Relationships between Vertebral Heart Size (VHS) and Echocardiographic Parameters in Dogs with Mitral Regurgitation

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(Received 31 October 2006; Accepted 10 January 2007)

Abstract. The primary objective of the present study was to compare vertebral heart size (VHS) to echocardiographic parameters which were used to monitor the degree of cardiomegaly and cardiac function, to see if there are relationships between them. Medical records of 34 dogs with mitral regurgitation (MR) were reviewed. Used as control were 18 beagles without cardiac diseases. VHS was measured in the right lateral radiographic views of dogs with or without MR. There were significant positive relationships to echocardiographic parameters as follow; the end-systolic left atrial to end-diastolic aortic root ratio (LA/AO; \( r = 0.696, p = 0.0014 \)), peak E-wave velocity, peak A-wave velocity, cardiac index (CI), left ventricular end-diastolic volume index (LVEdV/BSA), stroke volume index (SVI) and heart rate, respectively. On the single regression line, the ranges of VHS which corresponded to the ranges of LA/AO, peak E velocity, peak A velocity, CI, LVEdV/BSA, SVI and heart rate in dogs without MR were 9.8–10.7, 9.8–11.2, 9.3–10.7, 9.2–10.8, 9.2–11.7, 8.5–11.5 and 7.8–12.4, respectively. It is suggested that the value of VHS corresponded to a status of left sided volume overload in dogs with MR.

Key words: dog, echocardiography, mitral regurgitation, vertebral heart size

Introduction

Determination of heart size is important in evaluating patients with heart disease because an enlarged cardiac silhouette in radiographs is a reliable indication of pathologic cardiac changes. The method of quantifying cardiomegaly by vertebral heart size (VHS) has been used frequently.1,2) The measurement of VHS has also been shown to be relatively easy to perform.3) Observers’...
accuracy of diagnosis did not change significantly as a result of using VHS as an adjunct to a subjective assessment of the radiographs. For all observers, dogs with cardiac disease had a higher mean VHS than normal dogs. In lateral radiographs of 100 clinically normal dogs, the sum of measurements of the long and short axes of the heart yielded VHS $9.7 \pm 0.5$. A VHS over 10.7 on a lateral radiograph was a moderately accurate sign of cardiac disease. However, more concrete correlations between VHS and echocardiographic parameters have been unknown.

Chronic valvular disease is the most common cause of cardiac disability in dogs. Indeed, as many as three fourth of all dogs with signs of congestive heart failure suffer from mitral regurgitation caused by myxomatous degeneration of the valve leaflets or chordae tendineae. Insufficiency of the mitral valve can also develop secondary to myocardial diseases and other cardiac disorders, causing volume overload of the left side of the heart. In these circumstances, valvular insufficiency results from the combined effects of chamber dilatation, enlargement of the mitral annulus, and ventricular or papillary muscle dysfunction.

It would be useful for veterinarians to be able to infer echocardiographic status from radiography. However, there have been few comprehensive studies on the correlation between radiographic findings and echocardiographic variables related to left atrium and ventricle. Such studies would be useful to ascertain that correlation.

The primary objective of the present study was to compare VHS to echocardiographic parameters which are used to monitor the degree of volume overload and cardiac function and to see how VHS values are related to echocardiographic findings in dogs with MR.

**Materials and Methods**

**Criteria for selection of cases**

Medical records of 34 dogs, aged $8.5 \pm 4.4$ years (mean $\pm$ SD), weighing $9.9 \pm 11.9$ kg, were reviewed. These dogs were diagnosed and treated at the Nihon University Animal Medical Center between 1998 and 2003. Information about the breed, history, signalment and findings of physical examinations, thoracic radiography and echocardiography was obtained from their medical records. Diagnosis of MR was based on two-dimensional color Doppler echocardiography. The dogs, 5 Shih Tzus, 4 Malteses, 4 Cavalier King Charles Spaniels, 2 Golden Retrievers, 2 Miniature Schnauzers, 2 Yorkshire Terriers, 2 Beagles, 2 Miniature Dachshunds, 1 Poodle, 1 Chihuahua, 1 Keeshond, 1 Pomeranian, 1 Shiba and 7 mongrels were reviewed. The patients which had a pericardial effusion were excluded.

Eighteen beagles (aged $2.7 \pm 1.5$ years, weighing $13.0 \pm 3.6$ kg) were considered to be in good health and free of underlying cardiac disease based on activity, absence of murmur or gallop, and normal thoracic radi-
ography and echocardiography. Those dogs were used as control.

**Measurement of the VHS**

The measurements were made by one investigator on right lateral radiographic views of dogs with or without MR, using the method described by Buchanan. This involved marking the length of the long axis of the cardiac silhouette, from the ventral border of the left mainstem bronchus to the cardiac apex, on a strip of light card held in contact with the radiograph. The maximal short axis of the cardiac silhouette perpendicular to the long axis was measured in the same way, and the card was then repositioned over the thoracic vertebrae, measuring caudally from the cranial edge of T4. The measurements of the long and short axis on the card were recorded in terms of the numbers of vertebrae covered (estimating the 10th) and the two numbers were then added together to give the value of the vertebral heart size as a unitless ratio.

**Echocardiographic imaging review**

Echocardiographic images were reviewed retrospectively on the static images. Color Doppler and M-mode echocardiographic examinations were undertaken using an ultrasound scanner (EUB565A, HITACHI, Tokyo) with 2.5–7.5 MHz transducer, whose wavelengths were varied according to the size of the dog. By setting the echo window at the 4th to 6th intercostal spaces, images of right parasternal long-axis four chamber view were obtained and used for this study. Those echocardiographic parameters were derived from the M-mode data (Teicholz method) and the end-systolic left atrial to end-diastolic aortic root ratio was measured. However, peak E-wave velocity and peak A-wave velocity were measured by the left apical for chamber view. The images were recorded on magnetico-optical disk during the examination and were reviewed on static images. Echocardiographic parameters were divided to body surface area (BSA), which was calculated using the following formula: $\text{BSA} = \frac{(\text{body weight}^{2/3} \times 10.1)}{100}$.

**Statistical analyses**

All echocardiographic measurements were plotted against VHS values. Scatter plots of various echocardiographic measurements (ordinates) were made against VHS (abscissa) values in all dogs. Regression equations and their correlation coefficients ($r$) were calculated for all the echocardiographic parameters, and $p$ values were calculated by Spearman’s rank correlation. Statistical analyses were done using a software package (Stat View Ver.5.0, SAS Institute, Cary, NC, USA). For all analyses, a value at $p < 0.05$ was considered significant.

**Results**

There were significant positive relationships of VHS to echocardiographic parameters as follow; the end-systolic left atrial to end-diastolic aortic root ratio (LA/AO), peak E-wave velocity, peak A-wave velocity, cardiac index (CI), left ventricular end-diastolic...
RELATIONSHIPS BETWEEN VHS AND ECHOCARDIOGRAPHIC PARAMETERS IN DOGS WITH MR

Table 1 The mean and standard deviation value of VHS and echocardiographic parameters in dogs with or without MR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal</th>
<th>MR</th>
</tr>
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<tbody>
<tr>
<td>VHS</td>
<td>10.90±0.69</td>
<td>11.20±1.47</td>
</tr>
<tr>
<td>LA/AO</td>
<td>1.66±0.17</td>
<td>2.17±0.79</td>
</tr>
<tr>
<td>Peak E wave velocity</td>
<td>0.65±0.11</td>
<td>0.77±0.36</td>
</tr>
<tr>
<td>Peak A wave velocity</td>
<td>0.41±0.07</td>
<td>0.57±0.31</td>
</tr>
<tr>
<td>LVPWd/BSA (mm/m²)</td>
<td>15.20±3.251</td>
<td>19.31±6.48</td>
</tr>
<tr>
<td>LVEdV/BSA (mm/m²)</td>
<td>80.20±32.16</td>
<td>102.13±67.79</td>
</tr>
<tr>
<td>LVEsV/BSA (mm/m²)</td>
<td>28.44±15.19</td>
<td>29.23±36.49</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>111.04±26.00</td>
<td>127.75±42.85</td>
</tr>
<tr>
<td>SVI (ml/m²)</td>
<td>51.74±19.30</td>
<td>69.88±48.02</td>
</tr>
<tr>
<td>CI (L/min/m²)</td>
<td>5.59±1.90</td>
<td>9.55±6.96</td>
</tr>
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VHS: vertebral heart size
LA/AO: End-systolic left atrial to end-diastolic aortic root ratio
LVPWd/BSA: left ventricular posterior end-diastolic thickness index to body surface area
LVEdV/BSA: left ventricular end-diastolic dimension index to body surface area
LVEsV/BSA: left ventricular end-systolic volume index to body surface area
SVI: stroke volume index to body surface area
CI: Cardiac output index to body surface area

Fig. 1 Scatter plots of echocardiographic parameters (ordinates) versus vertebral heart size (VHS) (abscissa). Regression equations and their coefficients of correlation ($r$) were calculated. Broken lines were upper limit of reference value in echocardiography. Upper limit of reference $r$ value* (Ref), left atrial to aortic root ratio (LA/AO), peak E-wave velocity, peak A-wave velocity, cardiac index (CI).

* Lamb and others 2000
volume index (LVEdV/BSA), left ventricular end-systolic volume index (LVEsV/BSA), stroke volume index (SVI), heart rate and left ventricular posterior wall diastolic thickness index (LVPWd/BSA; $r = -0.324$, $p < 0.05$). Though some of the echocardiographic variables are age-dependent in clinically normal dogs, there were no significant positive relationships in dogs with MR.

Table 1 shows the mean values±SD of echocardiographic parameters in the dogs with or without MR. On the single regression line (Figs. 1 and 2), the ranges of VHS values which corresponded to the range of LA/AO, peak E velocity, peak A velocity, CI, LVEdV/BSA, LVEsV/BSA and SVI, heart rate, LVPWd/BSA in the dogs without MR were 9.8–10.7, 9.8–11.2, 9.3–10.7, 9.2–10.8, 9.2–11.7, 9.7–12.2, 8.5–11.5, 7.8–12.4, and 10.7–15.0, respectively.

There were no significant positive relationships between VHS and echocardiographic parameters, namely left ventricular end-diastolic dimension index (LVEdD/BSA), left ventricular end-systolic dimension index (LVEsD/BSA), left ventricular posterior wall systolic thickness index (LVPWs/BSA), interventricular septal end-diastolic thickness index (IVSd/BSA), interventricular septal end-systolic thickness index (IVSs/BSA), E/A ratio, M-mode fractional shortening,
ejection fraction, peak mitral regurgitant velocity, peak aortic velocity and peak pulmonary arterial flow velocity.

**Discussion**

In the dogs with naturally acquired MR, it was found that the VHS reflected some echocardiographic parameters which were important for evaluating the pathologic status of MR. The pathophysiologic status of left sided volume overload was shown on VHS. In the present study, the mean VHS value of control was 10.90 ± 0.69 and higher than general reference value (9.7 ± 0.5). VHS of 10.5 is commonly recognized as a clinical and useful upper limit for normal heart size in most breeds of dogs. Exceptions may exist in some breeds. For example, the Boxer’s normal was reported as 10.3–12.6, the dog where a VHS up to 11.0 is probably normal. Conversely, an upper limit of 9.5 may be more appropriate in dogs with a long thorax, such as Dachshunds. Beagles without MR might show a higher VHS value than that of other breed dogs without cardiac diseases. Beagle is comparatively a wide chest breed. The heart of this breed may be large in relative to thoracic vertebral length. On the other hand, the range of LA/AO in control dogs corresponded to VHS 9.8–10.7 on a single regression line. This upper limit corresponded with the indicator described by Lamb et al. A VHS over 10.7 on the lateral radiograph was a moderately accurate sign of cardiac disease. Therefore, it was found that the reference VHS range calculated from the single regression line was correct. LA/AO correlated well with VHS because the left atrium is a component of the short width of heart. It was shown that a VHS over 10.7 on the lateral radiograph was a sign of left atrial enlargement. In this study, LA/AO sensitivity and specificity was 73.0% (17/23) and 18.2% (2/11) on the cut off value of VHS 10.7, respectively. It may be derived from the truth that left sided congestive heart failure does not merely require the radiographic presence of left atrial enlargement or an increase in vertebral heart size. A correlation was also detected between peak A-wave velocity and VHS, as well as between CI and VHS. The reference ranges of A-wave velocity and CI corresponded to VHS 9.3–10.7 and 9.2–10.8, respectively. From those results, it was suggested that VHS over 10.7 was a sign of left atrial enlargement, left atrial volume overload and heart compensation. Though the degree of left atrial enlargement is not specific for MR, it is related to the severity of MR in human and dogs. The buffering effect of a very large and compliant left atrium was a compensatory mechanism in chronic MR to delay the onset of clinical failure in the form of pulmonary edema. On the other hand, there is a report that absolute M-mode echocardiographic measurements did not reflect the extent of the heart size increase as well as the VHS method in a dog with progressive cardiomegaly. This is because the echocar-
diographic measurements represent only a single dimension (mainly short axis). The VHS ranges corresponded to the reference peak E-wave velocity and SVI were 9.8–11.2 and 8.5–11.5, respectively. It was shown that VHS over 11.5 was accompanied by the progression of diastolic function and increased stroke volume. Though peak E-wave velocity is also non-specific parameter for MR, a good correlation has been reported between regurgitant fraction (RF) and peak E-wave velocity in humans. Because VHS upper limits of SVI and LVEdV/BSA were nearly, it was found that increase in SVI might be secondary to an increase of left ventricular diastolic volume. The greater the regurgitant fraction, the higher the total stroke volume required to maintain forward stroke volume.

The VHS range corresponded to the reference LVEsV/BSA and their heart rates were 9.7–12.2 and 7.7–12.4, respectively. Therefore, it was suggested that VHS over 12.0 was compensated by the increases in left ventricular diastolic volume and heart rate. However, in this circumstance, left ventricular systolic volume was also increased and other parameters of systolic function did not show a significant correlation with VHS. The pacing-induced model of cardiomegaly results in biventricular and biatrial enlargement. In Cavalier King Charles Spaniels, there is a report that HR increased significantly in proportion to the severity of MR. Dogs with naturally acquired heart disease showed elevated sympathetic activity, the degree of which depended on their degree of heart failure. It was suggested that the sympathetic system was activated in dog with decompensated MR.

From the present study, it is suggested that dogs with MR are considered to have generalized the left atrial enlargement and dysfunction when VHS was higher than 10.7. At the same time, the status changes to heart compensation on higher than that value. In addition, a VHS higher than 11.0 is considered to accompany the progression of diastolic function. With the progression of heart enlargement, a VHS higher than 12.0 is thought to have a heart compensation due to an increase in left ventricular volume and heart rate. However, relative improvement of systole is not shown in this status.

It was suggested that the VHS value corresponded to the left sided volume overload on echocardiography in dogs with MR. Further studies are needed to find if the VHS can be used for other animals or for other heart diseases, for example dilated cardiomyopathy (DCM).

References

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僧帽弁閉鎖不全症犬における vertebral heart size (VHS) と超音波パラメーターとの相関性

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要 約

本研究の目的は、心の形態および機能評価に用いられるエコーパラメーターと vertebral heart size (VHS) を比較し、それらの間に相関性があるか否かを検討することにある。僧帽弁閉鎖不全 (MR) の犬 34 頭をカルテより抽出し、心疾患が認められなかったビーグル犬 18 頭をコントロール群とした。VHS は、右側ラテラル X 線画像より両群において計測した。VHS は、左心房-大動脈径比 (LA/AO), 拡張早期流入波, 左房収縮期波, 心拍出量-体表面積比 (CI), 左室拡張末容積-体表面積比 (LVEDV/ BSA), 一回拍出量-体表面積比 (SVI) および心拍数に対して有意な相関性が認められた。単回帰直線において、LA/AO, 拡張早期流入波, 左房収縮期波, CI, LVEDV/BSA, SVI および心拍数に相当する VHS 値は、それぞれ 9.8–10.7, 9.8–11.2, 9.3–10.7, 9.2–10.8, 9.2–11.7, 8.5–11.5 および 7.8–12.4 であった。

以上より MR 犬において、VHS 値は左室容量負荷の病態と合致することが示唆された。

キーワード：犬, 心エコー法, 僧帽弁閉鎖不全, VHS

動物の循環器 第 39 巻 2 号 55–63 (2006)