Spatial Vectorcardiograms in Normal Dogs
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The spatial vectorcardiogram was recorded on 34 normal mongrel dogs employing the equilateral tetrahedral reference system. The QRS sE-loop was long, narrow, and elliptical, and oriented slightly to the left, ventrad and caudad, the majority of the maximal vectors lying in the fifth sextant of the triaxial reference system in both the anterior and left sagittal plane projections. The trace was inscribed in a counterclockwise direction in the frontal and left sagittal plane projections for most of the dogs. The P and T sE-loops were essentially of the same configuration and had the same spatial orientation as the QRS sE-loops, except that T sE-loops were often oriented in the second sextant of the triaxial reference system in both the frontal and left sagittal plane projections.

RECENT increased interest in re-examining and improving the methods of electrocardiography has focused attention on the timing and spread of electric activity in the dog's heart. Vectorcardiographic investigations thus far have been limited almost entirely to man. However, certain types of these investigations must be conducted on experimental animals, and their interpretation requires a knowledge of the vectorcardiogram of the normal animal. Recent observations on the effect of experimentally produced myocardial injury on the spatial vectorcardiogram (sVCG)1 led to the recording of the spatial vectorcardiogram of the "normal" intact mongrel dog under the influence of an anesthetic.

METHODS AND MATERIALS
Spatial vectorcardiograms in the equilateral tetrahedral reference system were recorded for 34 apparently normal mongrel dogs, weighing between 5.2 and 18.8 Kg. The dogs, which were in the supine position, had been anesthetized with pentobarbital. Electrocardiograms recorded at the same time included the standard limb leads and chest leads topographically analogous to the conventional Vi through V6 leads in man. The hearts of 30 of the animals that were used for experiments involving acute myocardial damage2 were available for postmortem examination. These hearts were examined for the presence of heartworms, Diroflaria immitis, relative ventricular thickness, and, in 11 instances, weight of the fresh specimen. Four animals were rotated about the long and transverse axes of their bodies to determine the effect of an extreme alteration in cardiac position upon the spatial vectorcardiogram and electrocardiogram.

RESULTS
QRS sE-loop. The typical QRS sE-loop resembled a long, narrow ellipse (fig. 1). Its mean spatial orientation varied only slightly to the right, left, ventrad or dorsad from a strictly caudal orientation.* The scatter diagram in figure 2 illustrates the magnitude and direction of the maximal mean instantaneous vectors in the frontal and left sagittal plane projections of the QRS sE-loops. These maximal vectors lie almost totally within the fifth sextant of a triaxial frame in both plane projections.

The direction of inscription of the trace in the frontal plane projections was counterclockwise for 26 dogs and clockwise for 1; the configuration was linelike or "on-edge" for 2 and figure-eight for 5. In these figure-eight loops, the proximal portion was counterclockwise in inscription in 3 instances and clockwise in 2. The inscription was counterclockwise in the left sagittal plane projections for all 34 dogs. Slight alteration in the direction of inscription of the frontal plane projections of the QRS sE-loop was observed when the body of the dog was rotated or tilted about its transverse or

* Spatial orientation of the spatial vectorcardiogram in the dog, as in man, is defined in the anatomic position1 except that in the dog the term "caudad" corresponds to inferior in man, "cephalad" to superior, "ventral" to anterior and "dorsal" to posterior.
Fig. 1. Typical examples of the QRS sE-loop of the spatial vectorcardiogram of normal mongrel dogs (A, no. 516; B, no. 532; C, no. 517). Note slight deviation from a true caudal direction in frontal and left sagittal planes.

Fig. 2. Magnitude and direction of the maximal mean instantaneous vectors of the frontal and left sagittal plane projections of 34 QRS sE-loops (medium-sized dots) and 28 T sE-loops (small dots) on triaxial reference frames. Maximal QRS vectors lie in the fifth sextant in both frontal and sagittal views; average for each view indicated by the large black dot. Likewise, 19 of the maximal T vectors lie in the fifth sextant, but 9 that are discordant lie in second sextant in both planes. Averages for two groups of T vectors indicated by the open circles. (See fig. 4.)

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longitudinal axes. A figure-eight configuration was produced in 3 of 4 dogs so studied. Clockwise inscription of the distal portion of the QRS sE-loop developed in one instance both when the dog was turned on its left side and when its head was lowered; in a second dog, when the head was elevated; and in a third, only when the head was lowered. In the second dog, turning or tilting the dog to its right side resulted in clockwise inscription of the proximal portion of the loop. Figure 3 illustrates slight, but definite, effects upon the spatial vectorcardiogram of tilting the dog.

T sE-loop. The T sE-loop was typically a narrow, almost linelike, closed ellipse directed caudally in both the frontal and left sagittal plane projections (fig. 4). The maximal mean instantaneous vectors lay in the second and fifth sextants in both plane projections. Those in the second sextant were associated with diphasic T waves in standard lead I. These loops tended to have the same spatial orientation as the
QRS sE-loops along the longitudinal axis of the body, except that a portion of the T sE-loop lay in both the fifth and second sextants of the triaxial reference system in both the frontal and left sagittal projections.

P sE-loop. Although generally a nearly vertical, narrow ellipse in configuration, the P sE-loop varied considerably from time to time and from dog to dog, suggesting changes in the site of the atrial pacemaker (fig. 4).

FIG. 3. Influence on the spatial vectorcardiogram of tilting dog about longitudinal and transverse axes. Corresponding positions of dog for each recording are (A) supine, (B) left lateral, 75° from the horizontal, (C) right lateral, 72° from the horizontal, (D) head lowered, 70° below the horizontal, and (E) prone. Note the small change in rotation of the distal portion of the QRS sE-loop in (B).

FIG. 4. Three spatial vectorcardiograms of normal mongrel dogs (A, no. 508; B, no. 534; C, no. 514) recorded at high amplification to illustrate details of T and P sE loops. The first two records are typical of the majority of the T sE loops; the elliptical loops were either (A) closed or (B) slightly open. The third record (C) is typical of a group of 9 discordant T sE loops.

DISCUSSION

It is not known to what degree differences in configuration, direction of inscription of the trace and spatial orientation of the vectorcardiograms of normal man and of "normal" dog can be attributed to gross anatomic or physiologic differences. It is possible that the greater caudal orientation of the apex of the canine heart may be related to the greater caudal orientation of its QRS sE-loop. Similarly, the difference in inscription of the QRS sE-loop in the frontal plane projection may result from differences in anatomic orientation of the interventricular septum, as well as anatomic, physiologic and electric characteristics of the body and its various tissue components. The canine septum is relatively more perpendicular to the ventral thoracic wall than is the human septum, thus vectors representing initial septal activation (from the left side preponderantly) in the dog may be more likely to project toward the right on the frontal plane than in man. This may account in part for the usual counterclockwise inscription of the projection of the QRS sE-loop in the frontal plane in the dog as com-
pared with the usual clockwise inscription in the normal man. Figure 3 shows the changes in direction of inscription of the plane projections produced by rotating the dog to allow spatial displacement of the heart by gravity.

It would appear that changes in position of the body of the dog with other associated changes in cardiac and extracardiac conditions could have altered the order of depolarization and repolarization to some extent. However, this seems unlikely for, whereas spatial orientation was modified with resultant alteration in the projections of the spatial vectorcardiogram upon the frontal and sagittal planes, the configuration of the spatial vectorcardiogram changed little. The slight alteration in configuration could have been due to alteration in the anatomic relation between the heart and extracardiac tissue of different electric characteristics and was not necessarily attributable to changes in the order and magnitude of the intracardiac electric events. When the spatial vectorcardiograms of dog and man are being compared, the absolute and relative differences between man and dog must be considered with regard to conductivity of tissue, contour of hemic, vascular, cardiac, pulmonary and thoracic surface boundaries, degree of eccentricity, and ratio of cardiac to thoracic volume; all with unknown influences upon the peripherally recorded tracing. The probability of species differences, with an even more fundamental influence on the order of activation, is not clearly defined. It was remarkable, however, that despite some differences, the configuration of the spatial vectorcardiogram of the dog fell into the two types described previously for man.

The question of normalcy may be raised with regard to the myocardia of these dogs, especially in those with discordant maximal mean instantaneous T vectors (fig. 2). The significance of this divergence in the tracings of the dogs is not known, but present-day electrocardiographic knowledge suggests that an analogous phenomenon in man would indicate significant alterations in the order of repolarization which, in certain clinical studies, would be considered abnormal. This finding was apparently not related to the presence of heartworms, because only 4 of the 11 dogs with worms had discordant maximal mean instantaneous T vectors (or diphasic T waves in standard leads II or III). The influence of the anesthetic is not known. All dogs received the same drug, pentobarbital, in equivalent doses per kilogram of body weight, but the myocardial sensitivity of the dogs may have varied individually.

Summary

The spatial vectorcardiogram was recorded in the equilateral tetrahedral reference system in 34 "normal" mongrel dogs. The configuration of the QRS s£-loop was a long, narrow ellipse directed caudally and inscribed in a counterclockwise direction in the frontal plane projection in most dogs as well as in the left sagittal plane projection in all dogs. Similar configuration and orientation of the T and P s£-loops were also observed.

Summario in Interlingua

In 34 normal canes hybrida le vectocardio-
gramma spatial esseva registrate in le systema
de referentia equilatero-tetrahedral. Le con-
figuration del spira s£ de QRS esseva un
allongate e striete ellipse de direction caudal,
inscrita sinistrorsemente in le projection in
le plano frontal pro le majoritate del canes e
etiam in le projection in le plano dextero-
sagittal pro omnne le canes. Esseva etiam ob-
servate simile configurationes e orientacions
del spiras s£ de T e P.

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Circ Res. 1957;5:133-136
doi: 10.1161/01.RES.5.2.133

Circulation Research is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7330. Online ISSN: 1524-4571

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