT dogs were in moderate group. The asymmetry between the left and right ventricular size was present in a few dogs. Only one maltese dog had a severe asymmetry ventricles.

Table 4. Lateral ventricular configuration and asymmetry in three breed dogs.

		ST	MAL	YT
Configuration	Normal (Vh/Bh < 15%)	18 (60)	15 (50)	9 (30)
	Moderate (15 < Vh/Bh < 25%)	10 (33)	10 (33)	16 (53)
	Severe (Vh/Bh > 25)	2 (7)	5 (17)	5 (17)
Asymmetry	Mild (rVh < 1.5)	29 (97)	28 (93)	27 (90)
	Moderate (1.5 < rVh < 2)	1 (3)	1 (3.3)	3 (10)
	Severe (rVh > 2)	0	1 (3.3)	0

Number of dogs (%)
rVh; ratio of left and right ventricular height, ST; shih-tzu, MAL; maltese, YT; Yorkshire terrier

Discussion

The excessive accumulation of CSF may be responsible for neurologic signs due to an increase in intracranial pressure or the loss of brain parenchyma. A method to quantify ventricular volume has been developed and these data has been used to compare ventricular volume with hydrocephalus (18). CT and MRI allow exact assessment of ventriclular size and shape *in vivo* among diagnostic imaging modalities (1,9). Also, ventricular size has been determined at specific anatomic sites on ultrasonography and CT images (7,17).

In this study, brain and ventricular size were measured at the level of the optic canal, interventricular foramen, and temporomandibular joint because these sites are the anatomic landmarks on transverse CT images. Measurements of the lateral ventricular size using CT were useful and possible in all of three breed dogs. The relationship between the body weight and ventriculomegaly has been reported. In Selby's study, an inverse relationship was identified between the risk of hydrocephalus and increasing body weight (14). Also, Vite *et al.* suggested a possible trend between increasing percentage of ventriculomegaly and decreasing body weight in English bulldogs (18). In the other study, however, body weight had no statistical relationship to size of lateral ventricle (8). Body weight had no statistical relationship to Vh/Hh at the level of interventricular foramen in all of three breed dogs in this study. However mild correlation was shown between body weight and right ventricular height at IVF level in maltese dogs, and to Bh at the level of interventricular foramen in Yorkshire terrier dogs. In one study, a mildly inverse relationship was identified between the left ventriculomegly and increasing body weight in Beagle dogs and a mildly statistical relationship was detected between the left ventriculomegly and increasing body weight in German shepherd dogs (5). These discrepancies of the results might be due to breed difference or small numbers of studied dogs, so further study should be required.

The mean value of Vh, Vw, Vh/Hh, and Vw/Hw was largest at the level of interventricular foramen in maltese and shih-tzu dogs. Yorkshire terriers had maximum values at TMJ level.

Mean + 2SD values of Vh at IVF level are 11.23 mm and 10.23 mm in maltese and YT dogs respectively. Maximum values of Vh at IVF are 11.2 mm in MAL and 11.7 mm in YT. Therefore, upper limits of lateral ventricles might be suggested as approximately 11 mm in clinically normal small breed dogs. Some differences were shown between left and right ventricular heights and widths in all three dogs. Especially Maltese dogs had significant difference between the left and right values in all three levels. Further study was required to identify the tendency of asymmetric ventricles in maltese dogs.

In the present study, the ratios of ventricle height to brain height at the level of interventricular foramen of the brain were determined in three breed dogs. The percentages were categorized into 3 groups of mild (0-15%), moderate (15-25%), or severe (> 25%) ventriculomegaly. The method of ventricular classification was established from a comparison in people between the sonographic appearance of the normal brain and hydrocephalus (15), and from a report of actual measurements of ventricular size in dogs with induced hydrocephalus (3,15). About 33% malteses and 53% Yorkshire terriers had unilateral or bilateral moderate ventriculomegaly. Severe lateral ventricular enlargement was observed in 17% of malteses and Yorkshire terriers. Based on these data, clinically insignificant ventriculomegaly was relatively common in malteses and Yorkshire terriers compare to shih-tzu dogs.

Degree of asymmetry was categorized on the basis of rVh as mild (rVh < 1.5), moderate (1.5 < rVh < 2), or severe (2.0 < rVh) (8). In this study, most of the dogs had normal or mildly asymmetric lateral ventricles even in maltese dogs showing significante difference between left and right ventricular heights at all three levels. Only five dogs had moderately asymmetric lateral ventricle. The severe asymmtric ventriculomegaly was identified in only one maltese dog. Asymmetry of lateral ventricles may occur secondary to partial or incomplete unilataeral obstruction of the foramen of Monro, unilateral abnormality of CSF circulatio or pressure with the patent foramen (8). In human neonates, 30% or 37.9% of the infants had asymmetric lateral ventricles on ultrasound examination (6,20). It was further noted that the left lateral ventricle was larger than the right in 84% of the patient (6). It was suggested that human ventricular asymmetry may be related to functional hemispherical specialization (11). In this study, the percentage of severe asymmetry was only one maltese dog. It is possible that asymmetry of the lateral ventricles may be due to partial or incomplete strictures of the interventricular foramen (5,8), unilateral abnormality of CSF circulation (8) or CNS inflammatory disorders (12), although this was not confirmed.

In conclusion, we found that ventriculomegaly in some degree were often presented in clinically normal small breed dogs. However, severe asymmetry was shown in only one maltese dog. Based on these reports, upper limits of ventricular size in clinically normal small dogs are suggested as value of 11 mm. Further studies using neurologic diseased dogs with large sample size will be necessary to identify discrepancies between normal range and abnormal values.

Acknowlegement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (KRF-2008-331-E00384).

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시쮸, 말티즈, 요크셔테리어 견에서 컴퓨터단층촬영을 이용한 뇌실 크기의 비교 평가

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요 약 : 본 실험은 서로 다른 세 품종의 소형견인 요크셔테리어, 말티즈, 시쮸 견 각각 30두 에서 컴퓨터단층촬영 검사를 이용하여 뇌실의 크기와 대칭성을 평가하고자 실시되었다. 측뇌실의 크기는 뇌의 시신경수준, 뇌실사이구멍수준, 그리고 악관절 수준에서 뇌실 높이와 너비 그리고 뇌반구의 높이 및 너비가 측정되었다. 뇌실의 크기는 뇌반구의 높이(Bh)와 뇌실의 높이(Vh)의 비율(Vh/Bh)로 평가하였고, 뇌실의 좌우 대칭성은 좌측과 우측의 뇌실 높이의 비(rVh)로 표시하였으며, 각각 정상 (rVh < 1.5), 경미한 확장 (1.5 < rVh < 2), 또는 심한 확장 (2.0 < rVh)로 구분하였다. 실험 결과 임상적으로 유의적이지 않은 뇌실 확장이 세 소형견종에서 흔히 관찰되었다. 그러나, 심각한 뇌실의 비대칭성은 거의 관찰되지 않는 것으로 나타났다. 또한, 측정 결과에 기초하여 약 11 mm의 뇌실 크기가 소형견종에서 정상적으로 나타날 수 있는 뇌실 확장의 상한치로 적용할 수 있을 것으로 생각된다.

주요어 : 뇌실 확장, 컴퓨터단층촬영, 개