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Age Changes in the EKG of Beef Cattle

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Contents

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Age Changes in the EKG of Beef Cattle

WILLIAM C. VAN ARSDEL III, HUGO KRUEGER, and RALPH BOGART

Introduction

The relative stability of electrocardiogram (EKG) patterns, unless pathological conditions intervene, encourages investigators to use an internal control technique (before and after comparisons in the same animal) for test procedures utilizing physiological systems as a research tool. This is an attempt, of course, to circumvent high costs and inadequate numbers characteristic of large-animal research. Differences in EKG patterns associated with age are mentioned in all clinical electrocardiology textbooks, but they are usually minor and considered to be of little consequence for short-term experimental studies. This is a reasonably safe assumption for cattle, except for the first 100 days of a beef calf's life.

A newborn calf is not a functional ruminant, but it achieves this function before 100 days of age. Changes in the cardiac electrical axes of a calf approach 90° during this period (3). Confusions between changes attributable to development or age with treatment-effects appear to be present in the work of investigators unfortunate enough to have utilized young calves in their experiments. Any investigator who uses a cardiovascular physiological system as a research tool must know the parameters of age change before proper evaluation of data can be attained. The EKG record is an important tool that reflects certain aspects of cardiovascular physiology.

Information concerning age differences in cattle electrocardiograms is at present undefined. The need for basic information concerning age changes in the EKG records of cattle has led to the following explication of these changes.

Materials and Methods

Obtaining the record

Electrocardiographic recordings were obtained from three closed lines of Hereford cattle maintained at the Oregon Agricultural Experiment Station, Corvallis, Oregon. The three lines are known as the Lionheart, Prince, and David breeding lines. The Lionheart line has been closed to outside breeding since 1950. The Prince and David lines have a common origin separate from the Lionheart line. No outside bulls have been used for breeding in the Prince line since 1948, and in the David line since 1950. Before 1950, some cows contributed calves to both Prince and David lines, but since 1950 these two lines have been maintained separately.

Data for this study were obtained from 42 of the Hereford cattle maintained in this herd. Records were obtained at various ages from the first day of life to day 4,570. The number of recordings obtained from the same animal varied from one to six. Breeding variation extends from a foundation cow to highly inbred calves. Sample records presented here represent a pooling of recordings from several studies which covered a wide age span (as stated above). In spite of innumerable variables, an age-effect trend may be discerned.

Electrical characteristics of the heart beat, cardiac potentials, and the various theories that have evolved to explain these electrical manifestations are well described in available textbooks for clinical (human) electrocardiology. Adaptation of this human clinical knowledge to bovine electrocardiology and a review of previous bovine electrocardiological studies have been discussed previously and need not be repeated (2). Technical requirements for obtaining bovine EKG's and the preparation and handling of animals also have been described (2).

Ancillary information routinely obtained included ambient temperatures, in degrees centigrade, and rectal temperatures, in degrees fahrenheit, of the animals under study. Rectal temperatures were usually obtained after the animals were tied to the hitching post where EKG's were taken.

Analyses of records

Leads and lead systems used in this study have been described previously (2, 3). For convenience, a sketch (4) of the principal lead systems is shown on page 5.

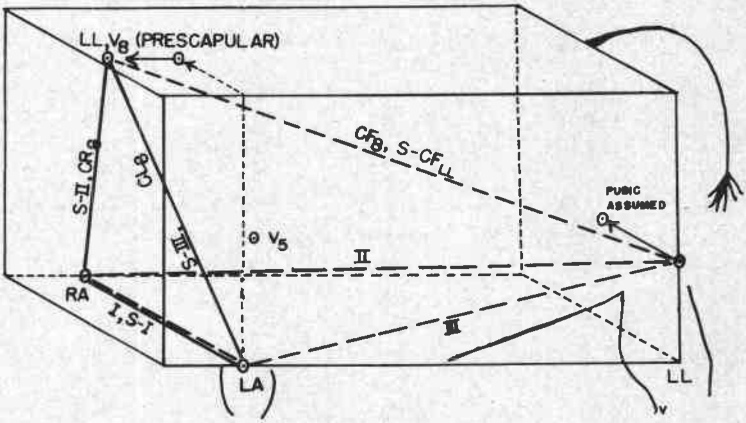
Wave patterns obtained from these lead systems can be seen in Figures 1, 2, and 3.

Variations of these EKG lead patterns, their derivatives that accompany different age periods, and the influence of line differences in these age variations will be discussed.

Methods of the EKG record analysis have all been described (1). The use of the factor 1.15 to adjust the augmented unipolar lead potential to equivalence with the bipolar leads was not adequately explained in the above-mentioned publication (2), and needs to be reviewed.

According to Dimond (1), the augmented unipolar leads are $\frac{1}{2} \times \sqrt{3}$ or 86.6% of the amplitude registered by the bipolar limb leads

SCHEMATIC COW AND LEAD SYSTEMS



when an identical potential is measured. If only 86.6% of the potential (P) is recorded by this unipolar procedure, then the actual potential would be $\frac{100}{86.6}$ x P or 1.15 P. No inconsistencies were observed in the application of this correction factor to the bovine EKG.

Lead systems

Application of the standard limb leads used in human electrocardiology to cattle provides one plane, the limb lead plane. These leads form a triangle somewhat like the Einthoven triangle in humans. The hexaxial modification of this triangle (1), provides six point estimates of the cardiac electrical vector projections onto this limb lead plane.

Simply moving the LL electrode to the prescapular position provides a similar plane, the S-lead plane, which is oriented about 90° to the limb-lead plane. Information from these two planes allows all vector values to be calculated (2).

Routine use of precordial lead positions has been discontinued, except for the prescapular position (V_8). This position with leads V_8 or CF_8 usually presents all three cardiac waves with adequate amplitude to follow visually. These waves may be inverted (positive P) by exchanging the chest lead electrode with the left hind leg electrode to obtain $S\text{-}CF_{LL}$.

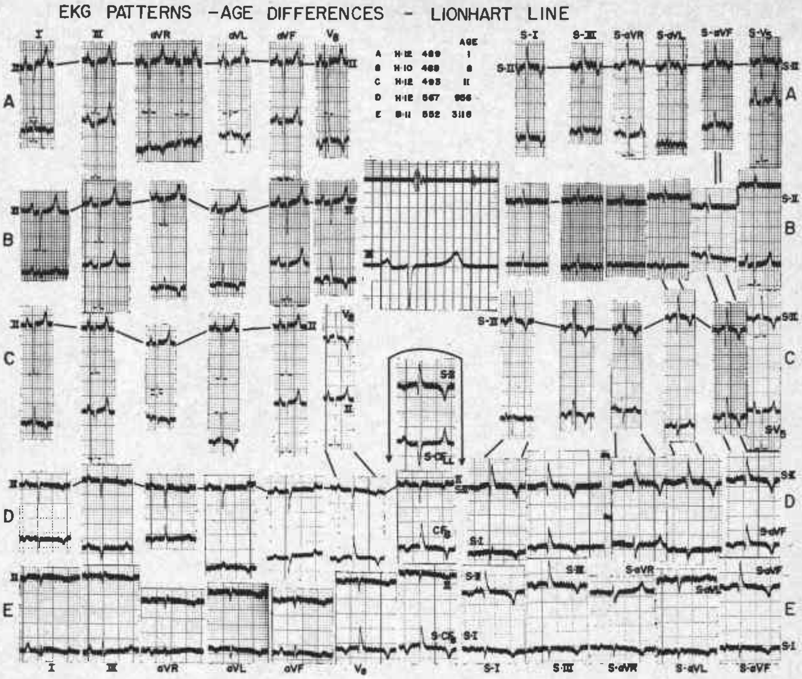


Figure 1. EKG patterns of Lionheart line cattle at ages from day 1 to day 3,118. Leads were obtained with a twin-beam recorder and mounted to demonstrate comparisons possible with common reference leads.

Lead wave patterns

Figure 1 shows all twin beam examples from the Lionheart line for the five different recordings shown. The reference lead pattern is usually in the upper portion of the record. Lead II is the reference lead for the leg lead plane; S-II for the S-lead plane, except for line E. In line E, the reference lead is S-I which is located in the lower portion of the record.

The S-V_5 lead patterns are included for the young calves to show the prominent P-wave obtainable from this position in young calves. The CF_8 lead generally provides a clear P-wave and is shown for older animals.

Nine sets of EKG patterns from eight different recordings from Prince-line Herefords are presented in Figure 2. Single patterns are illustrated, except in a few cases where the double channel (D) record did not require additional area.

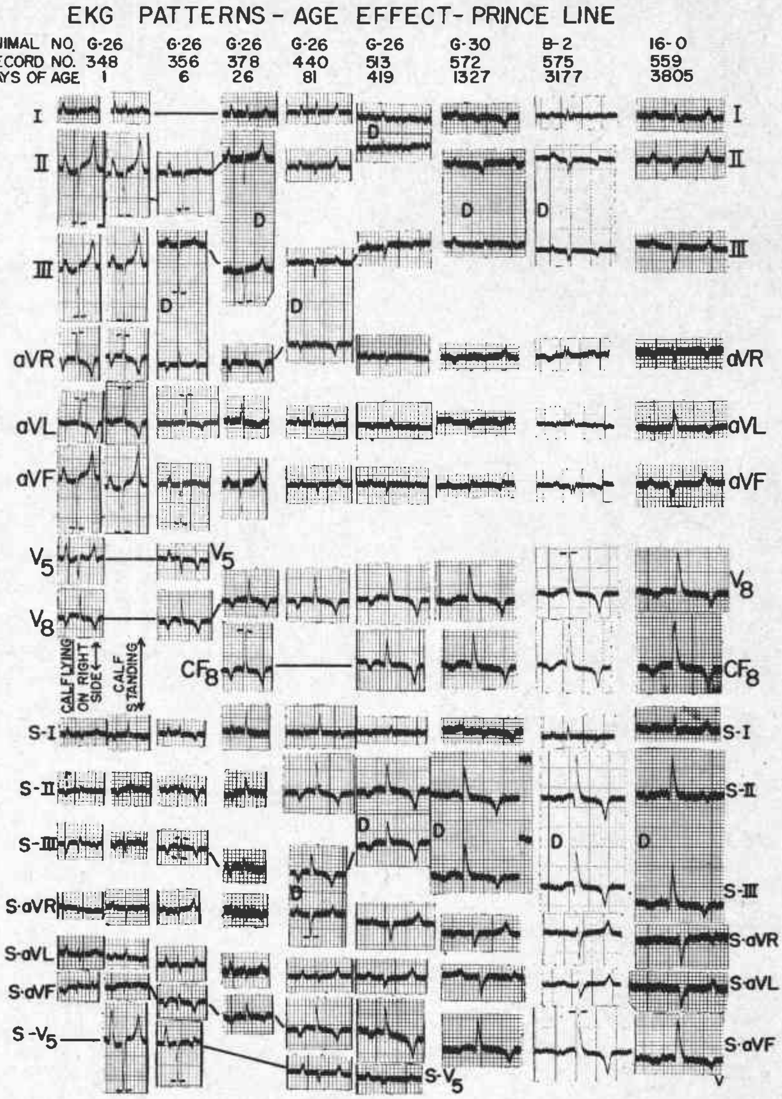


Figure 2. Patterns from Prince line cattle obtainable with an EKG recorder. Cattle ages vary from day 1 to day 3,805. Record No. 348 illustrates the difference obtained between an animal standing or lying on its right side.

Figure 3 illustrates 14 sets of leads for variously aged David-line Herefords. The format is similar to Figure 2, and it presents double channel (D) recordings only where space is not sacrificed. Many examples of bipolar and unipolar leads for position V_5 are shown; in this case using the S-lead system for the Einthoven triangle base.

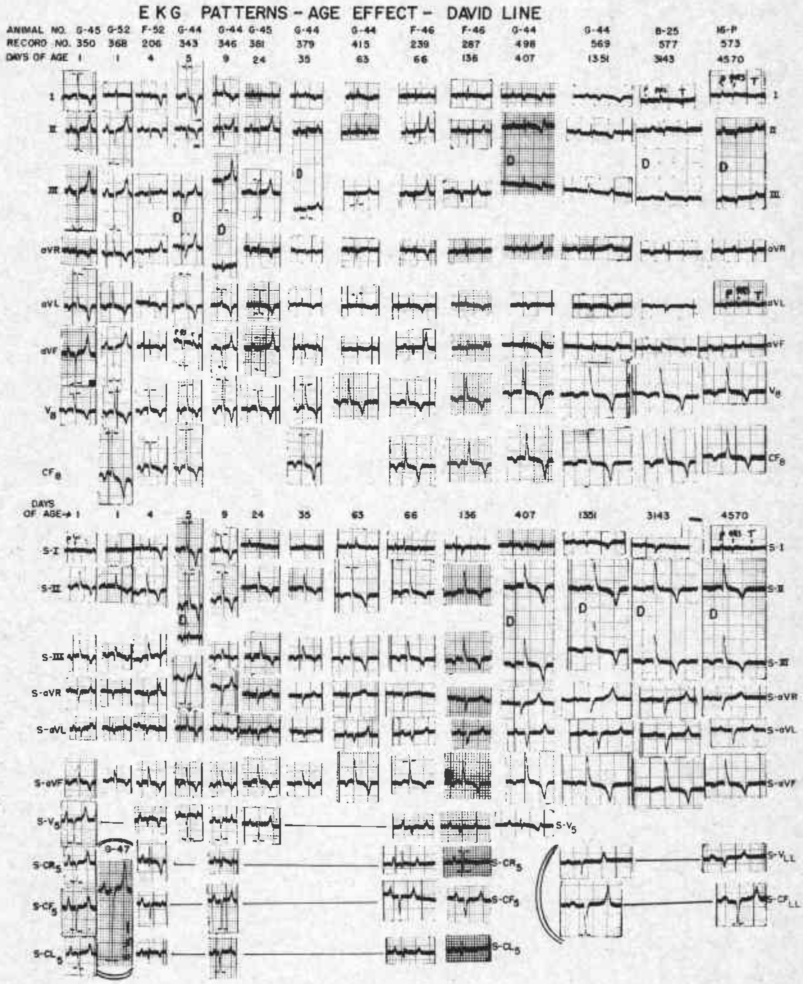


Figure 3. David line cattle electrocardiograms obtainable from day 1 to day 4,570.

Extra inserts appear where space for additional information was available. Insert S-V_5 from newborn calf G-47 demonstrates the variability of V_5 recordings. Recordings based on the S-lead system, but with the chest electrode on the left hind limb, are available for cows G-44 and 16-P. These leads (S-V_{LL} and S-CF_{LL}) provide patterns easily followed on an oscilloscope screen.

Vector potentials

Vector potentials have been calculated as described by Van Arsdel, Krueger, and Bogart (2). Potentials of the QRS and the P wave are shown in Figure 4 where the potential appears in millivolts on the ordinate and the age of the animal appears on the abscissa as day of life. T-wave cardiac-vector potentials are similarly graphed in Figure 5.

QRS-T axes angles

The angle between QRS and T wave vectors has been determined by the law of cosines (2). The QRS-T angle, in degrees, has been graphed on semi-log paper and appears as Figure 6. The ordinate is divided into angle degrees, while the abscissa shows day of life. All points for the same animal are interconnected.

Vector axis orientation

The vector axes of the QRS and T waves have been plotted on an oblique sterographic projection centered on a 40° latitude.* This projection is essentially a globe which has had its polar axis tipped forward by 40°. This orientation of the projection globe allows the QRS wave vectors to be plotted dorsally and the T-wave vectors to be plotted ventrally.

The vector axes of the QRS and T waves have been graphed for each breeding line. Orientations of these vectors are illustrated in Figures 7, 8, 9, 10, 11, and 12. Each line requires two figures, one for the QRS vector and one for the T wave vector. Information for the Lionheart line appears in Figure 7 for the QRS vectors and in Figure 8 for the T wave vectors. Similarly, Figures 9 and 10 concern QRS and T wave vector information for Prince line cattle, while Figures 11 and 12 concern David-line cattle. In each graph the azimuth and elevation point is plotted. The number by the point provides age information (day of life); lines interconnect points referable to the same animal and circled numbers identify the animal.

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* Projection prepared by Jon M. Leverenz, Cartography Department, Oregon State University.

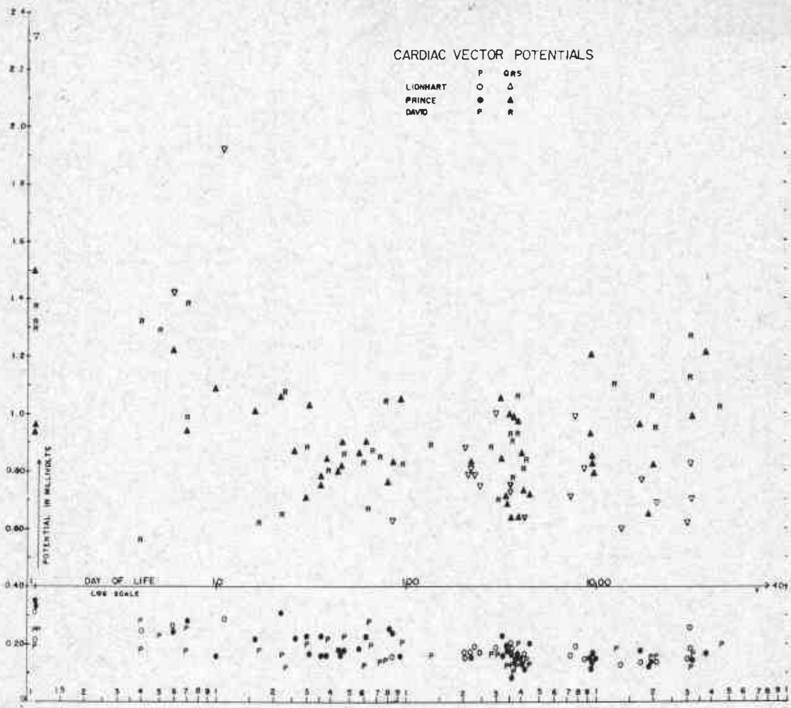

Figure 4. Cardiac vector potentials at various ages for cattle in this study. One day-four QRS value is absent because of a low potential exhibited by a double loop. QRS and P-wave vector potentials are both plotted on the same figure.

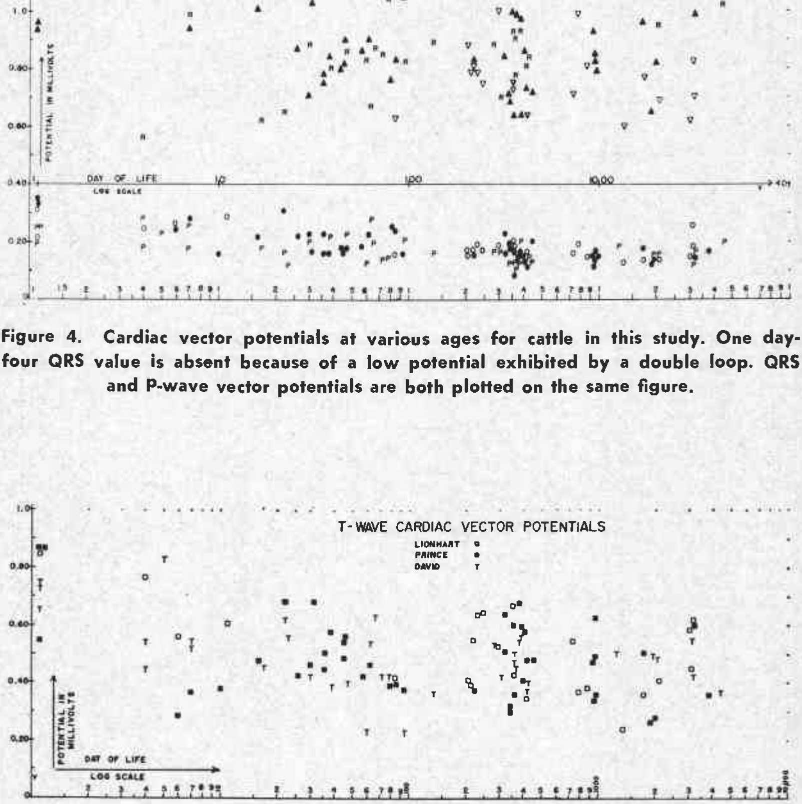

Figure 5. T-wave cardiac vector potentials for all three groups of cattle in this study plotted against the ages of the animals.

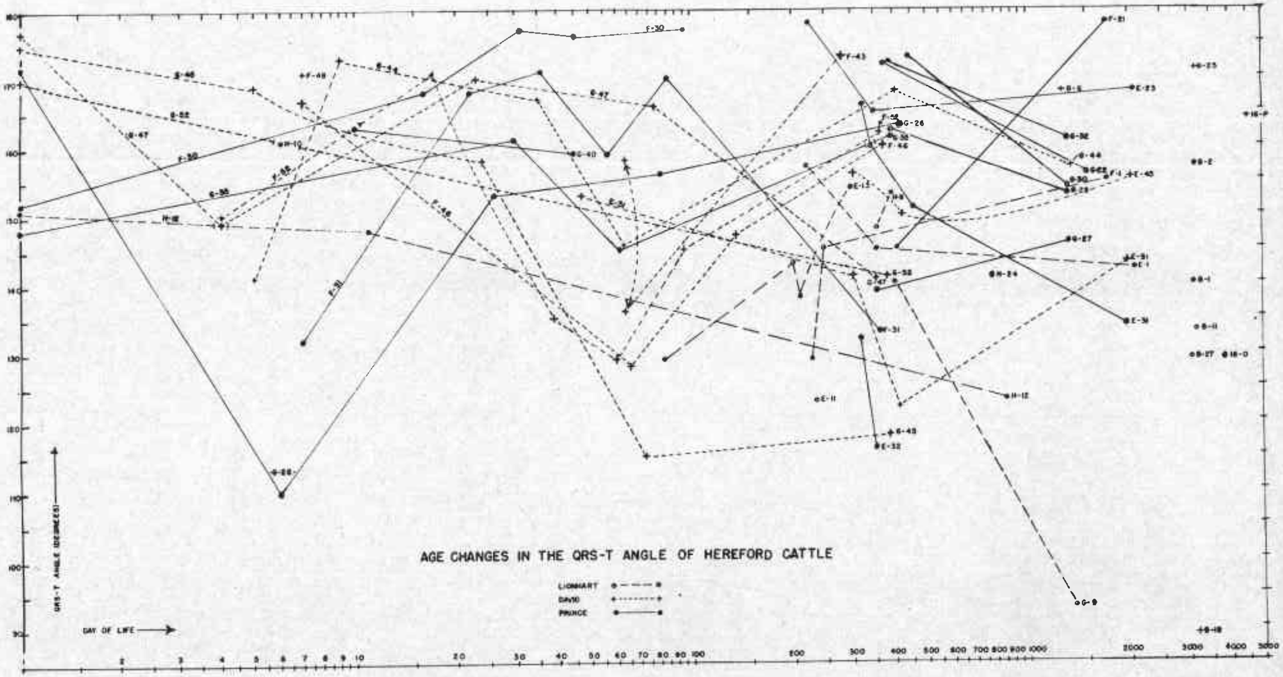

Figure 6. QRS-T angles for variously aged cattle. Points referable to the same animal are interconnected. Calf F-43 at 64 days of age was recorded while lying on its right side and a QRS-T angle value of 158° was observed. After this record was obtained, the calf became more cooperative and a routine record (calf standing) became available. Both QRS-T angle values are plotted and interconnected with a double-arrowed line.

Observations

Lead wave patterns

Wave patterns in all three breeding lines exhibit basic similarities (Figures 1, 2, and 3). Young calves have the greatest potential in leg leads for all three cardiac electrical axes, indicating that the vector axes are in the plane of the limb leads. At all other ages, maximum wave potentials are recorded in the S-lead system. Recordings obtained between day 4 and day 7 often have unusual configurations.

In spite of similarities, there are differences between lines in the wave patterns, but derived calculations make them more apparent. At the present time, numbers available are inadequate to establish parameters. Lionheart cattle all show a Q wave in leads S-II and V_8, a wave which is generally absent in these leads for both Prince-line and David-line cattle. An observable potential is to be found in lead S-II for all ages of David calves. Young Prince and Lionheart calves do not exhibit such potentials.

Calculated cardiac vector potentials

The QRS potential for Lionheart cattle is not only greater in young calves, but is greater than the QRS potentials of either Prince or David calves. This relationship is reversed for cattle over 3 years of age. In this older-age area of the graph, the potentials of Lionheart cows appear lower on the distribution graph. Most of the QRS vectors have a calculated potential between 0.60 and 1.20 millivolts (Figures 4).

The P- and T-wave potential differences referable to breeding lines are not readily apparent. While the P-wave potential appears to decrease with age, most will be found between 0.10 and 0.30 millivolts. Most of the T-wave potentials were found to be between 0.30 and 0.70 millivolts (Figure 5).

QRS-T angle

The QRS-T angle appears relatively constant regardless of age, except during days 4 to 7 and for a few older cattle (Figure 6). These older cattle could be developing pathologies.

Vector orientations

The interconnection of points referable to the same animal tends to demonstrate an age-change pattern (Figures 7 to 12). Basically this pattern involves change from horizontal to vertical orientation, although the change continues beyond the vertical. Age tends to exhibit a slight reversal of this clockwise directional tendency. One immediate observation is that points for days 4 to 7 often have unusual

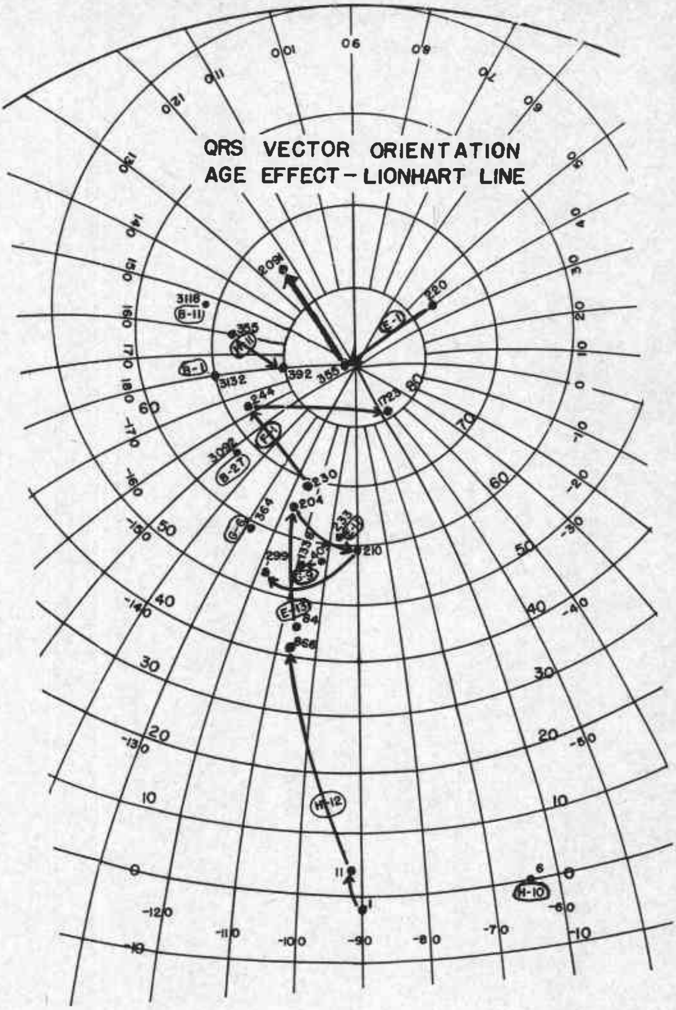

FIGURE 7

Figures 7, 9, and 11. The QRS vector orientations of Lionheart, Prince, and David calves, respectively, plotted on an oblique sterographic projection centered on 40° latitude. All QRS values appear in the upper hemisphere, the equivalent of the northern hemisphere of a geographic globe. In Figure 11, calf F-43 at 64 days of age is recorded with an extra value (–97°) obtained while the calf was lying on its right side. Calf F-52 at 95 days of age changed its stance during the recording and another record was obtained because the animal had finally assumed a normal stance. Both values are plotted.

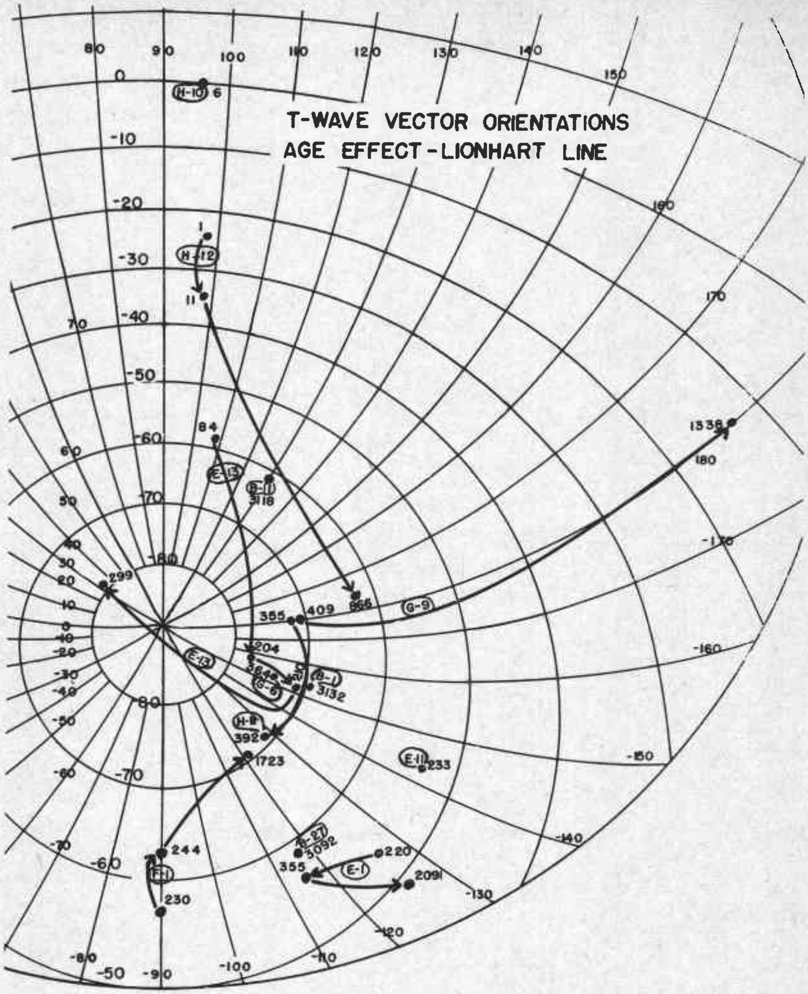

FIGURE 8

Figures 8, 10, and 12. T-wave vector orientations of Lionheart, Prince, and David calves, respectively, plotted on the lower hemisphere, the equivalent of the southern hemisphere of a globe. In Figure 12, calf F-43, at 64 days of age is plotted with an extra T-wave value obtained while it was lying on its right side. Calf F-52 at 95 days of age is plotted with an extra value obtained before the calf assumed a normal posture. The T-wave vector orientation of cow G-9 at 1,338 days of age (Dec. 1960) in Figure 8 could represent developing pathologies. This cow was born in 1957 and produced calves in 1960 and 1961. In 1962 she was culled from the herd because of vaginal prolapse.

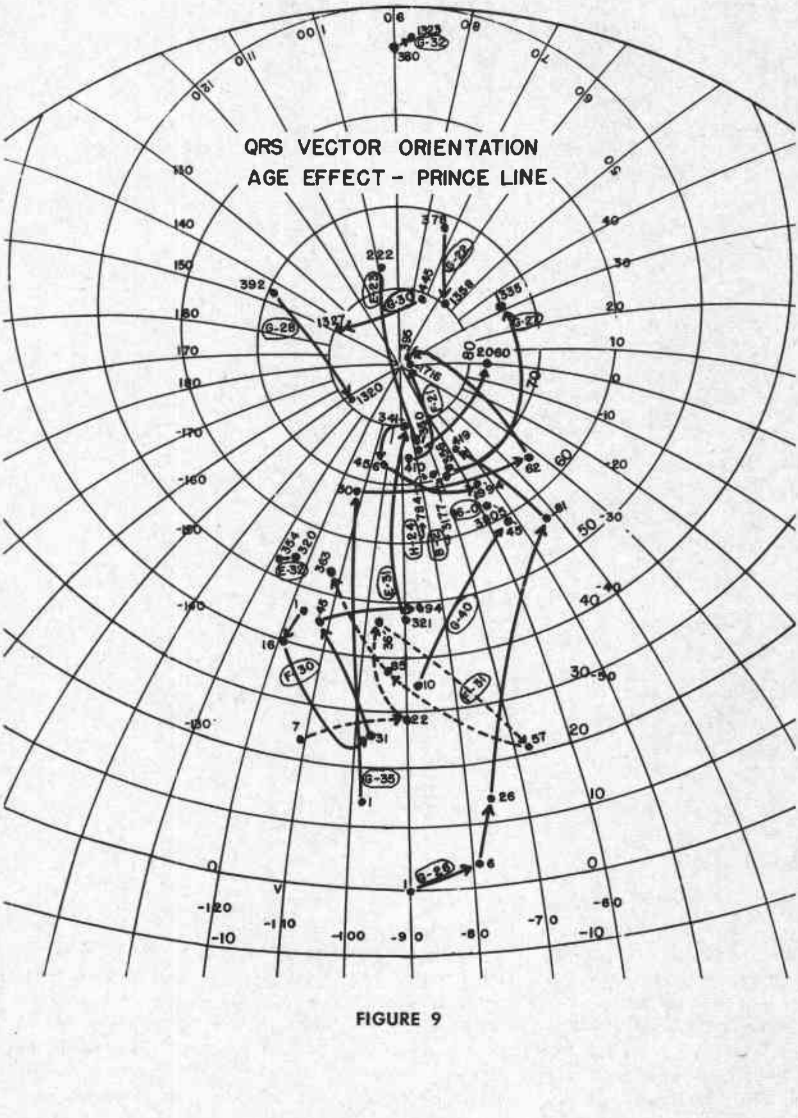

FIGURE 9

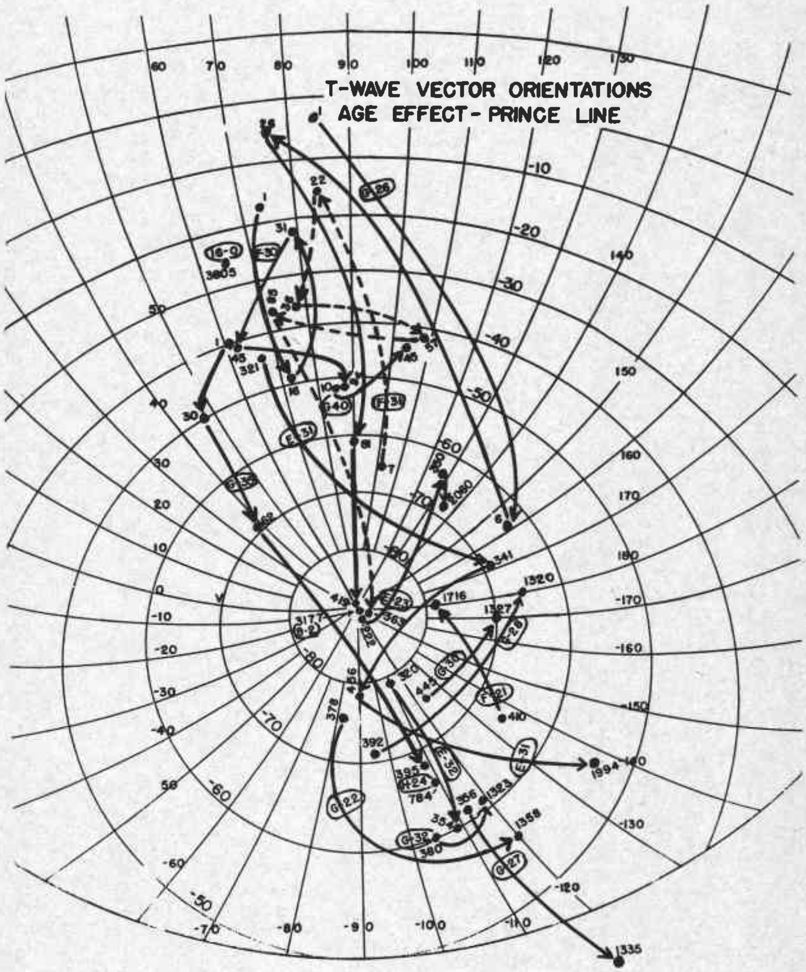

FIGURE 10

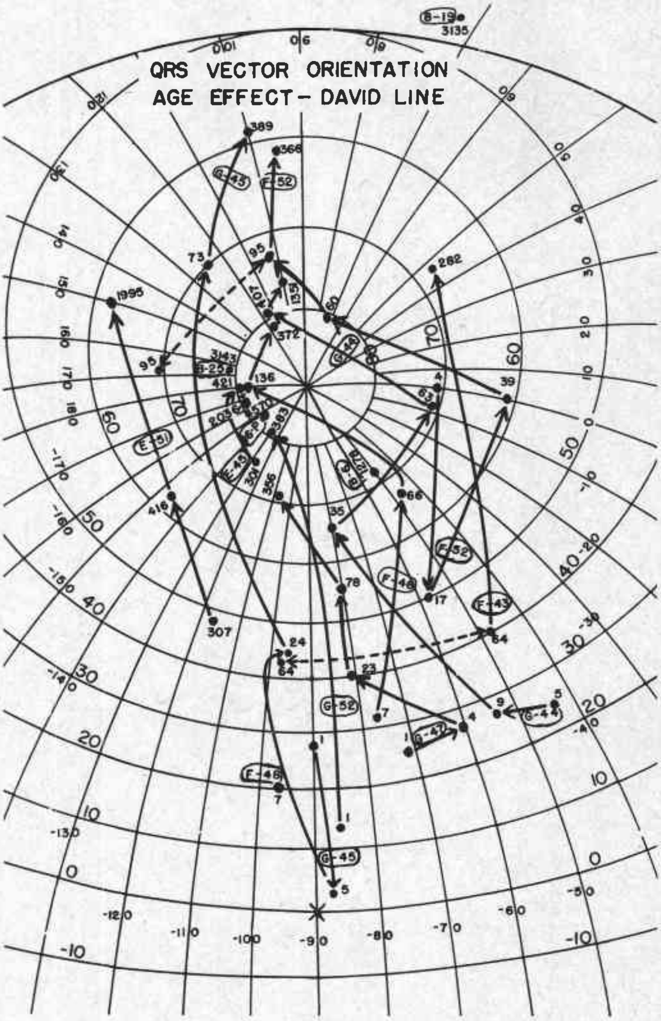

FIGURE 11

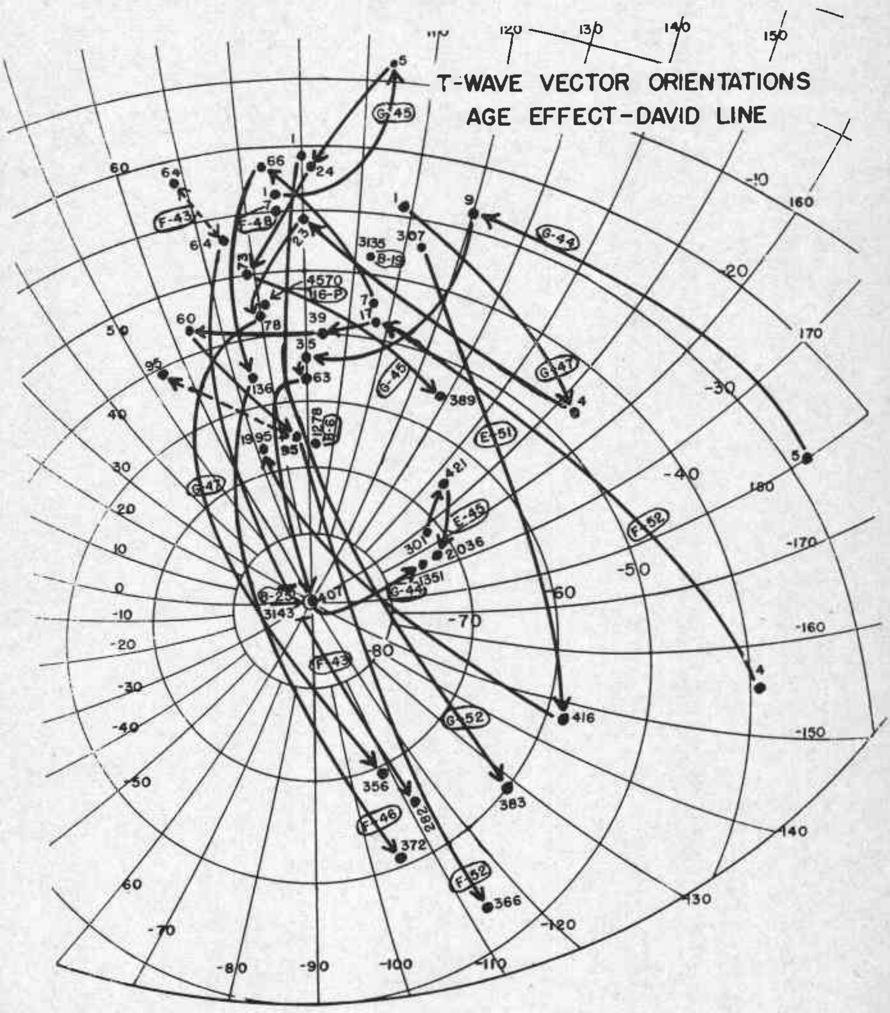

FIGURE 12

positions on the graph. One QRS point (day 4) is absent because its double loop could not be translated into a single vector value.

P-wave vector distributions, due to age or line, overlap and are not readily differentiated. All points appear within an area bounded by 20° to 110° longitude and 0 to –90° latitude.

Temperature effect

Rectal temperatures of calves less than a hundred days old appear in Figure 13 plotted against ambient temperature. At 16° C. (61° F.),

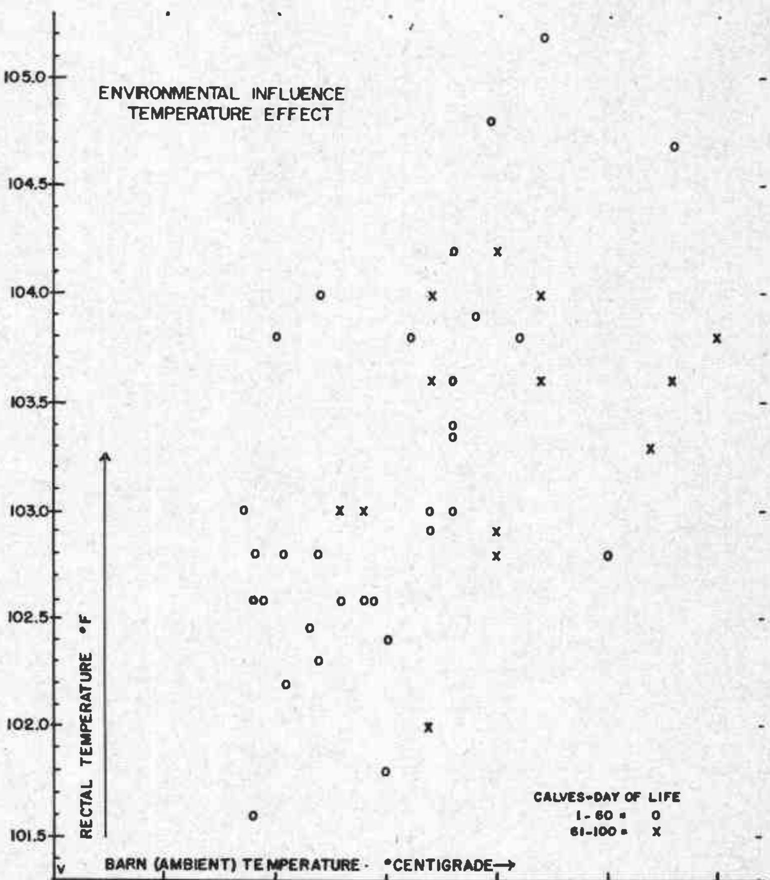

Figure 13. Rectal temperatures of calves less than 100 days of age graphed against ambient temperatures. Notice the apparent sharp break at 16° C.

there appears to be a break in the points graphed. This physiological variation observable near 60° F., has been previously observed (5) for these cattle.

Table 1 lists all records which were obtainable when the ambient temperature was above 16° C. Many of the points that do not appear to be consistently progressive in the general trend for Figures 6 to 12 will be found in this table.

Table 1. AMBIENT TEMPERATURES ABOVE 16° C. (62° F.)

EKG record no.	Animal no.	Date EKG obtained	Age	Rectal temperature	Barn temperature
				°F.	*°C.*
1. Lionheart line					
551	B-1	10/20/60	3,132	101.8	18.5
552	B-11	10/20/60	3,118	101.9	19.0
553	B-27	10/20/60	3,092	102.5	19.5
508	G-9	5/17/58	409	....	20.0
493	H-12	4/29/58	11	105.2	22.0
II. Prince line					
180	E-31	4/18/56	321	105.4	18.0
199		5/ 8/56	341	102.6	16.0
288		8/31/56	456	102.3	22.0
179	E-32	4/18/56	320	102.6	16.5
217		4/22/56	354	102.7	25.0
218	F-30	5/22/56	16	102.8	25.0
240		6/ 6/56	31	103.0	17.0
259		6/20/56	45	103.4	18.0
280		8/ 8/56	94	103.3	27.0
241	F-31	6/ 6/56	22	103.6	18.0
258		6/20/56	36	103.4	18.0
276		7/11/56	57	103.0	20.0
279		8/ 8/56	85	103.6	28.0
400		5/13/57	363	101.8	16.0
440	G-26	6/19/57	81	104.0	22.0
513		5/24/58	419	102.3	18.0
535	G-30	7/ 3/58	445	....	20.0
416	G-35	5/23/57	30	104.2	18.0
446		6/24/57	62	104.0	17.0
512		5/24/58	395	103.1	18.0
437	G-40	6/18/57	10	103.9	19.0
462		7/23/57	45	104.8	19.5
548	H-24	5/11/60	784	103.0	20.0

Table 1. (*Continued*)

EKG record no.	Animal no.	Date EKG obtained	Age	Rectal temperature	Barn temperature
				°*F.*	°*C.*
III. David line					
264	E-45	6/27/56	421	103.8	24.0
284	E-51	8/10/56	416	103.3	22.0
229	F-43	5/29/56	64	103.8	30.0
239	F-46	6/ 6/56	66	103.2	17.0
287		8/15/56	136	103.2	21.5
193	F-48	5/ 2/56	7	104.2	16.0
206	F-52	5/16/56	4	103.5	22.0
228		5/29/56	17	104.3	30.0
260		6/20/56	39	103.0	18.0
275		7/11/56	60	102.8	20.0
286		8/15/56	95	103.6	22.0
439	G-47	6/19/57	78	104.2	20.0

Discussion

Age variation in the EKG records of cattle must be understood before research projects are undertaken which utilize EKG changes as criteria for treatment effects. The data presented here shows that the EKG pattern changes rapidly in the first 60 days of the calf's life. Subsequent changes are as persistent, but they do not progress at the same rate.

The great variation to be observed during days 4 to 7 indicates changing physiological processes that need additional study. Variations due to temperature are also indicated, but cannot be proved by the limited data available.

EKG patterns representing only uniaxial recordings show great similarity, lead for lead, for most phases of this study. Indications of line differences must be studied under more uniform conditions. Vector analysis aids in detecting these differences.

The cardiac vector potential, utilizing information from 12 different leads, provides a more accurate method of analysis which also allows one to detect breed-line differences.

Vector orientations

Vector orientations indicate that such differences do occur. Lionheart QRS potentials are directed chiefly to the left of the animal, while T-wave potentials are directed to the right. Prince line QRS potentials appear centrally distributed, but T-wave potentials of both Prince and David cattle appear early to the left and later in life become predominately oriented to the right of the animal. David line QRS potentials are oriented mainly to the right for young animals, but they appear on the left side later in life. It thus becomes apparent that line differences which may appear at one stage of life will not be present at some other age.

Line differences

Data presented are not definitive for line differences. The fact that persistent indications for such differences exist in spite of the great number of variables present in this study indicates a rewarding area for future research. Variables to consider in this study include small numbers, year differences, climatic and temperature differences, inbreeding differences, feed differences, animal stance and reaction differences, and different animal handlers, as well as varied housing environments for the cattle studied.

The material presented does provide basic data which should help establish the normal parameters of bovine electrocardiograms.

Temperature effects

Indications of a critical temperature area near 60° F. for local Herefords has been reported previously (5). Figure 13 indicates that, depending on temperatures, calves experience a difference in their response to the handling necessary to obtain records. At temperatures above 16° C. the young calf cannot control body temperature as well as it can below this temperature. The high body temperature values appearing below the 16° C. line may be indications of inadequate numbers, but the vageries of fever response could also explain these points. Another explanation would consider that some animals exhibit undue excitement and protest against a halter, because one point represented a newborn animal and the other an animal haltered for the first time.

Another effect of temperature that might have influenced these data could be differences in the orientations of the QRS and T-wave vector axes. Only a few points calculated from records obtained during high temperatures present interpretation problems. The explanation is not apparent. It is possible that there is a time-relationship factor wherein a certain length of exposure time is necessary for changes to occur. This explanation does not fit all cases, and there are indications of acclimatization or recovery.

Observations concerning the age change tracts of F-31 (Figure 9) could well be a forerunner of complexities to be uncovered by extensive study. On the other hand, most nonconforming recordings will be found in Table 1—a list of records taken when temperatures were above 16° C. The complete understanding of the effect of temperature on the EKG will require studies under more controlled conditions.

Age effect trend

In spite of all these variables, an age-effect trend has been shown by these data. The newborn calf has cardiac electrical vectors which are horizontally oriented. In older cattle, vectors are more vertically oriented. The change between these two age periods is persistent and relatively consistent.

Summary

EKG recordings from day 1 to day 4,570 have been obtained from 42 Hereford cattle by means of electrocardiograms. These age samples per animal vary from one to six recordings. Thirteen figures, one table, and one sketch have been presented to illustrate the findings.

Cardiac vector orientations vary with age and often with line of breeding. A given line will often show EKG age-pattern vector orientation changes that are opposite to the changes of another line. These opposing changes mean that a definite age must be stated whenever line differences are described.

In general, horizontally oriented cardiac electrical vectors of newborn calves change with age to the more vertical orientation of older cattle.

Records obtained during days 4 to 7 of a calf's life often assume unusual configurations. Indications of induced EKG changes resulting from high environmental temperature require further study before definitive statements can be made.

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