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James Walter Buchanan
University of Pennsylvania

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Vertebral scale system to measure canine heart size in radiographs

James W. Buchanan, DVM, M Med Sci, and Jörg Bücheler, Dr Med Vet

Summary: *A method for measuring canine heart size in radiographs was developed on the basis that there is a good correlation between heart size and body length regardless of the conformation of the thorax. The lengths of the long and short axes of the heart of 100 clinically normal dogs were determined with calipers, and the dimensions were scaled against the length of vertebrae dorsal to the heart beginning with T4. The sum of the long and short axes of the heart expressed as vertebral heart size was 9.7 ± 0.5 vertebrae. The differences between dogs with a wide or deep thorax, males and females, and right or left lateral recumbency were not significant. The caudal vena cava was 0.75 vertebrae ± 0.13 in comparison to the length of the vertebra over the tracheal bifurcation.*

Differences in conformation of the thorax among dog breeds have limited the use of measurement to ascertain cardiac enlargement. Studies using planimetry and various cardiothoracic ratios have been reported, but these methods have not proved suitable for general clinical use.[1-7] A guideline of 2.5 to 3.5 intercostal spaces for dogs with a deep or wide thorax, respectively, was introduced in 1968[a] and still is used by many radiologists and cardiologists as an indicator of normal heart size in lateral radiographic views.[8,9] Limitations of this method include variations in the axis of the heart, conformation of the thorax, phase of respiration, superimposition of ribs, and imprecise measurement points.

To overcome these limitations, various alternative heart:skeletal ratios have been explored in recent years to identify a method that would be anatomically justifiable, reasonably precise, and simple to use and explain. Emphasis was placed on comparisons of heart size and vertebral length, because both are measureable in thoracic radiographs, and good correlations are known to exist between heart weight and body length.[10]

From the Section of Cardiology, School of Veterinary Medicine, University of Pennsylvania, 3850 Spruce St, Philadelphia, PA 19104. Dr. Bücheler's present address is Cardiopet, 56 Atlantic Ave, Floral Park, NY 11002.

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In the study reported here, we compared cardiac dimensions to the length of midthoracic vertebrae and sternebrae in 100 dogs with normal hearts and various thoracic conformations. Our objectives were to: (1) evaluate and standardize the method for cardiac mensuration; (2) determine values for relative heart size in 100 clinically normal dogs by use of this method; (3) determine the influences of conformation of the thorax, sex, body size, and right vs left lateral positioning on the measurement system; and, (4) compare radiography and M-mode echocardiography for assessing progressive cardiomegaly.

Materials and Methods

Lateral and ventrodorsal (VD) or dorsoventral (DV) radiographic views of 100 dogs with no clinical evidence of cardiac or pulmonary disease were selected from current case material. Included were VD radiographic views of 79 dogs and DV radiographic views of 21 dogs. All dogs were mature and ranged in weight from 2 to 75 kg. There were 43 males, 52 females, and 5 dogs of unknown sex. Radiographs of no more than 4 dogs of any 1 breed were included. Plain film radiographs were examined by radiologists and cardiologists on clinical service duty. Heart sizes were subjectively considered normal. Only radiographs in which there was no evidence of rotation of the body were used. Right and left lateral radiographic views were available from 20 dogs, and were used to assess the influence of right vs left recumbency on heart size/vertebra correlations. Dorsoventral and VD radiographs of 17 Basenjis were measured to assess differences between DV and VD views in the same animals. Lateral and DV radiographic views of only 4 of these dogs were included in the 100-dog analysis to avoid biasing the data with an excessive number of dogs of 1 breed.

In lateral radiographic views, the long axis of the heart was measured from the ventral border of the left main stem bronchus to the most distant ventral contour of the cardiac apex (Fig 1). This dimension reflects the combined size of the left atrium and left ventricle (Fig 2). The measurement was made using an adjustable caliper, which was then repositioned over thoracic vertebrae beginning

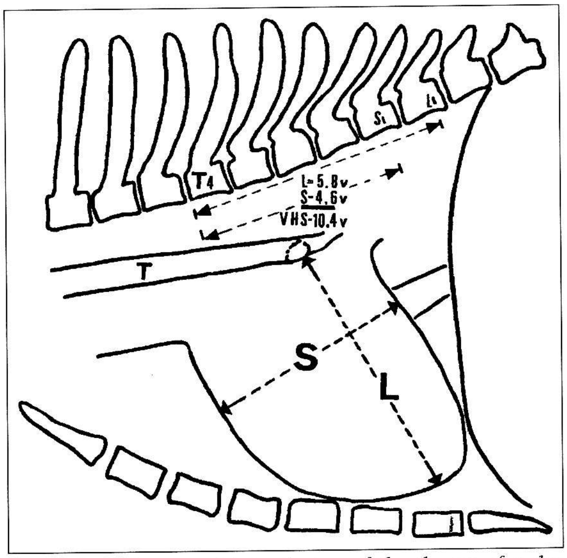

Figure 1—Diagram of lateral view of the thorax of a dog illustrating the vertebral heart size measurement method. The long axis (L) and short axis (S) heart dimensions are transposed onto the vertebral column and recorded as the number of vertebrae beginning with the cranial edge of T4. These values are then added to obtain the vertebral heart size. (T = trachea).

with the cranial edge of T4. The distance to the caudal caliper point was estimated to the nearest 0.1 vertebra (v). The caliper was then placed on a metric ruler and the interval recorded to the nearest millimeter to obtain more precise measurements for statistical analysis.

The maximal short axis of the heart in the central third region, perpendicular to the long axis, was recorded in the same manner starting at T4. The short and long axis dimensions were then added to yield a vertebra/heart sum as an expression of heart size in relation to a vertebral indicator of body length. The overall size of the heart was thus expressed as total units of vertebral length to the nearest 0.1v and termed the vertebral heart size (VHS). A 10-vertebrae-long index of body length was estimated by doubling the length of 5 vertebrae from the cranial edge of T4 to the caudal edge of T8.

In VD and DV radiographic views, the maximal long and short axes of the heart were determined with calipers in similar fashion and measured against vertebrae in the lateral radiographic view beginning with T4 (Fig 3). The maximal diameter of the caudal vena cava (CVC) was measured in lateral radiographic views and compared to the length of the single vertebra dorsal to the tracheal bifurcation (usually T5).

Separate measurements of the lengths of 3 and 4 sternebrae also were recorded. The sternal measurements extended from the cranial edge of the second sternebra to the caudal edge of the fourth and fifth sternebrae. The manubrium was purposely excluded because of its variable size. The sternal measurements were compared to cardiac and vertebral dimensions to determine whether sternal length might be more reliable than vertebral length as an index correlate for heart size.

Depth:width ratios of the thorax were determined in all dogs to obtain an expression of breed conformation differences. The depth of the thorax was measured in lateral radiographic views from the cranial edge of the xiphoid process to the ventral border of the vertebral column along a line perpendicular to the vertebral column. Thoracic width was measured in VD or DV radiographs as the distance between the medial borders of the eighth ribs at their most lateral curvatures. Dogs with depth:width ratios of ≥ 1.25 were considered to have a deep thorax (n = 11). Those with depth:width ratios of ≤ 0.75 were considered to have a broad thorax (n = 11).

Statistical analysis—All statistical calculations were done using metric measurements. Data are expressed as mean ± SD. Regression and correlation analyses were used to determine whether depth:width ratios influenced the relationship between VHS and the 10v reference length, and to assess the relationship of the sternal and vertebral measurements to those of the short and long axes of the heart individually and summed. Probability of $P < 0.05$ was considered significant.

Radiographic and echocardiographic measurements were made to compare the efficacy of the 2 procedures in characterizing progressive cardiomegaly in the same dog. Seven sets of sequential echocardiograms and thoracic radiographs were made over 3.5 years of a dog with chronic valve disease, mitral regurgitation, and progressive cardiomegaly. Echocardiographic measurements were made at end diastole from two-dimensional guided M-mode echocardiograms. Radiographs obtained the same day as the echocardiograms were measured by the VHS method described.

Results

Lateral radiographs—The sum of the long and short axes of the heart, or VHS, in 100 clinically normal dogs was 9.7v ± 0.5v (SD). The range of 8.5 to 10.6v had a normal distribution (Fig 4). The long and short axis dimensions each correlated well with the 10v reference length ($r = 0.92$ and $r = 0.94$, respectively; $P < 0.0001$); but the sum had a higher correlation coefficient ($r = 0.98$; $P < 0.0001$; Fig 5).

Good correlations also were detected between heart size and the length of 3 or 4 sternebrae ($r = 0.94$ and $r = 0.95$, respectively; $P < 0.0001$). The CVC diameter correlated moderately with the maximal length of the fifth or sixth thoracic vertebra ($r = 0.78$). The mean CVC:v ratio was 0.75v ± 0.13. Three dogs had a CVC diameter essentially equal to T5 or T6, whereas the CVC was smaller than either of these vertebrae in the 97 other dogs.

Thoracic size and depth:width ratios had no influence on the correlation between heart size and

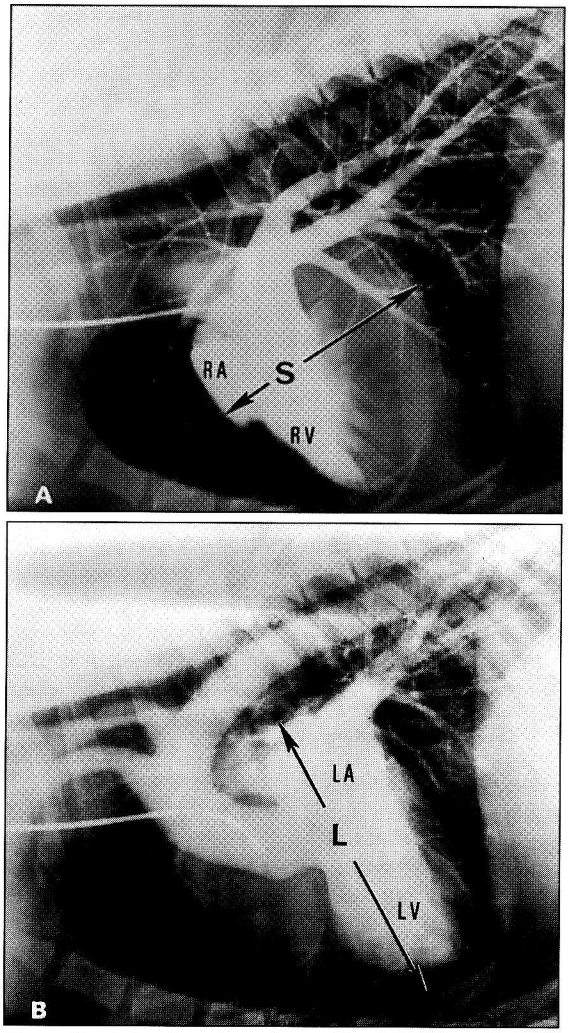

Figure 2—Lateral angiocardiographic views of a clinically normal 6-year-old Collie. In the dextrophase (A), notice that the short axis dimension (S) includes left and right heart chambers in the region of the coronary groove. (RA = right atrial appendage; RV = right ventricle). In the levophase (B), notice that the long axis measurement (L) from the left main stem bronchus to the cardiac apex represents the combined size of the left atrium (LA) and left ventricle (LV).

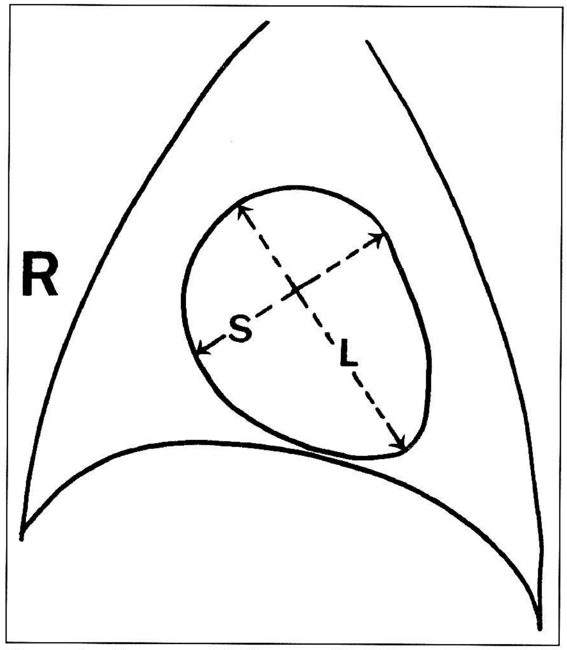

Figure 3—Dorsoventral diagram illustrating the short (S) and long (L) axis dimensions of the heart that were measured in ventrodorsal and dorsoventral radiographs.

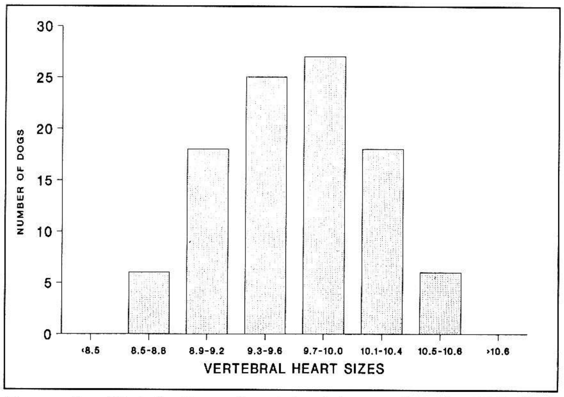

Figure 4—Distribution of vertebral heart sizes in 100 clinically normal dogs.

vertebral length. The relationship between VHS and the 10 vertebrae reference length was linear and essentially identical in dogs with a deep, intermediate, or broad thorax. Eleven dogs with a deep thorax in which the depth was > 1.25 times the width had a large long axis and a small short axis, but the sum of the two (9.54v ± 0.34) was not different from that in dogs with a wide thorax in which the VHS was 9.76v ± 0.33. Dogs with intermediate depth:width ratios from 1.25 to 0.75 (n = 78) had a mean VHS of 9.64v ± 0.54.

Sex and right vs left lateral recumbency did not significantly influence measurements. When right and left lateral radiographic views were compared for 20 dogs, heart sizes were essentially equal in 6 dogs. In 10 dogs, VHS in the right lateral view was 0.2 to 0.5v larger than in the left view. In 4 dogs, VHS in the left lateral view was 0.4v larger than the right. The lengths of 5 vertebrae (T4 to T8) measured in right and left lateral views of 20 dogs were essentially equal (± 1%).

Ventrodorsal and dorsoventral radiographic view—Dimensions of the heart in VD or DV radiographic views were more variable than in lateral radiographic views. In 79 VD views, the mean VHS was 10.2v (± 0.83). In 21 DV views, the mean VHS was 10.2v (± 1.45). The mean long axis dimension in VD or DV views was 11.9% (± 13.8) longer than in lateral views. The mean short axis dimension was slightly, but not significantly, narrower than in lateral view (0.7% ± 8.6). There were noticeable differences between measurements of VD and DV radiographic views of the same animals. Comparison of measurements in 17 dogs in which VD and DV views were available revealed that hearts in the VD view were 7.2% (± 4.5) wider and 5.3% (± 3.2) longer than in DV view. Because of the varia-

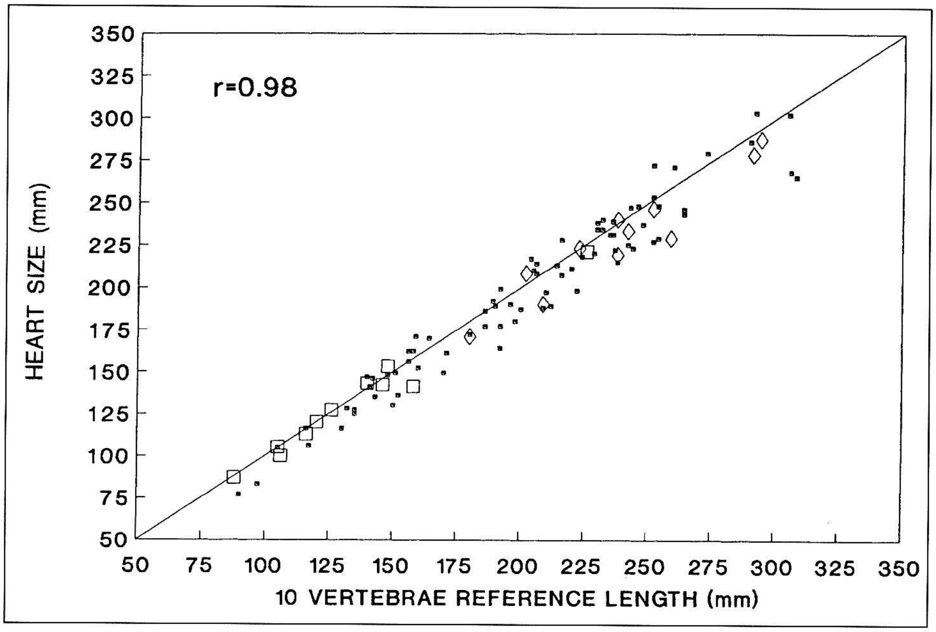

Figure 5—Correlation between the sum of long and short axis heart dimensions and the 10 vertebrae reference length in 100 clinically normal dogs of various body types. Small dogs with a broad thorax are indicated by open squares. Large dogs with a deep thorax are indicated with diamond-shaped symbols. The straight line represents the line of identity between heart size and the 10 vertebrae reference length.

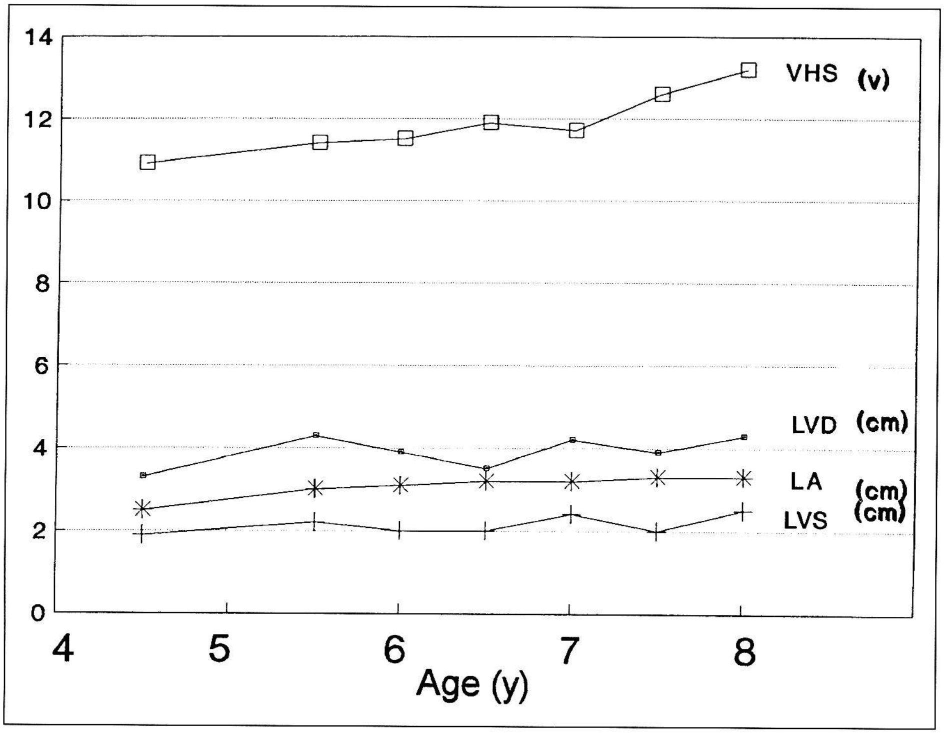

Figure 6—Echocardiographic and radiographic dimensions of the heart in a dog with mitral regurgitation and progressive cardiomegaly from age 4.5 to 8 years. The progressive increase in heart size was more apparent in radiographic measurements using the vertebral heart size method than M-mode echocardiographic measurements of individual cardiac chambers. VHS = vertebral heart size; LVD = left ventricular chamber in diastole; LA = left atrial dimension; LVS = left ventricular chamber in systole; V = vertebra; and CM = centimeters.

bility in VD and DV dimensions, and the fact that most radiographs available for analysis in this study were VD views, detailed correlation analysis of body length vs VD or DV heart size was not performed.

Comparison of 7 sets of radiographs and echocardiograms in a dog with mitral regurgitation and progressive cardiomegaly revealed that the VHS increased steadily over a 3.5-year period from 10.9 to 13.2v (21% increase; Fig 6). In echocardiograms, the left atrial dimension increased from 2.5 to 3.3 cm (28%), whereas the aortic dimension decreased slightly. Consequently, the standard left atrium:aorta ratio had the greatest change over the 3.5-year period, increasing from 1.5 to 2.2 (47%). Echocardiographic left ventricular dimensions did not increase over the final 2.5 years, whereas the VHS increased from 11.4 to 13.2v (16%) during the same period.

Discussion

Cardiac mensuration is helpful for inexperienced observers as a starting point in evaluating heart size. It is less important for experienced viewers who can usually recognize cardiomegaly empirically. But, even in this instance, measurement may ers who can usually recognize cardiomegaly empirically. But, even in this instance, measurement may be useful in questionable cases. Most notable has been the assessment of heart size in clinically normal dogs with a wide thorax. In lateral radiographic views of such dogs, the heart occupies more of thoracic depth than usual and the trachea appears elevated. However, VHS measurement consistently reveals a normal value for heart size in lateral views and, typically, the heart appears normal in DV or VD views. Many animals with this thoracic conformation and no heart disease have been referred for cardiac evaluation because of misdiagnosed cardiomegaly.

The VHS was ≤ 10.5v in 98% of the dogs in this study, and this value is suggested as a clinically useful upper limit for normal heart size in most breeds. Exceptions may exist in dogs with a short thorax, such as the Miniature Schnauzer, where a VHS up to 11v is probably normal. Conversely, an upper limit of 9.5v may be more appropriate in dogs with a long thorax, such as Dachshunds. Studies with larger numbers of dogs of each breed will be required to determine more precise values for individual breeds and changes that may develop with growth or aging.

Good correlations also were detected between heart size and the length of 3 or 4 sternebrae, however, these values were slightly less than vertebral correlations and yield no advantage over vertebral correlations except in dogs with hemivertebrae or other vertebral abnormalities. The CVC diameter was equal to or smaller than the length of T5 or T6 in all of the dogs, thus, the length of the vertebra over the tracheal bifurcation is proposed as a clinically useful upper normal limit for the diameter of the CVC.

In addition to initial assessment of heart size, the VHS method also is useful in monitoring the progression of heart enlargement over time in individuals. Recording the heart size in vertebral scale encourages objectivity and is a convenient way of recording changes in heart size in response to treatment or progression of cardiomegaly. The examples of radiographic and echocardiographic measurements in a dog with progressive cardiomegaly (Fig 6) reveal that absolute M-mode echocardiographic measurements did not reflect the extent of the heart size increase as well as the VHS method over the final 2.5-year period. This is because the echocardiographic measurements represent only a single dimension (mainly short axis), whereas the VHS method reflects change in 2 dimensions.

The major uses of the VHS method are in helping determine whether cardiomegaly exists in dogs with minimal radiographic changes and quantification of the progression of cardiomegaly over time in a given dog. Because the short axis measurement includes right and left heart chambers, it is increased with either right- or left-sided heart enlargement and does not help distinguish between diseases affecting the right and left sides. Such distinction usually can be made by analysis of chamber contours in lateral and VD or DV radiographic views.

Dorsoventral radiographic views are preferred over VD views for evaluation of heart size because cardiac contours are more consistent in DV view, and there is magnification in VD views caused by increased distance between the heart and the cassette. In 17 dogs in which VD and DV radiographic views were measured, hearts in the VD view were 7.2% wider and 5.3% longer than in the DV view. In 100 dogs, the mean long axis dimension in VD or DV radiographic views was 11.9% larger than in lateral views. In addition to magnification, the increased length also may reflect the fact that the VD or DV long axis extends through the right atrium and left ventricle, whereas it only includes the left atrium and left ventricle in the lateral view.

The similarity of 10 vertebrae reference lengths in right and left lateral radiographic views of 20 dogs was expected and reveals the advantage of using central vertebrae instead of intercostal spacing as a reference structure for comparison with heart size as well as other organ dimensions. The similarity of heart sizes in right vs left projections in most dogs indicated that one projection has no advantage over the other. It is recommended, however, that one radiographic view or the other be used consistently in a given animal so that subtle changes can be detected. The minor differences that were noticed in some of the dogs can be attributed to different phases of the cardiac cycle[11] and respiratory cycle.[12]

It is important to realize that normal heart size does not rule out heart disease, because substantial hypertrophy may exist without an increase in external heart size. The cardiac silhouette always must be examined for subtle changes in contour that may develop in dogs with concentric hypertrophy without dilatation. These dogs also may have other radiographic changes such as a prominent aortic arch, large or small main pulmonary artery size, and altered pulmonary vascularity.

The concept of using cardiac:skeletal ratios to assess heart size is not new. Cardiothoracic ratios (width of heart vs width of thorax) in human beings were relied on extensively before the advent of echocardiography and other more sophisticated diagnostic methods. In dogs, however, differences in conformation of the thorax between breeds make standard human-type cardiothoracic ratios of little value. Even in the same animal, standard ratios are unreliable to assess sequential change in heart size. As an example, comparisons of pre- and postoperative radiographs of dogs with patent ductus arteriosus and large hearts consistently reveals obvious reduction in heart size after surgery, but the width and depth of the thorax also decreases because of decreased respiratory effort. In addition, the midpoint of the cardiac silhouette, where standard ratios are determined, is displaced cranially into a narrower region of the thorax because of the reduction of left heart chamber size resulting from closure of the patent ductus arteriosus. Consequently, there often is no substantial change in cardiothoracic ratios.[13]

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