EQUINE ELECTROCARDIOGRAPHY DURING CHLORAL HYDRATE ANESTHESIA

by

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I. INTRODUCTION

A. Introductory Statements

Electrocardiography has made rapid advances as an aid in the diagnosis of heart disease since the introduction of the string galvonometer by Einthoven in 1903. This is particularly true of human medicine where a cardiac examination is not complete without an electrocardiogram.

In veterinary medicine, however, the electrocardiograph has had only limited clinical use. The lack of development has been largely due to the high cost of the machine, the need for an experienced technician, difficulty of interpretation of the electrocardiogram, and the lack of cooperation of veterinary patients.

The construction of smaller, portable, more easily operated, low cost electrocardiographs in recent years has developed interest in its use on animals. The use of the electrocardiograph clinically in the past few years has demonstrated that cardiac diseases of animals can be diagnosed much more accurately. It would therefore seem advisable to further investigate its potential use in veterinary medicine.

In order to determine the electrocardiogram of horses under general anesthesia this study was initiated.

B. Review of Literature

The reports of the clinical use of the electrocardiograph in animals are scarce. A number of reports have come from Europe. Reports about several of the domesticated animals have been presented. The animals included are horses, mules, cattle, sheep, goats, swine, dogs and poultry. There is one report on the recording of an electrocardiogram of a whale (White 1952).

Norr (1913), Kahn (1913), and Waller (1913) all reported on the electrocardiogram of the horse. Norr (1921) recorded studies of the electrocardiogram of the cow. Alfredson and Sykes (1942) described electrocardiograms in normal dairy cattle. Platner et al (1948) reported findings in electrocardiograms of mules, horses, cattle, sheep, swine and goats. Sturkie (1949) recorded the electrocardiogram of the chicken. Lannek (1949) wrote of clinical studies on the electrocardiogram of the dog.

The electrocardiographic studies of the horse by Norr (1913) revealed that a negative T wave of low amplitude was present in 85 to 90 per cent of the horses he examined. Dukes and Batt (1941) reported favorable electrocardiograms taken in the horse using the standard limb leads. They reported that Lead II was the most satisfactory for measuring intervals.

The average duration of intervals in the electrocardiogram of the horse was reported by Dukes and Batt (1941) and Steel (1949). Steel (1949) reported on experimental work on the effects of six anesthetic agents on the electrocardiograms of horses. Sporri (1949) reported that a negative T wave or a positive T wave in all three of the standard limb leads indicated significant cardiac pathology. Lannek (1951) presented a review of the literature pertaining to electrocardiography in horses. Lannek and Rutqvist (1951) reported that a systematic grouping of horses according to age and sex was not considered necessary, however, their investigations showed an extreme variation between breeds. Their analysis recommended that breeds of cold blooded types, draft horses, should be grouped together on one hand and that breeds of warm blooded types, race horses and saddle horses, should be grouped together on the other.

The use of intravenous anesthetics in the horse has been reported often in the literature. Fowler (1940) reports that a 7 per cent solution of chloral hydrate has been generally recommended for intravenous use in the equine. He states that he has found a 12 per cent solution of chloral hydrate to be more satisfactory because less volume of solution is required. Danks (1943) recommended a combination of two parts chloral hydrate and one part magnesium sulfate as a satisfactory equine anesthetic. Coffee (1949) recommended that a combination of three parts chloral hydrate and one part magnesium sulfate be used for anesthesia in the horse. Millenbruck and Wallinga (1946) did research work on equine anesthesia and reported that a combination of chloral hydrate, magnesium sulfate and pentobarbital sodium was a safe and reliable intravenous anesthetic for horses. This combination is henceforth referred to as Millenbruck's formula.

II. METHOD OF PROCEDURE

The electrocardiographic data reported in this thesis were obtained from six horses. These horses were of warm blooded types. The breeds included were Standardbred, American Saddle Horse, and Arabian. These horses were determined to have normal hearts by means of auscultation of the heart, examination of electrocardiograms taken in the standing position using the standard limb leads, and subsequent gross examination of the heart at autopsy.

Electrocardiograms were taken of each horse in the standing position, right lateral recumbency, and left lateral recumbency prior to each anesthesia. During anesthesia electrocardiograms of each horse were taken in the right and left lateral recumbent positions. On the day following anesthesia of each animal, electrocardiograms were recorded again in the same manner as before anesthesia.

During the course of the experiment the horses were housed in box stalls at the Iowa State College Veterinary Clinic. The horses were fed hay and grain of good quality twice each day and water was available to them at all times.

A. Auscultation of the Heart

Prior to the selection of the animal for the experiment, the heart was examined by means of the stethoscope. The horses were examined in their stalls in order not to excite them by changing their surroundings. The animals were approached quietly from the left side. The chest piece of the stethoscope was placed on the thorax over the intercostal space between the fourth and fifth ribs medial to the elbow. After placing the chest piece in position, several minutes were allowed to elapse before checking for abnormal sounds. The heart was examined for even intensity of heart sounds with normal volume, regularity of rhythm, and the absence of abnormal or extra sounds associated with the heart beat. Only animals fulfilling these qualifications were accepted.

B. Recording the Electrocardiogram

Electrocardiograms were taken of the normal animals in the standing position and with the animals in both the right and left lateral recumbent positions. The non-anesthetized animals were restrained in the lateral recumbent positions by placing them on a large animal operating table and strapping them in place.

A "Sanborn Instomatic Cardiette" was used to record all of the heart tracings. This is a portable amplifying type of electrocardiograph that records on photographic paper.

Metal electrodes were placed on the medial side of the front legs midway between the carpus and the elbow and on the medial side of the hind legs midway between the hock and the stifle. This position of the electrodes was used so that motion of the horse did not entangle the lead wires nor disturb the contact of the electrodes. Before selecting this site for the electrodes, electrocardiograms were taken of several horses with the electrodes placed at various positions on the legs. Examination of these electrocardiograms showed that the position of the electrodes had no effect on the tracing. (See Fig. 1.). Prior to the positioning of the electrodes the hair was clipped and a sodium chloride jelly was rubbed into the skin in order to insure good contact of the electrodes.

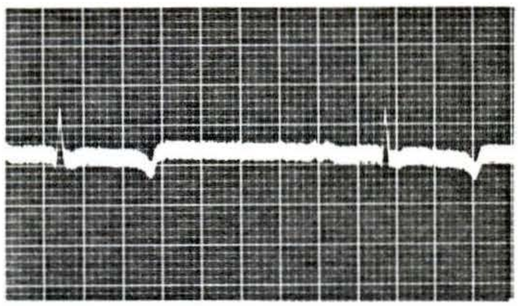
The electrocardiograph was standardized for each lead according to the international "sensitivity" standard so that one centimeter of vertical deflection on the electrocardiogram equaled one millivolt of electrical potential. Tracings were taken eighteen inches long for each lead. Only the standard limb leads were used. These leads were:

Lead I	Right foreleg and left foreleg
Lead II	Right foreleg and left hindleg
Lead III	Left foreleg and left hindleg
Ground Electrode	Right hindleg

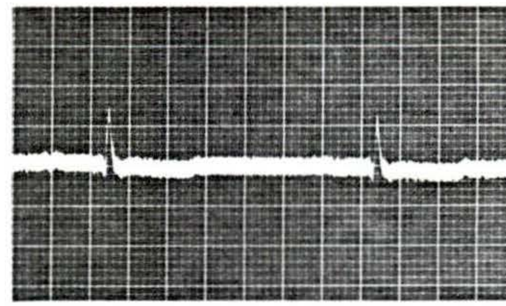
Fig. 1. Normal Equine Electrocardiogram Standing Position

Leads 1A, 2A, and 3A were taken with the electrodes placed midway between elbow and carpus on the fore-legs and midway between stifle and hock on the hind-legs.

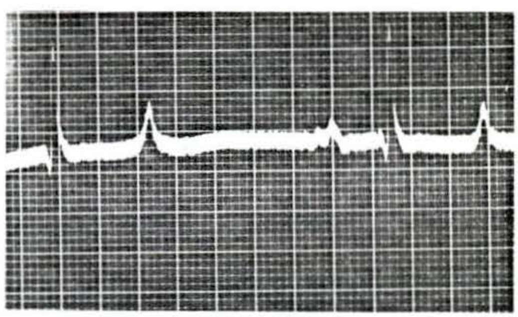
Leads 1B, 2B, and 3B were taken with the electrodes placed midway between carpus and fetlock on the forelegs and midway between hock and fetlock on the hindlegs.



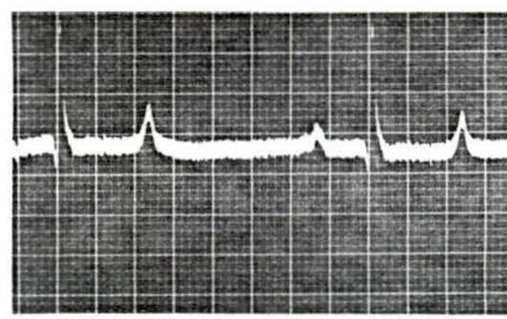
Lead 1-A



Lead 1-B



Lead 2-A



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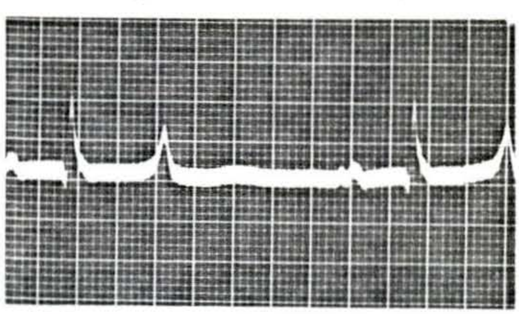
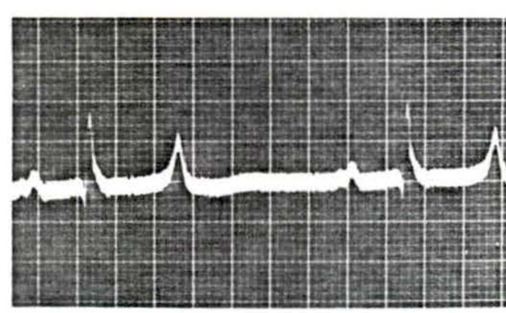


Lead 3-A



Lead 3-B

Electrocardiograms of the anesthetized horses were taken in the stall after the animals had been in surgical anesthesia for five minutes. The recordings were taken with the animal first lying on one side. The lead wires were detached and the animals were rolled over gently. The lead wires were then attached and the recordings were taken with the animals lying on the opposite side.

C. Processing the Electrocardiogram

All of the electrocardiograms were developed using "Kodak X-ray Developer" and "Kodak X-ray Fixer". The photographic paper was developed at 74°F for two minutes, washed in water, and placed in the fixer for fifteen minutes at 74°F. After fixing, the record was washed in cold running water for firty-five minutes. The records were then placed on a chrome ferro-type plate for drying. After drying the records were placed in permanent electrocardiogram holders.

D. Measuring of Intervals and Potentials

The electrocardiograms were examined by placing them under a "Dazor Electric Magnifier". With this magnification reasonably accurate measurements could be obtained. Measurements were taken from three different placed in each lead and the average of the three lead measurements was recorded.

The amplitudes of the wave forms have been recorded in millivolts. With standardization of the electrocardiograph a vertical deflection of 1 centimeter is equal to 1 millivolt of potential. The horizontal lines on the electrocardiogram are 1 millimeter apart and represent 0.1 millivolt of potential. The potentials were recorded for the P, Q, R, S, and T waves in all three leads from all of the tracings.

At times the QRS complex contains additional waves other than Q, R, and S, and these waves are designated with a prime mark (R'). The upright waves are R', R'', etc. The downward waves are S', S'', etc.

In the discussion of wave forms a wave letter designated with a sub-number (T_1) has reference to the lead of the electrocardiogram in which that particular wave occurs. For example:

The T wave in Lead I is T_1

The T wave in Lead II is T_2

When referring to waves in more than one lead, two sub-numbers are used (T_{1-2}) thereby indicating the T wave in Leads I and II.

The electrocardiogram time intervals have been recorded in seconds. The vertical lines on the electrocardiogram are spaced .04 second apart. The PR, QRS, QT and ST intervals have been recorded. These intervals were recorded from Lead II exclusively. All of the measurements are in accordance with the procedures recommended by Lannek and Rutqvist (1951) and numerous other recognized authors : Burch and Winsor (1949), Carter (1945), Katz and Johnson (1944), Barnes (1940), Katz (1941) and Pardee (1941). The electrocardiographic nomenclature used in this thesis is recommended by the American Heart Association (1943). The principles applied in measuring are indicated in Fig. 2. The average measurements for time intervals and wave potentials are found in tables 1, 2, 3, 4, 5, 6, 7, 8, and 9.

E. Administration of Anesthetics

The horses were anesthetized in the stalls. Anesthesia was accomplished by using a gravity flow intravenous unit attached to a 16 gauge needle that had previously been inserted into the jugular vein. All of the anesthetics were given at a rate of 100 cc each 1 minute and 20 seconds. The anesthesia was given to effect. Surgical anesthesia was considered to be the second plane of the third stage as described by Fowler (1940). This plane and stage of anesthesia was characterized by the absence of the palpebral reflex, the cessation of nystagmus, and a diminished corneal reflex. All animals made

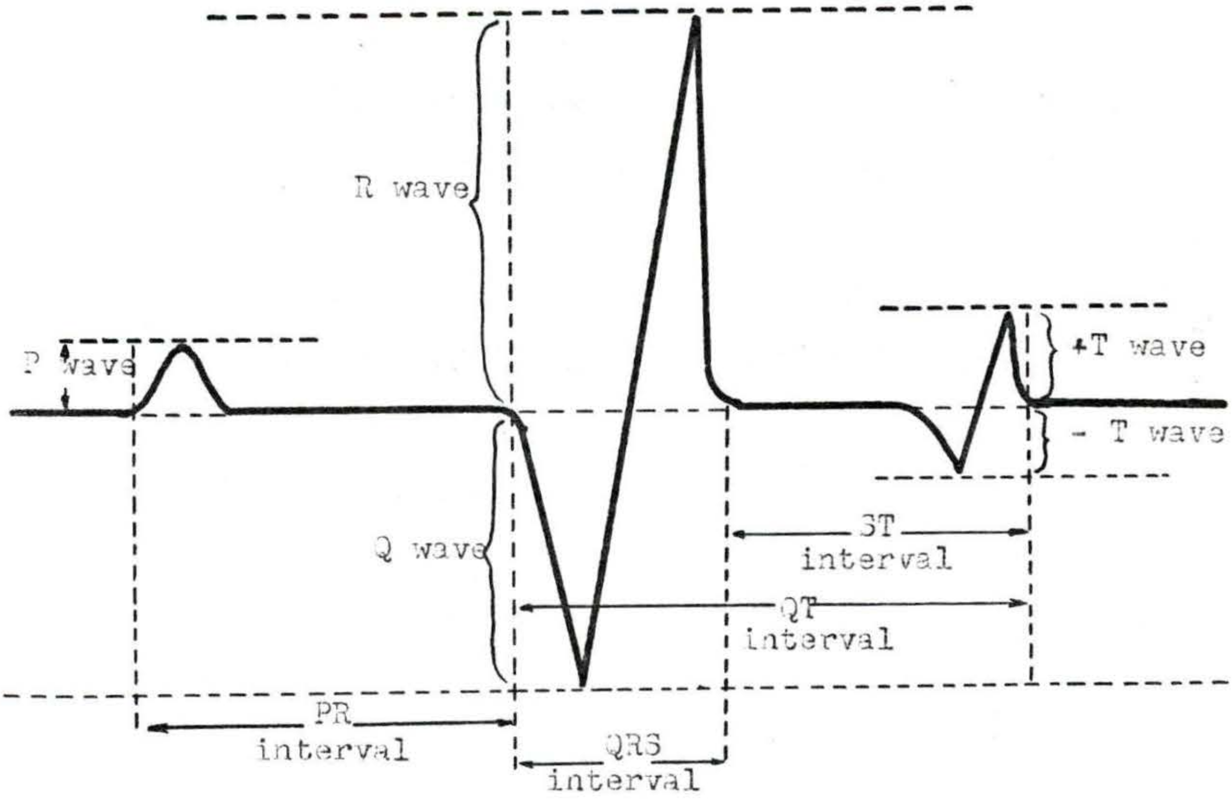


Fig. 2. The Principles Applied in Measuring Are Indicated in This Figure[a]

[a]Adapted from Lannek, N. and Rutqvist, L. Normal area of variations for the electrocardiogram of horses. Nord.Vet.Med. 3: 1094. 1951.

uneventful recoveries from anesthesia except when they were destroyed for autopsy at the conclusion of the work.

Representative electrocardiograms of the recumbent animals under anesthesia with the anesthetics as considered in the discussion are shown in Figs. 4, 5, 6, 7, 8, and 9.

The anesthetics used in this work are as follows: 7 per cent chloral hydrate, 12 per cent chloral hydrate, 12 per cent chloral hydrate and 6 per cent magnesium sulfate as recommended by Danks (1943) and henceforth referred to in this thesis as Dank's formula, 9 per cent chloral hydrate and 3 per cent magnesium sulfate as recommended by Coffee (1949) and henceforth referred to as Coffee's formula, and 3 per cent chloral hydrate, 1.5 per cent magnesium sulfate and 0.66 per cent pentobarbital sodium as recommended by Millenbruck and Wallinga (1946) and henceforth referred to as Millenbruck's formula.

All of the anesthetics were prepared in 500 cc volumes.

III. RESULTS

Tables 1, 2, and 3 give measurements for time intervals and wave potentials in the electrocardiograms of the normal animals in the standing and right and left lateral recumbent positions. Tables 4, 5, 6, 7, 8 and 9 give measurements for time intervals and wave potentials in the anesthetized animals. The average duration and range of the time intervals in Lead II have been recorded in the above mentioned tables. Only the range of the wave potentials has been recorded. These measurements of wave potential are recorded for all three leads. The numerous figures dealing with four time intervals and six wave potentials from three different leads have made it impractical to list all of the changes. The reader can refer to the tables for this information.

Figure 3 is a representative electrocardiogram of a horse in the standing position. Figures 4, 5, and 6 are electrocardiograms of the same horse in right lateral recumbency for Leads I, II, and III respectively. All electrocardiograms labeled A are of the horse without anesthesia. All electrocardiograms labeled B are of the horse during chloral hydrate anesthesia. All electrocardiograms labeled C are of the horse during anesthesia with Millenbruck's formula. All electrocardiograms labeled D are of the horse during anesthesia with Dank's formula.

Figures 7, 8, and 9 are of the same horse in left lateral recumbency for Leads I, II, and III respectively as described above.

Recumbency of the animals without anesthesia produced variable changes in the duration of the normal electrocardiogram time intervals of standing horses. The PR and QRS intervals remained reasonably constant. The QT and ST intervals were shortened in most instances. See Tables 1, 2, and 3. When the animals were lying in right lateral recumbancy the wave forms made changes in direction and amplitude in Leads II and III (Figs. 5A and 6A) as compared to the standing animals (Fig. 3). The changes in wave form and amplitude in Lead I were insignificant (Fig. 4A). When the horses were lying in left lateral recumbency the wave forms and amplitudes made definite changes in all three leads (Figs. 7A, 8A, and 9A) as compared to the standing animals (Fig. 4A).

Chloral hydrate injected intravenously in 7 per cent and 12 per cent concentrations in sterile distilled water produced identical changes in the electrocardiograms of the same animals. The only difference noted was that a greater volume of anesthetic was needed to produce surgical anesthesia when the lesser concentration was employed. The data recorded for chloral hydrate has been presented together as one anesthetic agent, chloral hydrate.

Dank's Formula and Coffee's Formula produced such similar results that the data obtained have been presented collectively as one anesthetic agent. These two anesthetics are henceforth referred to as Dank's formula.

The results noted from the use of anesthetics have been presented in this thesis by listing the effects in each lead of the electrocardiogram, first for right lateral recumbency and second for left lateral recumbency. The variations noted during anesthesia will be presented separately by leads as variations from the electrocardiograms of non-anesthetized horses in the recumbent position. Variations in wave forms and amplitudes have been recorded for all leads. Variations in time intervals have been recorded from Lead II exclusively.

With the horses in right lateral recumbency under chloral hydrate anesthesia the following wave variations were noted in Lead I. The P wave became inverted, diphasic, or W shaped. The P wave was present in all cases. A Q wave of low amplitude appeared in some cases. There was little change in the R wave. The T wave tended to become diphasic in most cases. Millenbruck's formula produced little or no change in the P wave. The R wave was depressed in amplitude in some cases and increased in amplitude in others but only slightly. An S wave of low amplitude appeared in most cases. The T wave became diphasic in most cases. Dank's formula caused the P wave to become diphasic or W shaped in most cases. The R wave decreased in amplitude in all cases. An S wave appeared in all cases and a few times a bizarre QRS complex was seen. The T wave became diphasic in all cases.

During chloral hydrate anesthesia the following wave variations were noted in Lead II right lateral recumbency. The P wave became W shaped, diphasic or increased in amplitude. The major portion of the QRS complex reversed its direction. The T wave was consistently diphasic and increased in amplitude. The average durations of the PR intervals were shortened, the QRS intervals remained constant, and the durations of QT and ST were increased. The average heart rate was increased slightly over the standing horse but decreased greatly as compared to the recumbent animal.

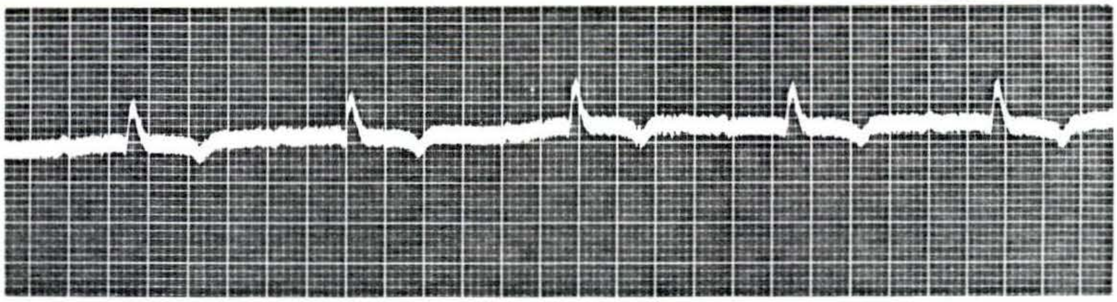
Millenbruck's formula caused the P wave in Lead II to be diphasic in some cases and increased in amplitude in others. The QRS complex was altered very little. The T wave was diphasic in most cases. The average durations of all of the time intervals were increased. The heart rate compared to that of chloral hydrate. Dank's formula produced wave changes similar to those produced by Millenbruck's formula. The heart rate compared to that of chloral hydrate. In Lead III, right lateral recumbency, chloral hydrate increased the amplitude of the P wave in most cases. Some diphasic and W shaped P waves were present.

The QRS complex was similar to that seen in Lead II. A positive T wave of increased amplitude was found in all cases in Lead III. Dank's formula caused a diphasic P wave in most cases. The QRS complex was not altered appreciably. The T wave was upright and of increased amplitude in all cases.

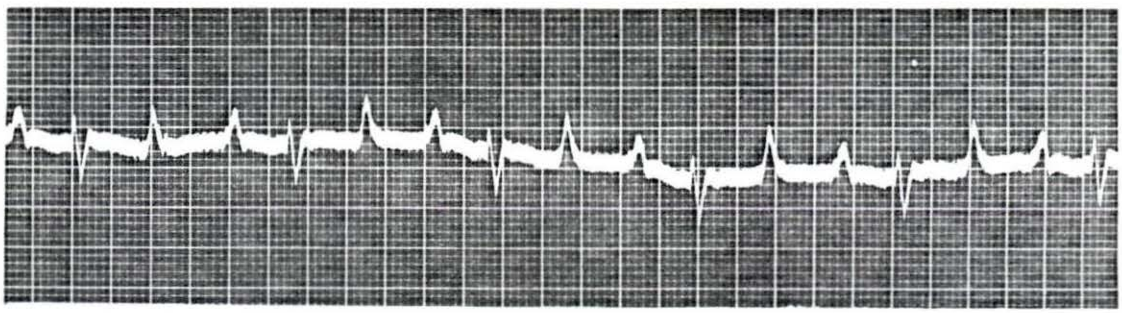
With the animals lying in left lateral recumbency chloral hydrate anesthesia caused a double P wave in some cases and increased the amplitude slightly in others in Lead I. The RS wave of the non-anesthetized animals became an R wave in some cases or a QS wave in others. An upright T wave was present in most cases. Millenbruck's formula did not alter the P wave to any degree in Lead I. The RS wave of the non anesthetized animal became a bizarre QRS complex in almost all instances. The T wave was not changed appreciably. Dank's formula caused little change in the P wave. The RS wave of the non anesthetized horses became a bizarre QRS complex in some cases, an R wave in others and was not changed in others. The T wave tended to be upright and of increased amplitude in most cases. The Lead II electrocardiogram, left lateral recumbency, during chloral hydrate anesthesia showed the following variations: The P wave was upright in all cases. A double P wave was present part of the time. The QRS complex was altered in every case. In some instances the waves were reversed, in some the amplitudes increased, and in others the amplitudes decreased. In four animals an R' wave appeared. The T wave was not changed appreciably. The average durations of the PR and QRS intervals were not changed. The QT and ST intervals were increased. The heart rate was increased an average of ten beats per minute over the standing horses. The heart rate was decreased when compared to the recumbent non-anesthetized animals. In Lead II, left lateral recumbency, Millenbruck's formula did not alter the P wave to any degree. The QRS complex of the non-anesthetized horses became an R wave or an RS wave in all cases. An upright T wave of moderate amplitude was found in all cases. The average duration of all of the intervals with the exception of the QRS interval were increased. Dank's formula caused a diphasic T wave in some cases. The QRS complex was not markedly changed. The T wave was upright and of moderate amplitude in all cases. The heart rate was slightly accelerated over that of the standing animals. In Lead III, left lateral recumbency, chloral hydrate tended to increase the amplitude of the P wave. The QRS complex was changed in direction and amplitude in most cases. The T wave was not altered appreciably. Millenbruck's formula increased the amplitude of the P wave. The QS wave and QRS complex of the non-anesthetized horses became an R wave or an RS wave in the anesthetized animals. An upright T wave of moderate amplitude was present in most cases. Dank's formula caused increased amplitude of the P wave. Only minor changes were seen in the QRS complex. The T wave was decreased in amplitude in most instances and diphasic in the others.

Fig. 3 Normal Equine Electrocardiogram Standing Position

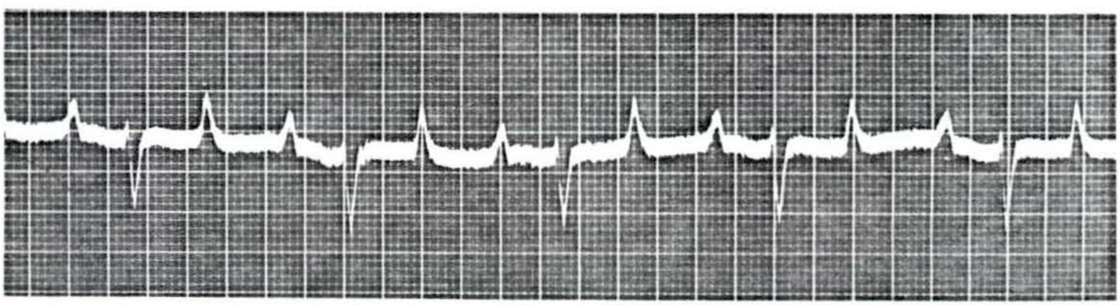
All of the tracings in Figs. 3, 4, 5, 6, 7, 8, and 9 are from the same horse.



Lead 1



Lead 2



Lead 3

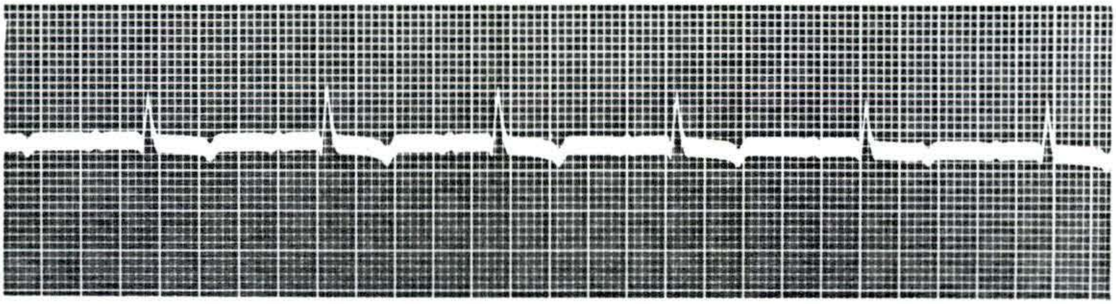
Fig. 4 Equine Electrocardiogram Lead I Right Lateral Recumbency

A. Tracing from a non-anesthetized horse

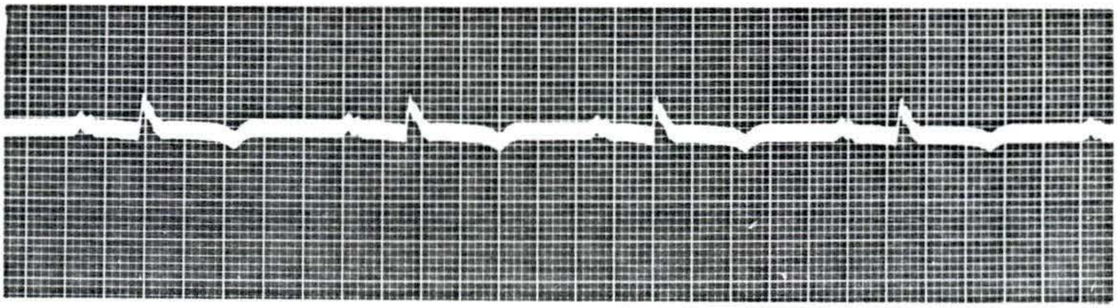
B. Tracing from the same horse during chloral hydrate anesthesia

C. Tracing from the same horse anesthetized with Millenbruck's formula

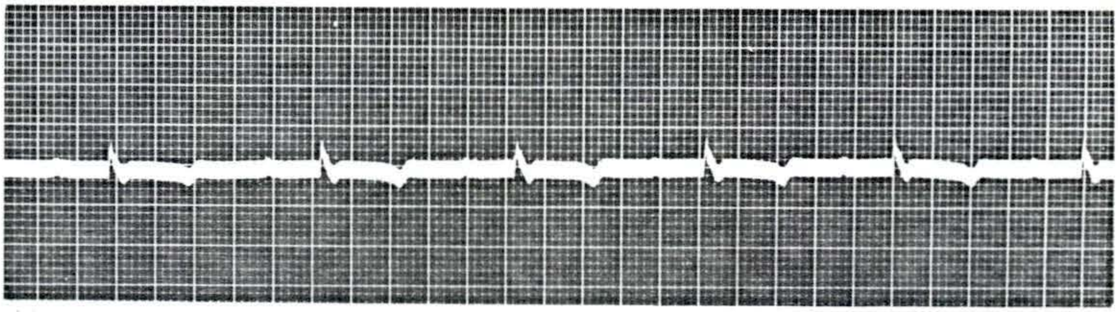
D. Tracing from the same horse anesthetized with Dank's formula



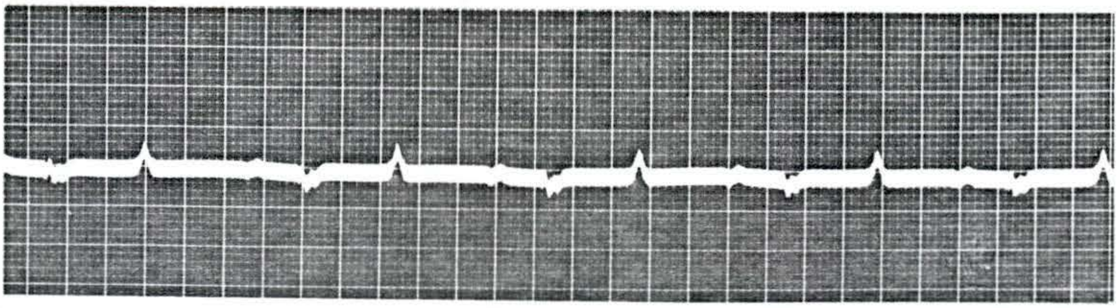
Lead 1-A



Lead 1-B



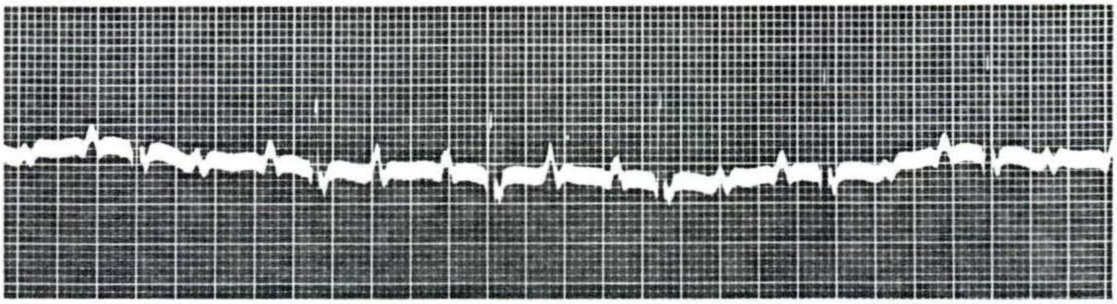
Lead 1-C



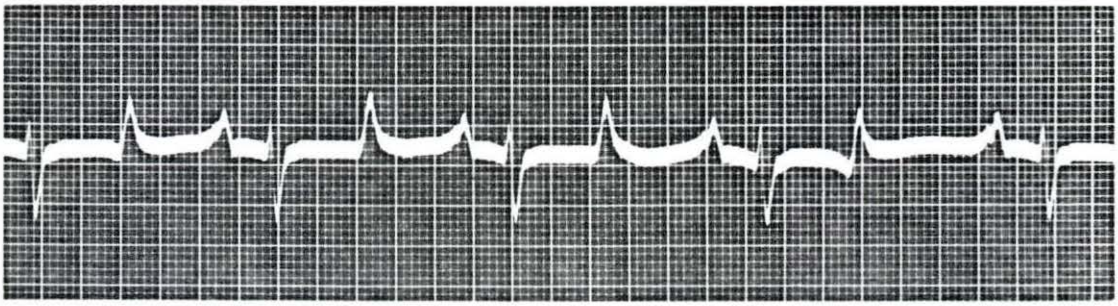
Lead 1-D

Fig. 5 Equine Electrocardiogram Lead II Right Lateral Recumbency

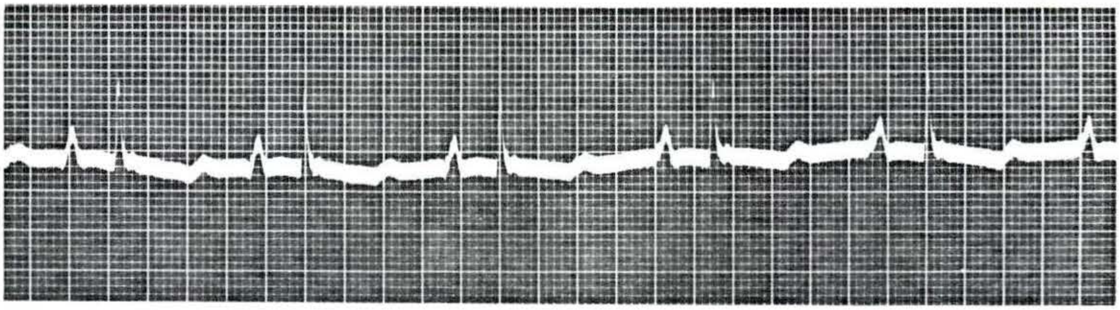
A. Tracing from a non-anesthetized horse
B. Tracing from the same horse during chloral hydrate anesthesia
C. Tracing from the same horse anesthetized with Millenbruck's formula
D. Tracing from the same horse anesthetized with Dank's formula



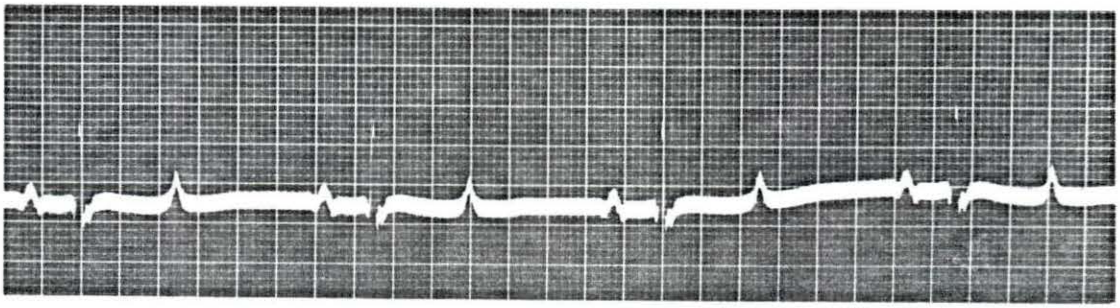
Lead 2-A



Lead 2-B



Lead 2-C



Lead 2-D

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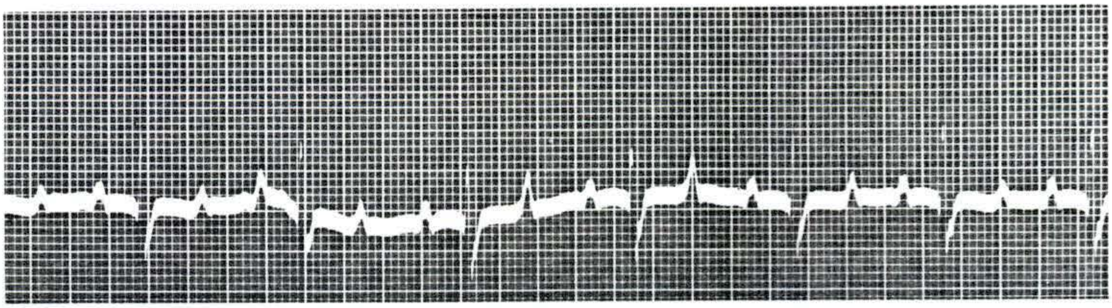
Fig. 6 Equine Electrocardiogram Lead III Right Lateral Recumbency

A. Tracing from a non-anesthetized horse

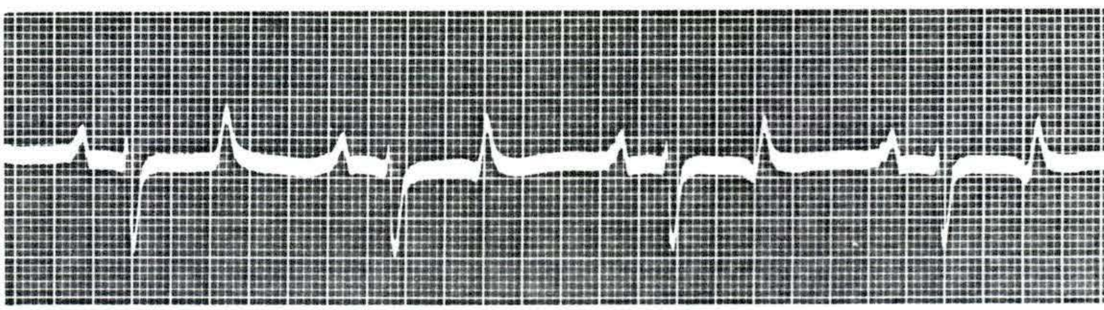
B. Tracing from the same horse during chloral hydrate anesthesia

C. Tracing from the same horse anesthetized with Millenbruck's formula

D. Tracing from the same horse anesthetized with Dank's formula



Lead 3-A



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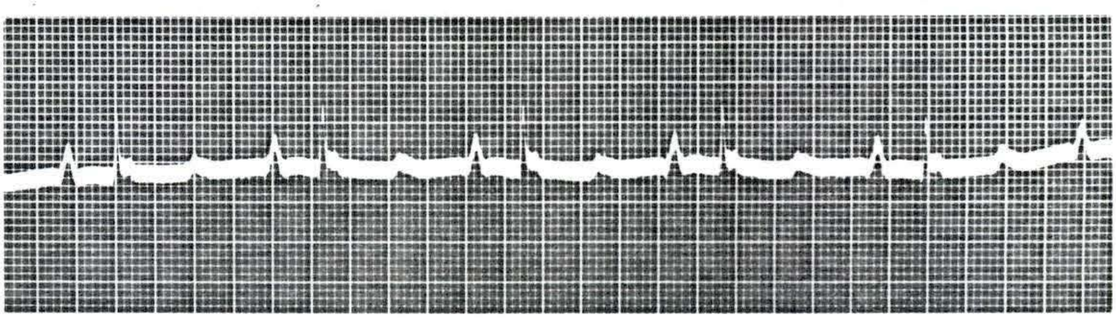
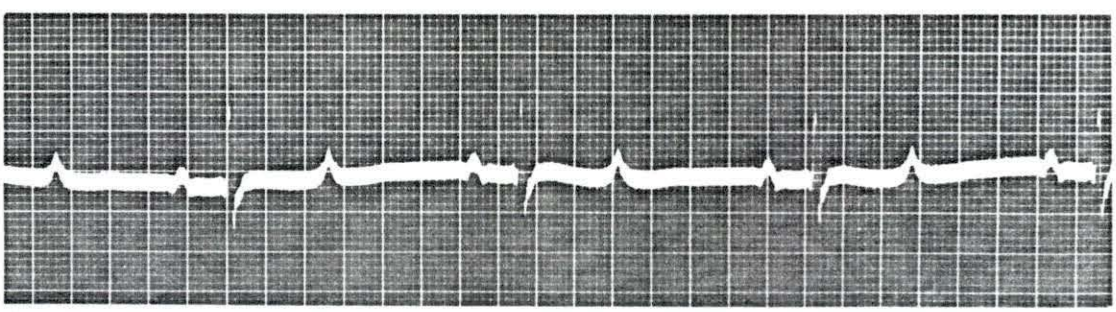


Lead 3-C



Lead 3-D

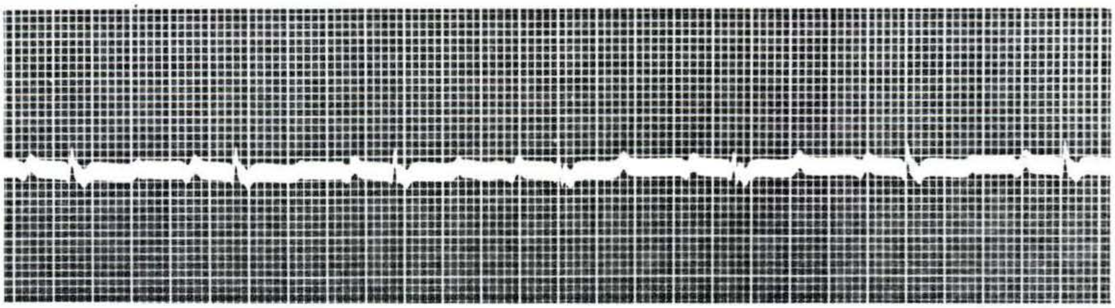
Fig. 7 Equine Electrocardiogram Lead I Left Lateral Recumbency

A. Tracing from a non-anesthetized horse

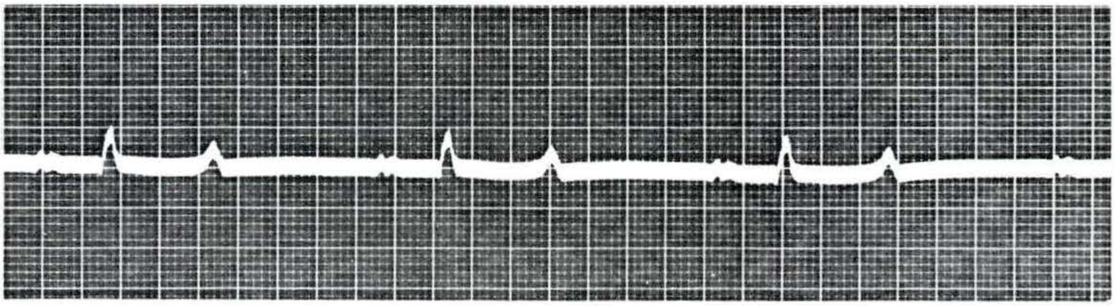
B. Tracing from the same horse during chloral hydrate anesthesia

C. Tracing from the same horse anesthetized with Millenbruck's formula

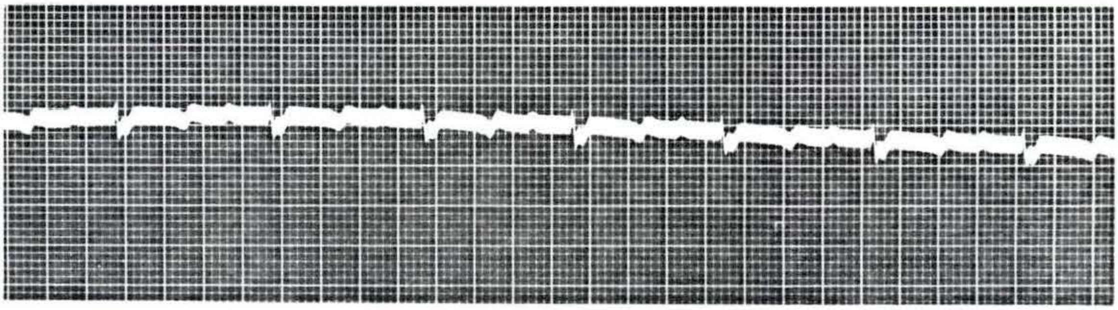
D. Tracing from the same horse anesthetized with Dank's formula



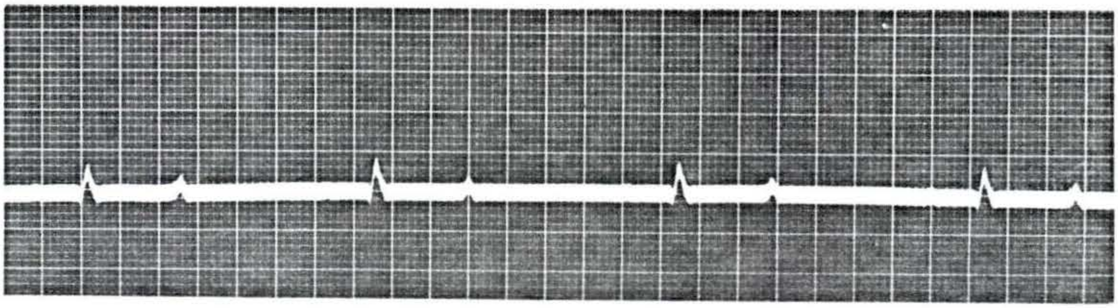
Lead 1-A



Lead 1-B



Lead 1-C



Lead 1-D

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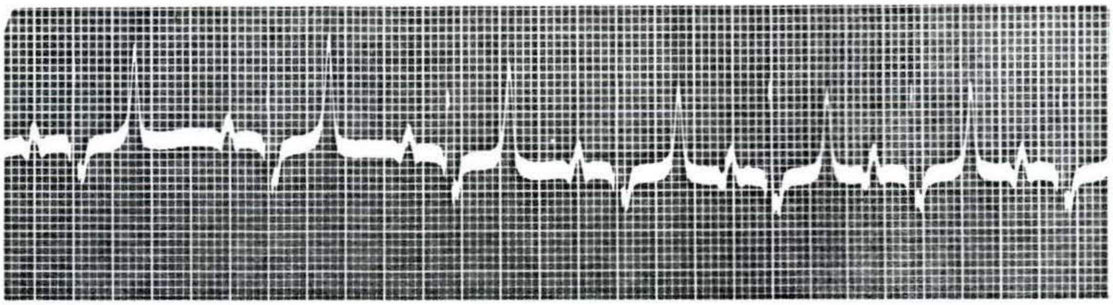
Fig. 8 Equine Electrocardiogram Lead II Left Lateral Recumbency

A. Tracing from a non-anesthetized horse

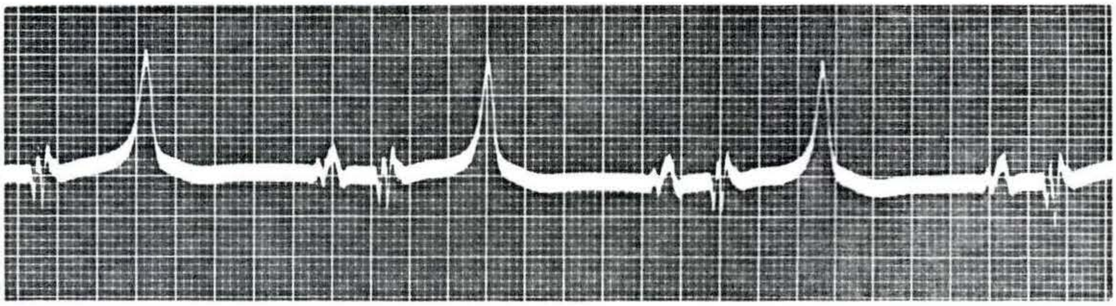
B. Tracing from the same horse during chloral hydrate anesthesia

C. Tracing from the same horse anesthetized with Millenbruck's formula

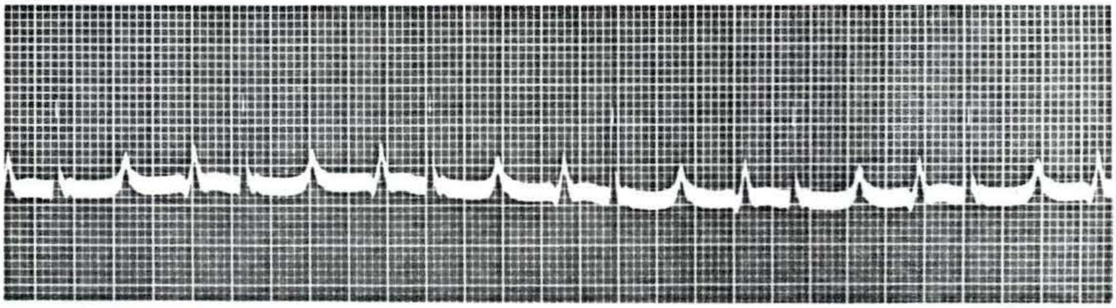
D. Tracing from the same horse anesthetized with Dank's formula



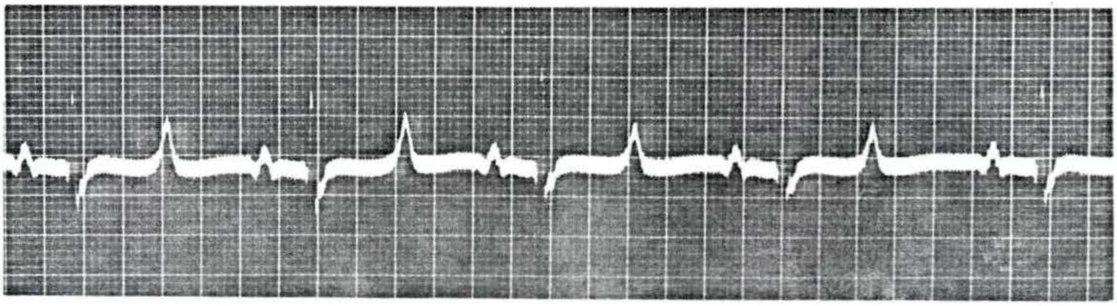
Lead 2-A



Lead 2-B



Lead 2-C



Lead 2-D

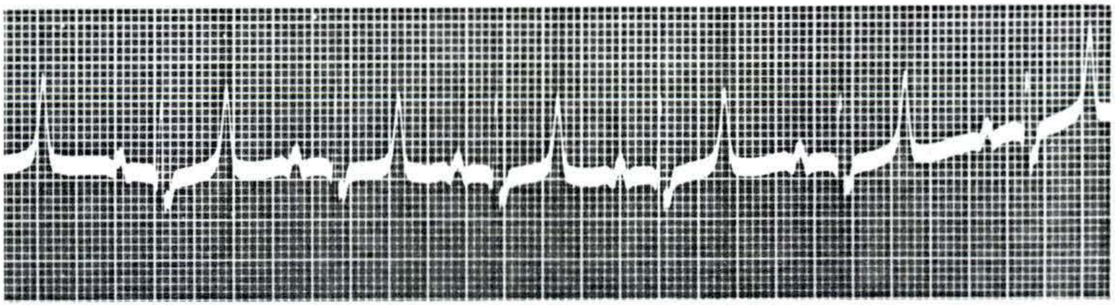
Fig. 9 Equine Electrocardiogram Lead III Left Lateral Recumbency

A. Tracing from a non-anesthetized horse

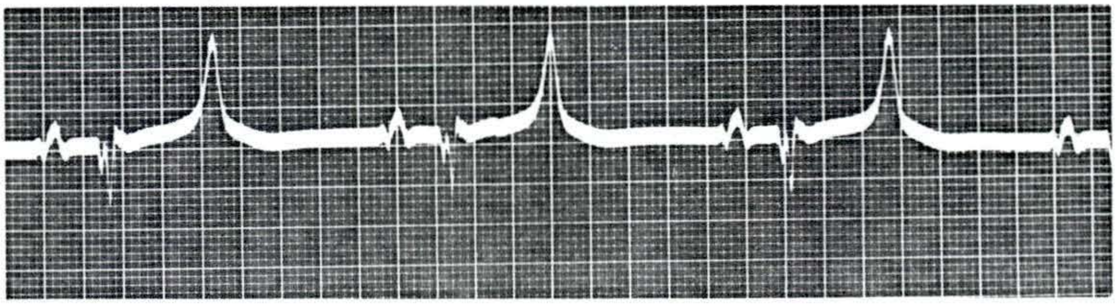
B. Tracing from the same horse during chloral hydrate anesthesia

C. Tracing from the same horse anesthetized with Millenbruck's formula

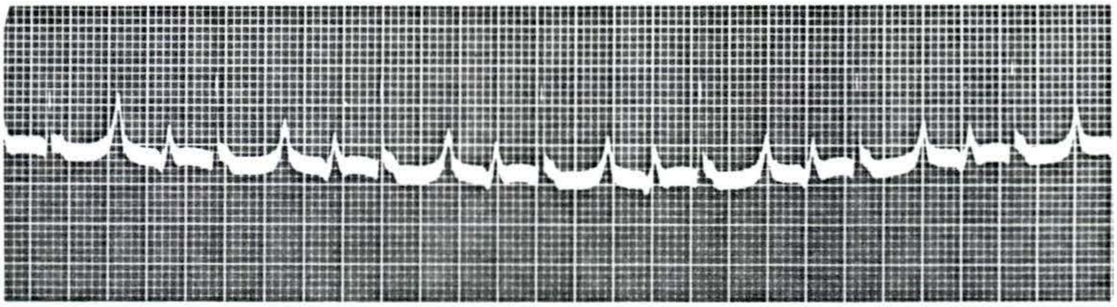
D. Tracing from the same horse anesthetized with Dank's formula



Lead 3-A



Lead 3-B



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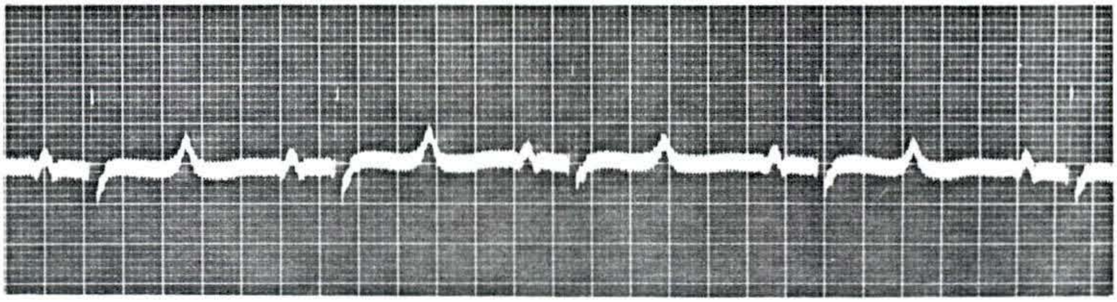

Lead 3-D

Table I. Normal Electrocardiogram Intervals and Amplitudes with Their Range (Equine)

Standing Position

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.26	.22 to .38
QRS	.08	.06 to .12
QT	.45	.38 to .50
ST	.37	.28 to .42

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	0 to .1	.15 to .3	.15 to .3
Q	0 to .1	0 to .8	0 to 0
R	.2 to .45	.2 to 2.0	.15 to .5
S	0 to 0	.2 to .5	.35 to .8
QS	0 to 0	0 to 1.3	0 to 0
T	-.2 to .1	-.6 to .7	-.35 to .7

Heart Rate

	Average	Range
Rate/min.	48	42 to 56

Table II. Normal Electrocardiogram Intervals and Amplitudes with Their Ranges (Equine)

Right Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.27	.22 to .28
QRS	.09	.06 to .11
QT	.40	.38 to .44
ST	.31	.29 to .36

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	0 to .05	.15 to .2	.15 to .2
Q	0 to 0	.1 to .15	0 to .1
R	.4 to .6	.15 to 1.0	.3 to .75
S	0 to 0	.2 to .5	.2 to .6
QS	0 to 0	0 to 0	0 to 0
T	-.05 to -.15	-.3 to .4	-.25 to .2

Heart Rate

	Average	Range
Rate/min.	61	44 to 80

Table III. Normal Electrocardiogram Intervals and Amplitudes with Their Ranges (Equine)

Left Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.25	.22 to .28
QRS	.09	.06 to .12
QT	.41	.38 to .48
ST	.32	.26 to .38

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	-.05 to .15	.2 to .4	.15 to .2
Q	0 to 0	0 to .1	0 to .1
R	.1 to .5	0 to 2.2	.25 to .9
S	0 to .1	0 to .5	.25 to .6
QS	0 to 0	0 to 1.1	0 to 0
T	-.15 to .15	-.2 to 1.0	-.05 to 1.1

Heart Rate

	Average	Range
Rate/min.	62	45 to 85

Table IV. Electrocardiogram Intervals and Amplitudes
with Their Ranges
during Chloral Hydrate Anesthesia (Equine)
Right Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.24	.20 to .28
QRS	.09	.06 to .10
QT	.47	.36 to .54
ST	.38	.30 to .44

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	-.05 to .1	-.05 to .4	-.05 to .25
Q	0 to .1	0 to .25	0 to .15
R	.35 to .6	.1 to 1.8	0 to 1.2
S	0 to 0	.2 to .7	0 to 1.0
QS	0 to 0	0 to 0	0 to .45
T	-.2 to .2	-.05 to .7	.2 to .6

Heart Rate

	Average	Range
Rate/min.	52	27 to 72

Table V. Electrocardiogram Intervals and Amplitudes

with Their Ranges

during Chloral Hydrate Anesthesia (Equine)

Left Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in Secs.	Range in Secs.
PR	.26	.20 to .30
QRS	.09	.06 to .12
QT	.48	.36 to .60
ST	.39	.30 to .48

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	.05 to .2	.1 to .4	.1 to .4
Q	0 to 0	0 to .2	0 to .75
R	0 to .6	.1 to 1.6	0 to 1.2
S	0 to 0	0 to .6	0 to .6
R^1	0 to 0	0 to .3	0 to 0
QS	0 to .2	0 to 0	0 to .6
T	-.1 to .2	-.2 to 1.3	-.1 to .9

Heart Rate

	Average	Range
Rate/min	58	34 to 80

Table VI. Electrocardiogram Intervals and Amplitudes
with Their Ranges
during Chloral Hydrate-Magnesium Sulfate Anesthesia
(Equine)

Right Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.25	.22 to .28
QRS	.09	.06 to .10
QT	.49	.36 to .58
ST	.40	.27 to .48

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	-.05 to .05	-.05 to .3	-.05 to .25
Q	0 to .05	0 to .1	0 to 0
R	.05 to .55	0 to 1.0	.1 to .8
S	0 to 0	0 to .3	.4 to .9
QS	0 to 0	0 to 1.8	0 to 0
T	-.1 to .1	-.3 to .3	.2 to .4

Heart Rate

	Average	Range
Rate/min.	54	38 to 88

Table VII. Electrocardiogram Intervals and Amplitudes

with Their Ranges

during Chloral Hydrate-Magnesium Sulfate Anesthesia (Equine)

Left Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.26	.20 to .28
QRS	.09	.06 to .10
QT	.49	.32 to .56
ST	.40	.23 to .46

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	-.05 to .05	-.05 to .35	-.05 to .45
Q	0 to .05	0 to .05	0 to 0
R	.05 to .3	0 to .9	0 to .9
S	0 to .05	0 to .6	0 to .5
QS	0 to 0	0 to 2.1	0 to .6
T	-.05 to .5	-.1 to .5	-.05 to .5

Heart Rate

	Average	Range
Rate/min.	57	48 to 86

Table VIII. Electrocardiogram Intervals and Amplitudes with Their Ranges during Chloral Hydrate-Magnesium Sulfate-Pentobarbital Sodium Anesthesia (Equine)

Right Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs.	Range in secs.
PR	.30	.26 to .38
QRS	.10	.07 to .12
QT	.49	.44 to .56
ST	.39	.32 to .46

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	0 to .1	-.1 to .35	.3 to .35
Q	0 to 0	0 to 0	0 to 0
R	.25 to .6	.5 to .95	.6 to .7
S	0 to .1	0 to .25	0 to .25
QS	0 to 0	0 to 0	0 to 0
T	-.2 to .1	-.05 to .5	.1 to .6

Heart Rate

	Average	Range
Rate/min.	51	32 to 62

Table IX. Electrocardiogram Intervals and Amplitudes

with Their Ranges

during Chloral Hydrate-Magnesium Sulfate-

Pentobarbital Sodium Anesthesia
(Equine)

Left Lateral Recumbency

EKG Intervals
Lead II

Interval	Average Duration in secs	Range in secs.
PR	.29	.28 to .36
QRS	.09	.08 to .11
QT	.46	.40 to .54
ST	.37	.30 to .47

EKG Potentials

	Lead I	Lead II	Lead III
Wave	Range in mv.	Range in mv.	Range in mv.
P	.05 to .1	.3 to .4	-.1 to .3
Q	0 to .05	0 to 0	0 to 0
R	.05 to .2	.7 to 1.0	.65 to 1.2
S	.15 to .2	0 to .4	0 to .4
QS	0 to 0	0 to 0	0 to 0
T	-.1 to .05	.3 to .5	.35 to .6

Heart Rate

	Average	Range
Rate/min.	52	40 to 62

IV. DISCUSSION

Six horses of warm blooded breeds, Standardbred, American Saddle Horse, and Arabian were selected for experimental work in electrocardiography during general anesthesia. The same six horses were used throughout the entire experiment. All of the horses were anesthetized at least once with each of the anesthetics. Electrocardiograms were taken of the animals prior to anesthesia, during anesthesia, and following anesthesia. The electrocardiograms were examined under an electric magnifier.

The anesthetics used in the experiment produced a wide variation in the wave forms of the electrocardiogram. These changes were transient and normal electrocardiograms were obtained in all cases following each anesthesia. A variation in the duration of time intervals was also noted. These variations were also transient changes.

Electrocardiograms of the animals in recumbency without anesthesia showed changes in the wave forms and time intervals. These changes were probably the most significant thing seen in this study. As similar changes are a result of axis deviation of the heart, it was thought that these variations in the electrocardiogram may be due to the position of the animal causing a change in the position of the heart. These wave variations and time interval changes were more pronounced during anesthesia. Carter (1945) states that a negative T_1 or T_{1-2} are usually associated with left axis deviation and that a negative T_{2-3} or T_3 are associated with right axis deviation. The electrocardiograms of the recumbent animals indicate a possible axis shift due to change in the position of the heart as evidenced by the appearance of diphasic T waves in Leads II and III. Burch and Winsor (1949) state that left axis deviation is characterized by S_3 greater than R_3 and by an S_1 which is greater in amplitude than R_1 and an R_3 which is higher than R_1 or R_2. Wave comparisons of this nature were not found in the electrocardiograms of the recumbent animals but a tendency of the wave forms to shift in this direction was noted in the electrocardiograms of the recumbant animals. During anesthesia a further shift of the wave forms in this direction was noted, thus indicating that relaxation of the animals in anesthesia allowed a further change in the position of the heart.

The change in the duration of the time intervals recorded during anesthesia is probably the result of incomplete heart block resulting from prolongation of the atrioventricular conduction time. Jones (1954) states that in chloral hydrate anesthesia the vital medullary centers of the brain stem are not affected. Therefore it may be concluded that the changes are a result of direct action on the nodal or conducting tissue causing evidences of local alteration of conduction. In general the PR and QRS intervals were not greatly affected. The QT and ST intervals were consistently lengthened. The longer durations of the QT and ST intervals are a result of a prolonged activation of the ventricles. It must be noted that the QT and ST intervals vary with the heart rate. However in the anesthetized animals that had average heart rates slightly higher than the standing animal the QT and ST intervals were increased. This is in contrast to the normal animal in recumbency with an increased heart rate and a decreased QT and ST interval which one would normally expect. It is therefore logical to assume that anesthesia causes local interference with the conduction of electrical impulses within the heart muscle itself.

It should be noted here that none of the changes in potential of the wave forms and the durations of the time intervals in recumbency and during anesthesia exceeded to any degree the normal ranges determined for the normal animals.

V. CONCLUSIONS

1. The major changes seen in the electrocardiogram as a result of recumbency are an alteration in the wave forms. These changes may be a result of axis deviation due to a change in the position of the heart.

2. The changes produced in the electrocardiogram as a result of chloral hydrate anesthesia are within the range limits of the electrocardiograms of normal horses.

3. The changes in wave forms in the electrocardiograms of the anesthetized animals may be a result of further axis deviation due to relaxation of the animal.

4. The changes in the QT and PR intervals may be a result of local alteration of conductivity within the heart itself.

5. The changes in the electrocardiogram resulting from anesthesia are transient.

6. None of the changes observed in time intervals and wave potentials exceeds the range limits reported for normal horses.

VI. SUMMARY

A review of the literature concerning electrocardiography in the horse has been given. The procedure for the taking and the examining of the electrocardiograms has been outlined.

Studies were made of the effects of intravenous chloral hydrate anesthesia on the electrocardiograms of six different horses. Two concentrations of chloral hydrate alone and three concentrations of chloral hydrate together with other anesthetic agents were used. Definite changes in the electrocardiograms of normal recumbent horses and anesthetized horses were noted.

These changes are assumed to be a result of axis deviation in the recumbent and anesthetized animals and to altered conduction time within the heart conducting tissues of the anesthetized animals.

The changes produced by anesthesia are transient. Normal electrocardiograms were obtained in all cases on the day following each anesthesia.

The findings of this study indicate that there is only a mild effect produced by chloral hydrate anesthesia on the heart of the horse as evidenced by the fact that none of the variations of time intervals and wave potentials noted exceed the range limits recorded in normal horses.

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