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RESEARCH ARTICLE

Comparing the Hearts of German Shepherd and Mongrel Dogs Using Statistical Shape Analysis

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ABSTRACT

The aim of this study was to conduct a statistical shape analysis of the heart of dogs and to compare this data between German Shepherd and Mongrel dogs. An effective way to examine these shapes is to record the locations of certain points on the object. In this study, 10 hearts were collected from each breed. EDMA and TPS techniques were used to examine genus-based changes in the shape of the heart**.** The shape deformations were expressed using expansion and compression grids. There was no statistically significant difference with respect to the general shape of the heart between the genera. However, there were local shape differences between the genera in some of the inter-landmark distances: 6% of the inter-landmark distances were greater in German Shepherd dogs, and 11% were greater in Mongrels. There are no heart shape differences between genera, although significant differences were found between the upper part of the left ventricle and the lower part of the right ventricle. The upper part of the left ventricle in Mongrels showed more enlargement than in German Shepherds. The lower part of the right ventricle in Mongrels had more enlargement than in German Shepherds; however, the middle part of the right ventricle of German Shepherds had more enlargement than in Mongrels. Although there were some local significant shape differences between the upper part of the left ventricle and the lower part of the right ventricle, however, there were no general heart shape differences between German Shepherd and Mongrel dogs.

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INTRODUCTION

Cardiac size and geometry have an important influence on clinical prognosis in heart disease. Hypertrophic and dilated cardiomyopathies are important diseases of the heart muscle, in which the heart muscle itself is structurally or functionally abnormal (Robinson and Maxie, 1993; Vleet and Freeans, 2001; Flores *et al*., 2012). Dilated cardiomyopathy (DMC) develops as a result of some diseases which damage and weaken the heart muscle. In dogs, the cause of the disease is generally unknown but the disease itself is highly breed-specific, being observed most commonly in Doberman Pinschers, Boxers, Great Danes, Irish Wolfhounds, Saint Bernards, Cocker Spaniels, Golden Retrievers and German Shepherd dogs. More than 90% of cases of canine DCM are confined to these eight breeds (Stephenson *et al.,* 2012). The disease is likely genetic in origin, although this has not yet been proved and the mode of inheritance has yet to be documented. Middle-aged dogs are most often affected (Van Vleet and Ferrans, 2007). In partial compensation for this weakness, the cardiac chambers dilate or enlarge. Hypertrophy of the ventricles results in an increase in heart size and weight. It may occur as a physiological response to sustained physical exercise; however, it is more commonly the result of pathological conditions such as hypertension, heart disease and lung disease. Hypertrophy generally occurs in conjunction with dilatation, a condition in which there is an enlargement of the heart cavities, which is especially observed in large-sized dogs such as German shepherd dog (Robinson and Maxie, 1993).

Anatomical differences between genders, age-related changes in the shape of the heart and disease/comorbidity-related evolution of the size of the heart are all important topics of medical research. Understanding the morphological changes caused by a particular disorder can help to identify the time of onset of a disease, quantify its development and potentially lead to better treatment (Golland *et al*., 2005). Statistical analysis of shape compares the forms of whole biological organs or organisms with specific landmarks, which are determined by anatomical prominences (Ozdemir *et al*., 2007; Slice, 2007; Colak *et al*., 2011; Ercan *et al*., 2012).

Little is known about ventricular shape differences between purebred, large-sized dogs, such as German Shepherds, and average-sized dogs, such as Mongrel dogs. The aim of this study was to conduct a statistical shape analysis of the hearts of German shepherd and Mongrel dogs and to examine the differences in the shape of the heart between these two genera.

MATERIALS AND METHODS

Subjects: In this study, 20 hearts (10 from each breed) were collected from German shepherd dogs and Mongrels whose weights ranged from 23 and 39 kg body and who were without known disorders. The atria were removed, and the hearts were preserved in 10% neutral buffered formalin until they were needed (Les *et al*., 2002).

Collection of two-dimensional landmarks and reliability: Ten landmarks were made on the heart images using TPSDIG 2.04 software (Table 1; Fig. 1). In this study, 10 landmarks were marked by the same investigator. After 1 month, this same investigator marked the landmarks on the 20 dogs (10 German, 10 Mongrel), and an analysis was performed to obtain a generalizability (G) coefficient. The intra-rater reliability coefficient was calculated for a two-facet crossed design ('landmark pairs-by-rater-by-subject, lxrxs) based on the generalizability theory (GT) (Ercan *et al*., 2008). In GT, the reliability of relative (norm-referenced) interpretations is referred to as the G coefficient (Dimitrov, 2007).

Statistical analysis: Euclidean Distance Matrix Analysis (EDMA) and Thin Plate Spline analysis (TPS) are the examples of frequently used methods in statistical shape analysis. In EDMA, form of an object is defined to be that characteristic which remains invariant under translation, rotation, and reflection of the object. Since the form of an object is invariant under translation, rotation, and reflection, an approach for comparing forms should start with a representation which is invariant under these operations (Lele, 1991; Ercan *et al*., 2012). The TPS function also known as the 'bending energy' is visualized as a set of landmarks. The height over each landmark is equal to the differences between the forms. If the two forms are identical, then the bending energy is zero, and the plate is flat. The magnitude and location of bending energy can be identified depending on the size and position of the deformation of the plate (McIntyre and Mossey, 2003).

To obtain an overall measure of shape variability, the root mean square of Kendall's Riemannian distance rho to the mean shape was considered (Kendall, 1984). The homogeneity of variance-covariance matrices was examined using the Box-M test. Given the heterogeneity of the variance-covariance matrices ($P<0.01$), the EDMA II method was used to compare the genus differences. For EDMA II, the geometric means of the distances among landmarks as scaling factors were used and standardized the form difference matrix for each sample by dividing each entry by the appropriate scaling factor. A parametric Bootstrap technique (Monte Carlo) was used to create 1,000 resamples. Statistical tests of the null hypothesis concerning the equality of the shapes for subsets of landmarks was performed and used confidence interval testing to evaluate the statistical significance of differences in individual linear distances. There were 10 (k) landmarks with 45 inter-landmark distances ($[k(k-1)]/2$), which were statistically compared.

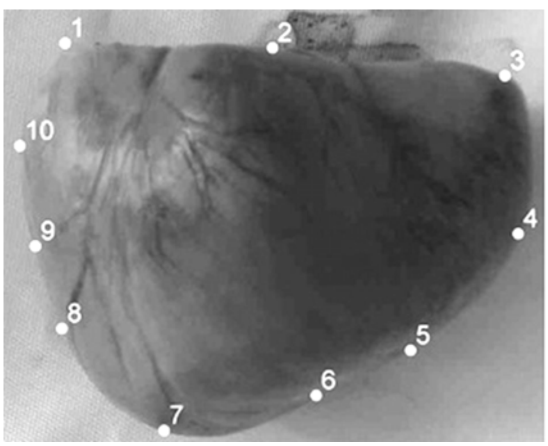

Fig.1: The digitized landmarks on the heart.

Table 1: Landmark definition of heart in German shepherd and Mongrel dogs

Landmark	Landmark definition
1, 2 and 3	Basement of the ventricles
4 and 5	Middle part of the right ventricle
6	Lower part of the right ventricle
7	Apical end of the heart
8	Upper part of the left ventricle
9 and 10	Lower part of the left ventricle

RESULTS

An intra-rater reliability coefficient was calculated, and good reliability was found for both German shepherd ($G=0.99771$) and Mongrel dogs ($G=0.99163$). According to this result, the reliability of the landmark location for the two groups is good. No statistically significant difference in terms of general shape was found between the genera. However, there were some local shape differences between the genera in some of the inter-landmark distances: 6% of the inter-landmark distances were greater in German Shepherd dogs, and 11% were greater in Mongrels ($P<0.05$; Fig. 2). Interlandmark distances 5-6, 4-5 and 4-6 were significantly different in German shepherd ($P<0.05$). Interlandmark distances 6-7, 1-8, 8-10, 1-9 and 9-10 were significantly different in Mongrel ($P<0.05$).

The general shape variability of the heart was 0.067 in German shepherd dogs and 0.078 in Mongrels. The procrustes mean shape configurations are displayed in Fig. 3. In accordance with the TPS analysis, the points exhibiting the most enlargement and shrinkage were labeled as deformations. Landmark 9 had the most enlargements and landmark 5 had the most shrinkage. Figure 4 shows the resulting TPS transformation grid, thus clarifying the degree of compression and expansion.

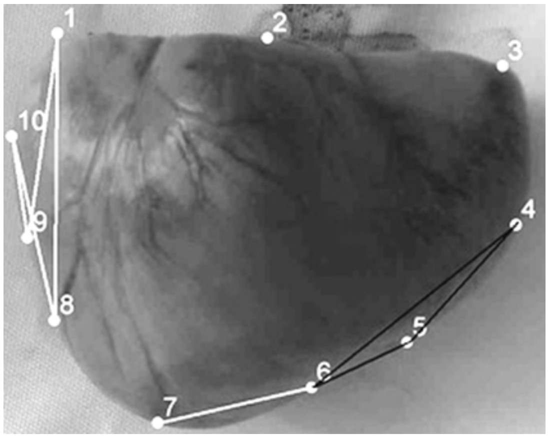

Fig. 2: White lines indicate the inter-landmark distances that were found to be greater in Mongrels. Black lines indicate the inter-landmark distances that were found to be greater in German shepherd dogs.

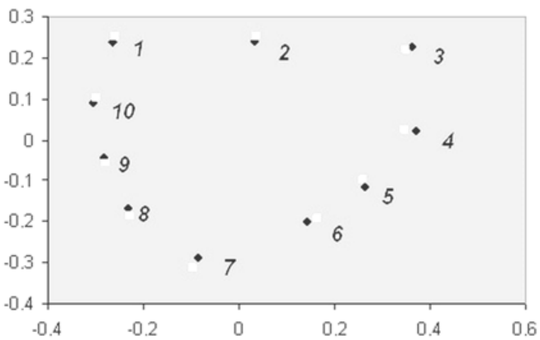

Fig. 3: Procrustes mean shape configurations for heart images of German shepherd dogs (□) and Mongrels (◊).

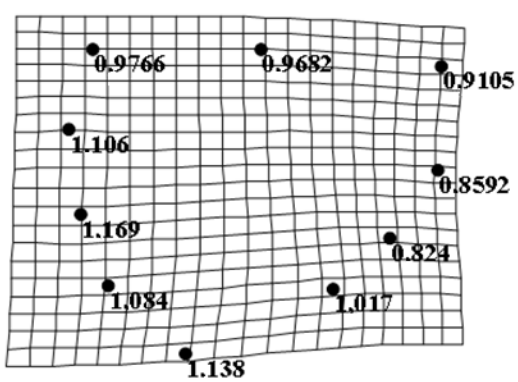

Fig. 4: A thin plate spline transformation grid from the mean shape of German Shepherds and that of Mongrels. The expansion (greater than one) and compression factors (smaller than one) at the landmarks are shown numerically.

DISCUSSION

Many studies in medicine include an examination of the geometrical properties of an organ or organism. In these studies, quantitative or qualitative data sets are commonly used in statistical analysis and are comprised of measured values. More recently, as a result of the advances in imaging techniques, the appearance or shape of the organism has been used as input data (Ercan *et al*., 2012). Statistical shape analysis compares the forms of whole biological organs or organisms with specific landmarks determined by anatomical prominences (Ozdemir *et al*., 2007; Slice, 2007; Colak *et al*., 2011; Ercan *et al*., 2012). This paper presents the application of statistical shape analysis to the hearts of German shepherd and Mongrel dogs.

Heart disease is very common in all breeds of dogs. Dilated cardiomyopathy is a heart disease that weakens the heart muscle and is generally observed in large dogs, such as German Shepherds. In this condition, the function of the heart is abnormal; therefore, the individual chambers of the heart enlarge to compensate for the increased volume of blood, resulting in an enlarged heart (Robinson, and Maxie, 1993).

The determination of a healthy heart shape and size as well as knowledge of the normal anatomical shape variations between animals are important in the evaluation of patients with heart disease (Litster and Buchanan, 2000; Litster *et al*., 2005). Although there are many studies of heart anatomy, there have been no studies that explore the morphological differences between the hearts of German shepherd and Mongrel dogs.

Several procedures for obtaining shape information from landmark data have been proposed (Richtsmeier *et al*., 1992; Ercan *et al*., 2012). In this study, EDMA and TPS methods were used with the aim of evaluating the general form differentiation in the heart of dogs Thus, this study is the first in which dog-genus-based shape differences were evaluated using a landmark-based geometrical morphometric method.

A greater intra-group variability was observed between individual Mongrel dogs than there was intergroup variability between mongrel dogs and German Shepherds. There is no difference in the heart shapes of pure bred dogs such as German shepherds. This can be very helpful for veterinarians who commonly examine heart size using cardiac images.

The results demonstrate that there were no general heart shape differences between the two genera studied, although there were significant differences between the upper part of the left ventricle and the lower part of the right ventricle. The upper part of the left ventricle of Mongrels is larger than that of German Shepherds. The lower part of the right ventricle of Mongrels is larger than that of German Shepherds; however, the middle part of the right ventricle of German Shepherds is larger than that of Mongrels. There is also more enlargements at the apical end of the heart of Mongrels than German Shepherds. Thus, Mongrel hearts have a more pointed shape than German shepherd hearts.

Although, imaging technics (i.e., chest radiography and conventional CT scans) provide detailed information on most structures in the canine thorax and heart, the vast majority of cases of dilated cardiomyopathy in dogs are considered to be idiopathic. The results of this study will give additional information concerning the anatomy of the heart in German Shepherds and Mongrels and could be used as a guide for the evaluation of images, such as chest radiography and conventional CT scans of the thorax of dogs with thoracic diseases. Additionally, this is the first study utilizing statistical shape analysis of the hearts of dogs.

Conclusion: It was concluded that there was no general heart shape differences between the two genera studied, i.e., German Shepherd and Mongrel, although there were some local significant shape differences between the upper part of the left ventricle and the lower part of the right ventricle.

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