The vertebral heart size (VHS) method by Buchanan is based on anatomic landmarks. A potential source of variation among observers is differences in the selection of measurement points. The objective was to test variability between observers with different levels of training in thoracic radiology and small animal clinical practice.

Fifty sets of thoracic radiographs of cavalier King Charles spaniels, were divided into five groups; (Normal) normal cardiopulmonary structures, (I) slight cardiomegaly, (II) moderate cardiomegaly, (II +) moderate cardiomegaly with congestive heart failure, and (III +) severe cardiomegaly with congestive heart failure. Cardiomegaly was confirmed by echocardiography to be caused by mitral regurgitation because of myxomatous mitral valve disease. Sixteen observers representing four levels of experience (four observers/level) evaluated the radiographs; (1) European Diplomates in Veterinary Diagnostic Imaging, (2) Experienced small animal clinicians, (3) Trainees in small animal clinical practice (4) Veterinary students.

Almost identical mean VHS values were found among the four experience levels for each of the five groups of radiographs with a low coefficient of variation, range 1.5–3.2%. Mean difference among the 16 observers was 1.05 ± 0.32 vertebrae (v). Mean difference among individuals in each observer group was approximately 0.5 v for all but the groups of trainees were the difference was 0.6–0.9 v.

The conclusion is that VHS method for heart size is independent of observer experience but dependent of individual observers selection of reference points and transformation of long and short axis dimensions into VHS units. Veterinary Radiology & Ultrasound, Vol. 46, No. 2, 2005, pp 122–130.

Key words: dog, interobserver, mitral regurgitation, thoracic radiology, vertebral heart size.

**Introduction**

Thoracic radiology is commonly used in dogs to evaluate suspected cardiomegaly. Differences in age, conformation, cardiac cycle, and respiratory phase are causes of normal variation that make it difficult to separate normal from enlarged hearts.1–5 However, the inexperienced observer may have difficulties in identifying cardiomegaly even under the best of circumstances. The trained interpreter can often recognize cardiomegaly based on experience but inexperienced veterinarians may benefit from a quantitative method to evaluate heart size.

Various methods have been used to estimate or measure heart size including planimetry and various cardio-thoracic ratios.3,6,7 Two frequently used methods for the lateral view are the intercostal6,9 and the vertebral heart size (VHS) method.10 The VHS method has the advantage of well-defined measurement points and objective numerical measurement. It uses the sum of the heart length and width, which is translated into total units of thoracic vertebral length (v) to the nearest 0.1 v. Based on evaluation of 100 clinically normal dogs of various breeds the mean VHS was 9.7 ± 0.5 v. As the VHS was ≤ 10.5 in 98% of the dogs this was suggested as a clinically useful upper limit for normal heart size in most breeds.10 Lamb et al. has published breed-specific ranges for six breeds in which mean VHS was higher than 10.5 in three out of the six breeds; cavalier King Charles spaniel (10.6 ± 0.5 v), Labrador retriever (10.8 ± 0.6 v) and Boxer (11.6 ± 0.8 v).11

If normal VHS values and ranges are to be generally applicable it is necessary that the interobserver variability be low among a typical group of users, which will include veterinarians inexperienced as well as experienced in thoracic radiology. Nakayama12 found a low coefficient of variation (CV) among observers, but the study included only observers who were experienced interpreters of thoracic radiographs. In a study by Lamb including three observers with different experience (veterinary radiologist, medicine resident, and veterinary nurse), the observers recorded similar mean values but a maximum likely difference of > 1.0 v.13

As the VHS method is based on anatomic landmarks a potential source of variation between observers is that
varying degrees of knowledge of thoracic radiographic anatomy might influence how the observer defines the various measurement points. Our objective was to study the variability of the VHS method in dogs with a range of different heart sizes among observers with different levels of experience in thoracic radiology.

### Material and Methods

#### Material

The material consisted of 50 sets of thoracic radiographs of privately owned cavalier King Charles spaniels. All dogs were radiographed at the Department of Biomedicine and Veterinary Public Health, Division of Diagnostic Imaging and Clinical Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden. Left lateral and ventrodorsal (VD) views were obtained from unsedated dogs. The radiographs were selected from examinations collected during a 10-year period, which involved several studies on progression and treatment of myxomatous mitral valve disease in cavalier King Charles spaniels.14–19 All dogs were mature, ranging in age from 1 to 12 years. The clinical evaluation of all dogs included physical examination, auscultation of the heart, electrocardiography (ECG), thoracic radiography, and echocardiography in that order. In all dogs with cardiomegaly, echocardiography confirmed the cause to be mitral regurgitation attributable to myxomatous mitral valve disease.

To be included in the study, the radiographs had to be of good technical and diagnostic quality. The basis for the selection of radiographs was to create a test situation such that the results would not be biased by great difficulties in finding the anatomic landmarks, by obliquity or uncommon variations of thoracic conformation.

The radiographic appearance had to be such that the images could be assigned into one of the five following groups: (Normal) normal cardio-pulmonary structures, (I) slight left atrial enlargement and slight cardiomegaly, (II) moderate left atrial enlargement and moderate cardiomegaly, (II+) moderate left atrial enlargement, moderate cardiomegaly and congestive heart failure, (III+ ) severe left atrial enlargement, severe cardiomegaly, and congestive heart failure (Table 1). Ten sets of radiographs were selected for each category. Two of the authors (K.H. and P.L.) made the selection. Each set of radiographs, consisting of one left lateral and one VD view, were assigned a randomized number between one and 50 and sorted according to number.

#### Observers

The observers represented four levels of experience with four individuals per level. The experience levels were: (1) European Diplomates in Veterinary Diagnostic Imaging (DipECVDI), (2) Clinicians with > 15 years experience of small animal clinical practice, (3) Clinicians enrolled in a 3 year national (Swedish) training program towards specialization in canine and feline diseases, all in their 2nd or 3rd year of training (trainees), (4) 5th year veterinary students whose small animal teaching was completed after the 4th year.

The 16 observers evaluated the radiographs following identical oral and written instructions presented to each observer immediately before the evaluation. The observers were informed that radiographs were obtained from a

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**Table 1. Radiologic Inclusion Criteria for Slight, Moderate and Severe Cardiomegaly and Congestive Heart Failure**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>II+</th>
<th>III+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left atrium</strong></td>
<td>Straight caudal border or slight concavity at the level of atrio-ventricular junction</td>
<td>Straight caudal border</td>
<td>Dorsal deviation and slight compression of left main stem bronchus</td>
<td>Obvious dorsal deviation and compression of left main stem bronchus on lateral view and obvious bulging of left auricle on VD view</td>
</tr>
<tr>
<td>Minimal dorsal deviation of left main stem bronchus on lateral view</td>
<td>Dorsal deviation and slight compression of left main stem bronchus</td>
<td>With or without bulging of left auricle on VD view</td>
<td>With or without bulging of left auricle on VD view</td>
<td></td>
</tr>
<tr>
<td>Normal VD view</td>
<td>Increased width of ventricular area with a rounded apex on lateral and VD view</td>
<td>Trachea dorsally displaced but not more than parallel to the spine on lateral view</td>
<td>Trachea dorsally displaced but not more than parallel to the spine on lateral view</td>
<td>Trachea dorsally displaced, towards the spine on lateral view</td>
</tr>
<tr>
<td><strong>Overall cardiac appearance</strong></td>
<td>Increased width of ventricular area with a generally rounded appearance on both lateral and VD view</td>
<td>Increased width of ventricular area with a generally rounded appearance on both lateral and VD view</td>
<td>Increased width of ventricular area with a generally rounded appearance on both lateral and VD view</td>
<td>Heart silhouette occupies the majority of the thoracic cavity on both lateral and VD view</td>
</tr>
<tr>
<td><strong>Vascular structures and pulmonary parenchyma</strong></td>
<td>Normal</td>
<td>Normal</td>
<td>Venous congestion and/or diffuse non-structured mainly perihilar increased interstitial opacity</td>
<td>Venous congestion and/or non-structured increased interstitial opacity mainly in the caudal lung lobes</td>
</tr>
</tbody>
</table>

I = slight left atrial and slight cardiomegaly; II = moderate left atrial and moderate cardiomegaly; II+ = moderate left atrial, moderate cardiomegaly and congestive heart failure; III+ = severe left atrial, severe cardiomegaly and congestive heart failure. VD, ventro-dorsal view.
population of dogs with varying degrees of mitral valve disease, ranging from no disease to severe disease, but were not aware of the disease status of any individual animal or the proportion of normal to diseased dogs. Each person evaluated the radiographs sequentially and at one sitting. The evaluation took 3–5 h.

Instructions for Radiographic Measurements

The interpreters were instructed to measure the heart using the lateral view (Fig. 1A). The measurements were performed according to the VHS method by Buchanan, with a clarification as to which structure that should be used as the reference point at the heart base (A) and a modification of the short axis measurement (B).

(A) The cardiac long axis was to be measured, in mm, with a ruler from the base of the heart to the apex. The observers were instructed to use the ventral border of the largest of the main stem bronchi seen in cross section as the reference point at the heart base. This was assumed to represent the end-on projection of the left cranial lobe bronchus before the bifurcation to the cranial and caudal lobe segments. If there were several stem bronchi of equal size, the most cranial was to be used. The same measurement points were to be used regardless of whether the left atrium was enlarged or not.

(B) The cardiac short axis was to be measured, in mm, perpendicular to the length measurement. The caudal reference point for width was halfway between dorsal and ventral border of the caudal vena cava in all dogs regardless of whether the left atrium was enlarged or not.

The cardiac long and short axes were transformed from mm into whole and 0.1 of VHS units by the observers. The observers were instructed that one VHS unit should include the length of a vertebral body and its caudal disc (Fig. 1B). Observers transferred the measurements of each axis to the vertebral silhouettes and measured each axis (in vertebrae to the nearest 0.1 v) from the cranio-ventral margin of T4 caudally.

The two VHS measurements (for long and short axis) were then summed after the study by the first author (K.H.). In addition to the axes for the VHS, all observers measured the distance between the main stem bronchus and the spine (Br–Sp) on the lateral view (Fig. 1A and B). This measurement was to be used as an indicator of whether variations in long axis measurements arose from variation in identifying the reference point at the heart base or the cardiac apex. For the Br–Sp measurement the same reference point at the base of the heart as described above was to be used. The second reference point was an extrapolated line between the cranio-ventral and caudo-ventral surface of the vertebrae dorsal to the heart base (usually T5) (Fig. 1B).

Additionally, the long axis of the fourth thoracic vertebrae (T4) including its caudal disc was measured in mm by all observers and used as an indicator of vertebral length in the thoracic spine (Fig. 1B).

No measurements were done on the VD view. The view was only used in the classification of the radiographs into one of the five groups.

Statistical Analyses

Statistical analyses were performed with a computerized statistical software package.*

For all VHS measurements, the mean, the standard deviation (SD) and the CV were calculated. The CV is de-

*JMP 4.02, SAS Institute Inc. Cary, NC.
fined as the SD divided by the mean value. Initially, a radiograph-specific VHS and CV were calculated using measurements from all 16 observers (top row, Table 2). Values for each group of observers and each group of radiographs (normal to severe cardiomegaly) were calculated in the same way (Table 2).

A randomized complete block analysis of variance (ANOVA) was performed with set of radiograph as blocking factor over observer as independent variable to evaluate the contribution to the overall variation. Values are reported as mean and 95% confidence interval for the individual observer (Fig. 2).

Mean values for cardiac long axis (Fig. 3) and Br–Sp, in mm, were determined for each observer separately. Furthermore, the mean difference and range of difference were determined for each set of films in each group of radiographs and each group of observers (Fig. 4).

**Results**

The overall mean VHS for the five groups of radiographs ranged from 10.8 v, in normal hearts, to 13.8 v in severe cardiomegaly (Table 2). The CV for all 16 observers was between 2.0% and 2.6% with lowest value for moderate enlarged hearts and highest value for slightly enlarged hearts. The largest difference in mean VHS value among the groups of radiographs was between mild (group I) and moderate (group II) cardiomegaly with no overlap in VHS range between these two groups.

**Variation Among Observers and Within the Levels of Experience**

Based on the randomized complete block ANOVA, observer had significant effect on the VHS value. The CV range was between 1.5% and 3.2% for all experience levels and all groups of radiographs. In all groups of radiographs, the highest mean and largest CV range was seen for the trainees (Table 2). However, the larger variation was because of one observer consistently measuring a lower VHS, than the other observers (Fig. 2). This interpreter measured a shorter cardiac long axis (Fig. 3) and a longer Br–Sp distance compared with all other observers. If the diverging observer was excluded, all CV values (mean and range) for the trainees were comparable with the other observer groups.

The mean difference among the 16 observers when comparing the VHS values for each of the 50 sets of radiographs was 1.0 ± 0.3 v. The smallest difference was 0.5 v and the largest 1.9 v. Excluding the single observer who systematically measured a lower VHS, the mean difference

<table>
<thead>
<tr>
<th>Experience of observers</th>
<th>Normal 10 rads</th>
<th>I 10 rads</th>
<th>II 10 rads</th>
<th>II + 10 rads</th>
<th>III + 10 rads</th>
</tr>
</thead>
<tbody>
<tr>
<td>All observers (N = 16)</td>
<td>10.8 ± 0.49</td>
<td>11.3 ± 0.35</td>
<td>12.3 ± 0.62</td>
<td>13.0 ± 0.36</td>
<td>13.8 ± 0.65</td>
</tr>
<tr>
<td></td>
<td>(10.0-11.4)</td>
<td>(10.9-11.7)</td>
<td>(11.8-13.9)</td>
<td>(12.3-13.6)</td>
<td>(13.0-15.2)</td>
</tr>
<tr>
<td>CV 2.5%</td>
<td>11.2 ± 0.38</td>
<td>12.2 ± 0.67</td>
<td>13.0 ± 0.41</td>
<td>13.8 ± 0.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(9.9-11.3)</td>
<td>(10.8-11.8)</td>
<td>(11.6-14.0)</td>
<td>(12.1-13.5)</td>
<td></td>
</tr>
<tr>
<td>CV 2.0%</td>
<td>11.0 ± 0.51</td>
<td>12.0 ± 0.70</td>
<td>12.8 ± 0.46</td>
<td>13.6 ± 0.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(9.7-11.2)</td>
<td>(10.7-11.6)</td>
<td>(11.5-13.6)</td>
<td>(12.5-14.4)</td>
<td></td>
</tr>
</tbody>
</table>

I = slight left atrial and slight cardiomegaly; II = moderate left atrial and moderate cardiomegaly; III = severe left atrial, severe cardiomegaly and congestive heart failure; III + = severe left atrial, severe cardiomegaly and congestive heart failure. Rads, radiographs, all radiographs are left lateral views; N, number of observers; DipECVDI, Diplomates of European College of Veterinary Diagnostic Imaging; VHS, vertebral heart size. All values are express as whole and decimal VHS units (v). For the group of Trainees, values are shown with and without (in italics) an observer who systematically measured a lower VHS compared to all other observers.
was 0.9 ± 0.2 v and the largest difference among the observers was 1.3 v.

When the radiographs were separated into different groups (normal to severe cardiomegaly), the mean difference was approximately 1 VHS unit for all groups (Fig. 4). Further separation into experience levels resulted in a mean difference among the four observers of approximately 0.5 v except for the trainees who had a higher interobserver difference for all groups of radiographs because of the diverging observer (Fig. 4). There was a tendency towards better agreement among the DipECVDI compared with the other groups of observers.

**Variation Among Experience Levels**

The agreement in mean VHS among the four experience levels in each group of radiographs was almost identical (Table 2). For radiographs with normal cardiac size and radiographs with slight cardiomegaly the mean VHS value

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**Fig. 2.** Mean (●) and 95% confidence interval for each individual observer, obtained from the randomized complete block ANOVA. One observer (number 11) measured a significantly lower vertebral heart size value. All values are corrected for the variation in heart size among the 50 sets of radiographs. Observers 1–4 = European Diplomates in Veterinary Diagnostic Imaging, observers 5–8 = clinicians with > 15 years experience of small animal clinical practice, observers 9–12 = trainees in small animal clinical practice, observers 13–16 = veterinary students.

**Fig. 3.** Scatter plot of mean cardiac long axis for individual observers. One observer (number 11) measured a shorter cardiac long axis compared with others. Observers 1–4 = European Diplomates in Veterinary Diagnostic Imaging, observers 5–8 = clinicians with >15 years experience of small animal clinical practice, observers 9–12 = trainees in small animal clinical practice, observers 13–16 = veterinary students.
was the same or differed by 0.1 v. For the other three groups of radiographs the difference was 0.2 v (Table 2).

The lowest difference in CV values among the experience levels was 0.4% and the highest 1.2% (Table 2). The lowest CV values were found in the moderately enlarged hearts for all groups of observers (Table 2).

Variation in Measurements of Long and Short Cardiac Axes

The mean VHS for normal cavalier King Charles spaniels was 10.8 ± 0.49 v (10.0–11.4) with a CV of 2.7% (Table 2). The long axis was 5.6 ± 0.37 v and short axis was 5.1 ± 0.28 v. The long axis CV was 4.0% and the short axis CV was 2.2%.

For all groups of radiographs (normal to severe cardiomegaly), the CV of the long axis dimension was higher than that of the short axis. The mean long axis ranged from 82.5 ± 7.6 mm (normal hearts) to 109.7 ± 9.5 mm (severe cardiomegaly) and the short axis from 74.9 ± 5.7 mm (normal hearts) to 102.6 ± 9.2 mm (severe cardiomegaly). The mean difference among the observers for measurements obtained from the same radiograph was 13.3 ± 5.6 mm in the long axis dimension and 5.8 ± 2.8 mm in the short axis dimension. If the observer measuring a shorter long axis was excluded the mean difference for long axis was 10.8 ± 3.6 mm.

Variation in Measurements of the Fourth Thoracic Vertebrae

The mean length of T4 was 14.6 ± 1.0 mm (9–17). The wide range, with 9 mm as lowest value was because of two outliers. Excluding these two values did not change the mean but decreased the range to 11–17 mm. One dog had a markedly shorter T4 with a mean length of 12.0 ± 0.4 mm (11–13). This dog had a moderately enlarged heart by subjective classification (Table 1) but VHS (13.9 ± 0.4 v) in the range of the severely enlarged hearts (Table 2). If this dog was excluded from the group of moderately enlarged hearts the mean VHS decreased from 12.3 to 12.1 v and upper value of the VHS range decreased from 13.9 to 12.5 v.

Discussion

In this study 16 observers representing four levels of experience in interpretation of thoracic radiographs measured the heart according to the VHS method in normal dogs and dogs with varying degrees of cardiomegaly. The use of one breed eliminated variations that could be caused by breed. The CV from 1.5% to 3.2% was in the same range as previous studies in dogs (2.7–2.8%) and in cats (4.0%) for all groups of radiographs and all levels of experience.

The major distinction between our study and previous studies using VHS is that the interobserver comparisons are between both individual observers and among groups of observers with different experience in interpreting thoracic radiographs. In this study, there was little variation in mean VHS values among the four groups of observers despite very different experience. For the two groups of radiographs with normal cardiac size and slight cardiomegaly the mean VHS value was the same among the observer groups or differed with only 0.1 v. In the other three groups...
of radiographs the largest mean VHS difference among the observer groups was 0.2 v. To convert the magnitude of 0.1 v in mm one can use the mean value of T4 (14.6 mm) in this study as a guide and 0.1 v would then correspond to approximately 1.5 mm.

Additionally, we analyzed the differences in VHS value measured on the same radiograph among all 16 observers and among the four observers in each experience level. When VHS values for the same radiograph were compared, the mean difference among all 16 observers was approximately 1.0 VHS unit regardless of the size of the heart. If the observer that systematically measured a shorter long axis was excluded the mean difference among the observers decreased with 0.1 VHS units. This is somewhat higher than reported by Lamb who found that the maximum likely difference (mean difference ± 1.96 SD) of >1.0 v among the three observers performing the measurements. The higher difference in our material is probably a reflection of including 16 different observers compared with three observers in the study by Lamb. These differences are surprisingly high and have a high impact on the use of normal VHS values and on sequential measurements on the same dog. It indicates that normal values for VHS should be used only as guidelines and not as cut off values to separate between normal and enlarged hearts. It is crucial that there is a common agreement on how measurements should be performed amongst clinicians monitoring progressive cardiomegaly in the same dog. The optimal situation is that the same clinician measures all follow up radiographs in a specific case.

The mean difference in VHS among the four observers in each group was approximately 0.5–0.6 v in all groups except for the trainees where the interobserver difference was higher and sometimes as high as 0.9 v. The higher range was because of one observer who diverged from all others by measuring a shorter cardiac long axis, with resulting lower VHS values both for the long axis and for the total VHS. The same observer also measured a longer Br–Sp. The most likely explanation is that the observer used a more ventral structure than the recommended bronchus as a reference point for the heart base.

Cardiac Reference Points

We decided to use a reference point on a bronchus seen end-on as it is easy to define and can be used in all dogs, regardless of cardiac size. In the original work by Buchanan the long axis was measured from the ventral border of the left main stem bronchus and according to the figure it seems that the ventral border of an end on bronchus is being used. We suspect it is the same reference point as the one we are using but it might also be slightly different from that in Buchanan’s original study. Our study also differs from another and later study by Buchanan that included dogs with left atrial enlargement where the long axis was measured caudal to the tracheal bifurcation to be sure of including left atrial enlargement. If the observers in our study were to use two different reference points this would have introduced a subjective evaluation of whether the dog had cardiomegaly or not. However, it is our impression that the long axis measurement would be almost the same in many dogs regardless of which method that were being used as the heart base is semicircular and the long axis can be regarded as a radius with the apex as the center point.

We found differences in consistency between measurements of both long and short cardiac axes. The higher CV value for the long axis dimension reflects more variability in the definition of the reference points. Even if the observer that systematically measured a shorter long axis was excluded the difference among observers for long axis measurements was still approximately two times that for the short axis. Possible explanations are that the reference point at the heart base can be difficult to define because of greater complexity and variability of the topographic anatomy compared with other reference points. Another difficulty might have been the presence of pulmonary edema and increased opacity in the hilar region and for this reason we elected to have two groups of radiographs with moderate cardiomegaly, one with and one without pulmonary edema. Pulmonary edema did not increased variation in long axis measurements.

The measurement of Br–Sp distance was used as a crude indication of how the reference point at the heart base was selected. One observer measured a longer distance compared with others indicating that this person systematically selected a reference point at the heart base that was more ventral.

The selection of the cardiac apex reference point is another potential cause of variation. Difficulties in defining the apex can be because of small amounts of pleural effusion or superimposition of ribs, skin folds or cranial parts of the liver in dogs with severe cardiomegaly.

Some differences are to be expected but the magnitude was larger than expected, considering that all observers were given both oral and written instructions on how to perform the measurements, and that the written instructions were available to them throughout their evaluation of the radiographs.

Cardiac Size

The mean VHS value in the normal dogs was 10.8 ± 0.5 v, which is slightly above the suggested upper limit for normal heart size in most breeds. It is also approximately one vertebral unit higher than the suggested mean value 9.7 ± 0.5 v. However, in the study by Lamb the normal value for cavalier King Charles spaniels was 10.6 ± 0.5 v.
which is consistent with our value. The number, and thus contribution, of each breed comprising the original 100 dogs that were used to derive the average was not stated, and this could well influenced the stated values. The use of breed-specific VHS values is needed for the VHS method to have a high specificity for normal heart size.

It was not the purpose of this study to establish reference ranges. Assigning the 50 sets of radiographs into five different groups was only a way to categorize the material for this study. We included radiographs with various heart sizes to cover the range encountered in practice. When comparing the VHS range for all observations and the different groups of radiographs there was an overlap between normal and slight cardiomegaly but no overlap between slight and moderate cardiomegaly. This is to be expected as dogs classified as slight cardiomegaly only had an increased cardiac width and no dorsal displacement of the trachea (Table 1). Dogs classified to have moderate and an increased cardiac width and no dorsal displacement of the VHS range with a high upper limit seen in the study. long axis 82 mm and short axis 75 mm, the VHS could range between 14.3 and 9.2 v because of variations in the vertebral lengths in individual dogs. This large variation in normal VHS values is not likely to be common but illustrates that when using the VHS method the observer also needs to examine the vertebral column for narrow discs and changes in vertebral length.

In our study there was one dog, which had a considerably shorter T4 than the others and narrow disc spaces from T4 to T11. The dog had a moderately enlarged heart by our subjective classification but its VHS was in the range of the severely enlarged hearts. This dog is the reason for the wide VHS range with a high upper limit seen in the group of radiographs with moderately enlarged hearts without congestive heart failure (Table 2).

**Measurement Errors**

Other sources of variation are mistakes such as writing the wrong numbers on the protocol, misinterpretation of the number on the ruler and the transformation of the mm measurement into VHS units. The significance of these errors in our study is uncertain. To have exact knowledge on how various observers performed measurements marks would have to have been made on each radiograph. For practical reasons this was not done.

**Conclusions**

The VHS values for heart size can be affected by several factors. Individual variations in actual heart size and vertebral length between dogs need to be considered as well as narrowed disc spaces.

The observer performing the measurements is also a cause for variation. It is shown that the VHS method for heart size is independent of observer experience but dependent on individual observers’ selection of reference points and the transformation of long and short axis dimensions into VHS units. The mean difference among observers in this study was approximately one vertebral unit.
REFERENCES