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The Effects of G-Strophanthin of the Electrical Activity of the Dog Heart as Recorded by the Time-Based Vectorcardiograph

Rene Richard Kempen
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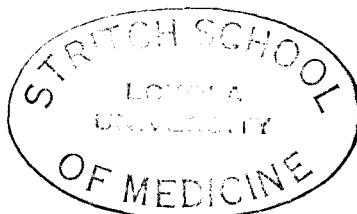
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THE EFFECTS OF G-STROPHANTHIN OF THE ELECTRICAL
ACTIVITY OF THE DOG HEART AS RECORDED BY
THE TIME-BASED VECTORCARDIOGRAPH

Rene Richard Kempen



A DISSERTATION SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF LOYOLA UNIVERSITY IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

February
1962

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LIFE

Rene Richard Kempen was born in Kankakee, Illinois, on March 24, 1928.

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TABLE OF CONTENTS

	Page
Chapter I, Introduction -----	1
Chapter II	
Review of Related Literature -----	4
Normal Dog -----	7
Literature Where Pre-treated Normal Dogs were Used -----	12
Electrocardiogram after Digitalis -----	13
Chapter III	
Methods and Materials -----	17
Experimental Animal -----	17
Recording Methods -----	18
Standard Clinical Electrocardiogram -----	18
Vectorcardiogram -----	20
Time-Based Vectorcardiogram -----	21
Calculations -----	28
Measurements and Analysis -----	30
Design of Experiments and Statistical Analysis -----	33
"Normal" Dog -----	34
Drug Experiments -----	35
Series I, Anesthetized Dogs -----	35
Series II, Unanesthetized Dogs -----	36
Series III, Anesthetized Dogs with Control Anesthesia -----	38
Chapter IV	
Results -----	40
"Normal" Dog -----	40
Standard Clinical Method -----	40
Vectorcardiograms -----	51
Time-Based Vectorcardiograms -----	63
Drug Studies - Series I - Anesthetized Dogs -----	84
Standard Clinical Method -----	84
Vectorcardiograms -----	114
Time-Based Vectorcardiograms -----	120
Drug Studies - Series II - Unanesthetized Dogs -----	141
Standard Clinical Method -----	142
Vectorcardiograms -----	159
Time-Based Vectorcardiograms -----	162
Drug Studies - Series III - Controlled Anesthesia -----	172
Standard Clinical Method -----	172
Vectorcardiograms -----	199
Time-Based Vectorcardiograms -----	207

TABLE OF CONTENTS (continued)

	Page
Chapter V	
Discussion and Conclusions -----	232
Chapter VI	
Summary -----	258
Bibliography -----	260
Appendix -----	272

LIST OF FIGURES

	Page
Fig. I Grishman Lead System -----	19
Fig. II Block Diagram of Vectorcardiogram Apparatus -----	22
Fig. III Block Diagram of Time-Based Vectorcardiogram Apparatus -----	23
Fig. IV Pre-amplifier Schematic -----	25
Fig. V Power Supply Schematic -----	26
Fig. VI Time-Based Vectorcardiographic Leads Showing Measurement of Waves -----	29
Fig. VII Measurement of the ST-T Segment of Dog -----	32
Fig. VIII Standard Electrocardiogram: A Control Record of Anesthetized Dog -----	41
Fig. IXa Standard Electrocardiogram: A Control Record of Anesthetized Dog -----	42
Fig. IXb-- Standard Electrocardiogram: A Record of the Same Anesthetized Dog One Hour After 0.25 mg Ouabain -----	43
Fig. IX _c Standard Electrocardiogram: A Record of the Same Anesthetized Dog Four Hours After 0.25 mg Ouabain -----	44
Fig. X Vectorcardiogram: QRS sE-loop with a Terminal Cephalid Inscription -----	55
Fig. XI Vectorcardiogram: QRS sE-loop with only a Caudal Inscription -----	56
Fig. XII Vectorcardiogram: QRS sE-loop with only a Caudal Inscription -----	57
Fig. XIII _a Vectorcardiogram: Narrow thin QRS sE-loop in Frontal Lead, more Ovoid sE-loop in Sagittal Lead immediately after Pentobarbital Anesthesia -----	58

LIST OF FIGURES (continued)

Page

Fig. XIII _b	Vectorcardiogram: After three Hours under Pentobarbital Anesthesia a Counter Clockwise Rotation of the QRS sE-loop Occurred so that a more Ovoid QRS sE-loop was Inscribed in the Frontal Lead and a Thin QRS sE-loop Inscribed in the Sagittal Lead -----	59
Fig. XIV	Magnitude and Direction of Maximal Mean Instantaneous Vectors of the QRS sE-loops and T sE-loops, Unanesthetized Dogs -----	61
Fig. XV	Magnitude and Direction of Maximal Mean Instantaneous Vectors of the QRS sE-loops and T sE-loops, Anesthetized Dogs -----	62
Fig. XVI	Time-Based Vectorcardiograms: A Typical Record Showing a QRS sE-loop with a Terminal Cephalad Inscription ----	64
Fig. XVII _a	Time-Based Vectorcardiogram: A Typical Record Showing a QRS sE-loop with a Terminal Cephalad Inscription ----	65
Fig. XVII _b	Time-Based Vectorcardiogram: A Record of the Same Anesthetized Dog One Hour after 0.25 mg Ouabain -----	66
Fig. XVII _c	Time-Based Vectorcardiogram: A Record of the Same Anesthetized Dog Four Hours after 0.25 Ouabain -----	67
Fig. XVIII	Time-Based Vectorcardiograms: Sample Records Illustrating the Four Divisions of the ST-T Wave -----	69
Fig. XIX	Standard Electrocardiograms: Sample Records Illustrating the Four Divisions of the ST-T Wave -----	70
Fig. XX	Oscilloscope Tracings Illustrating Three Dimensional Graphing with Rectangular pulses -----	245
Fig. XXI	Oscilloscope Tracings Illustrating Three Dimensional Graphing with Sine Wave Pulses -----	246

LIST OF TABLES

	Page
Table 1 Dose and Electrocardiogram Recording Schedule for Series II -----	37
Table 2 _a Means of Voltage Measurements of the Waves from the Limb Leads Standard Electrocardiogram -----	45
Table 2 _b Means of Voltage Measurements of the Waves from the Chest Leads Standard Electrocardiogram -----	46
Table 3 _a Means of Voltage Measurements of Waves of Limb Leads of Anesthetized Dog - Standard Electrocardiogram -----	47
Table 3 _b Means of Voltage Measurements of Waves of Chest Leads, Anesthetized Dog - Standard Electrocardiogram --	48
Table 4 Means of Heart Rate, Intervals, Axes and Angles from Standard Electrocardiograms of Unanesthetized Normal Dogs -----	49
Table 5 Means of the Heart Rate, Intervals, Axes, and Angles from Anesthetized Dogs - Standard Electrocardiogram ---	50
Table 6 _a Mean Differences of Voltage and Statistical Comparisons of Unanesthetized and Anesthetized Dogs - Standard Electrocardiogram -----	52
Table 6 _b Mean Differences of Voltage and Statistical Comparisons of Unanesthetized and Anesthetized Dogs - Standard Electrocardiogram -----	53
Table 7 Mean Differences in Millivolts of Heart Rates and Intervals and Statistical Comparison of Unanesthetized and Anesthetized Dogs - Standard Electrocardiogram ----	54
Table 8 Means of Measured Angles in the Frontal and Sagittal Leads of Unanesthetized Dogs - Time-Based Vectorcardiograms -----	73
Table 9 Means of Measured Angles in the Frontal and Sagittal Leads of Anesthetized Dogs - Time-Based Vectorcardiograms -----	74

LIST OF TABLES (continued)

	Page
Table 10 Analysis of Changes in Means of Angles in the Frontal and Sagittal Leads of Unanesthetized and Anesthetized Dogs - Time-Based Vectorcardiograms -----	75
Table 11 Means of Calculated Spatial Magnitudes of Waves from Unanesthetized Dogs - Time-Based Vectorcardiogram -----	76
Table 12 Means of Calculated Spatial Magnitudes of Waves from Anesthetized Dogs from Time-Based Vectorcardiograms ---	77
Table 13 Analysis of Changes of Means of Spatial Magnitudes of the Waves from Unanesthetized and Anesthetized Dogs - Time-Based Vectorcardiogram -----	78
Table 14 Means of Calculated Spatial Angles of Waves to the QRS Maximal Vector from Unanesthetized Dogs - Time-Based Vectorcardiogram -----	79
Table 15 Means of Calculated Spatial Angles of Waves to the QRS Maximal Vector from Anesthetized Dogs - Time-Based Vectorcardiogram -----	80
Table 16 Analysis of Differences of Means of Spatial Angles for Anesthetized and Unanesthetized Dogs from the Time-Based Vectorcardiogram -----	81
Table 17 Means of Measured Heart Rate and Intervals of Unanesthetized Dogs - Time-Based Vectorcardiogram -----	82
Table 18 Means of Measured Heart Rate and Intervals of Anesthetized Dogs - Time-Based Vectorcardiogram -----	83
Table 19 Analysis of Differences in Means of the Intervals Between Unanesthetized and Anesthetized Dogs - Time-Based Vectorcardiogram -----	83
Table 20 _a Amplitudes of Waves from Standard Electrocardiograms of Pre-treated Anesthetized Dogs -----	85
Table 20 _b Amplitudes of Waves from Standard Electrocardiograms of Pre-treated Anesthetized Dogs -----	86

LIST OF TABLES (continued)

	Page
Table 20 _c Amplitudes of Waves from Standard Electrocardiograms of Pre-treated Anesthetized Dogs -----	87
Table 21 _a Amplitude of Waves from Standard Electrocardiogram after Drug-treatment of Anesthetized Dogs -----	88
Table 21 _b Amplitude of Waves from Standard Electrocardiogram after Drug-Treatment of Anesthetized Dogs -----	89
Table 21 _c Amplitude of Waves from Standard Electrocardiogram after Drug-Treatment of Anesthetized Dogs -----	90
Table 21 _d Amplitude of Waves from Standard Electrocardiogram After Drug-treatment of Anesthetized Dogs -----	91
Table 21 _e Amplitude of Waves from Standard Electrocardiogram after Drug-treatment of Anesthetized Dogs -----	92
Table 21 _f Amplitude of Waves from Standard Electrocardiogram after Drug-treatment of Anesthetized Dogs -----	93
Table 22 _a Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, With Statistical Comparisons -----	94
Table 22 _b Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	95
Table 22 _c Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	96
Table 22 _d Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	97

LIST OF TABLES (continued)

	Page
Table 22 _e Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	98
Table 22 _f Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	99
Table 23 _a Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	100
Table 23 _b Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	101
Table 23 _c Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	102
Table 23 _d Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	103
Table 23 _e Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	104
Table 23 _f Amplitude Differences of Waves from Standard Electrocardiogram between Pre-treated and Drug- treated Anesthetized Dogs, with Statistical Comparisons -----	105

LIST OF TABLES (continued)

	Page
Table 24 Summary of Significant Differences of Voltage Means of the Standard Electrocardiogram Waves of Drug Times of Two Hours or Less -----	106
Table 25 Summary of Significant Differences of Means of Voltage from Standard Electrocardiogram Waves with Drug Times of More Than Two Hours -----	108
Table 26 Heart Rate, Intervals, Axes and Angles from Standard Electrocardiogram of Pre-treated Anesthetized Dogs -----	109
Table 27 Heart Rate, Intervals, Axes and Angles from Standard Electrocardiogram after Drug Treatment of Anesthetized Dogs -----	110
Table 28 Differences in Heart Rates, Intervals, Axes and Angles from Standard Electrocardiogram of Pre-Treated and Drug-Treated Anesthetized Dogs with Statistical Comparison -----	111
Table 29 Differences in Heart Rate, Intervals, Axes and Angles from Standard Electrocardiogram of Pre-Treated and Drug-Treated Anesthetized Dogs with Statistical Comparisons -----	112
Table 30 Summary of Significant Differences of Means of Intervals, Axes of Standard Electrocardiogram -----	113
Table 31 Summary of Significant Differences of Means of Intervals, Axes and Angles of Standard Electrocardiogram -----	113
Table 32 Angles of Waves from Vectorcardiogram Leads of Pre-Treated Anesthetized Dogs -----	115
Table 33 Angles of Waves from Vectorcardiogram Leads after Drug Treatment of Anesthetized Dogs -----	116
Table 34 Angles of Waves from Vectorcardiogram Leads after Drug Treatment of Anesthetized Dogs -----	117

LIST OF TABLES (continued)

		Page
Table 35	Differences of Angles of Waves from Vector- cardiogram Leads of Pre-Treated and Drug-Treated Anesthetized Dogs, with Statistical Comparison -----	118
Table 36	Differences of Angles of Waves from Vector- cardiogram Leads of Pre-Treated and Drug-Treated Anesthetized Dogs with Statistical Comparison -----	119
Table 36a	Summary of Significant Differences of Axes from Vectorcardiogram -----	119
Table 37	Spatial Magnitudes of Waves Calculated from Time- Based Vectorcardiographic Leads of the Pre-Treated Anesthetized Dogs -----	122
Table 38	Spatial Magnitudes of Waves Calculated from Time- Based Vectorcardiographic Leads after Drug Treatment of Anesthetized Dogs -----	123
Table 39	Spatial Magnitudes of Waves Calculated from Time- Based Vectorcardiographic Leads after Drug Treatment of Anesthetized Dogs -----	124
Table 40	Ratios of Magnitudes of Each Wave to the QRS _m Spatial Magnitudes Calculated from the Time-Based Vector- cardiogram of Pre-Treated Anesthetized Dogs -----	125
Table 41	Ratios of Magnitude of Each Wave to the QRS Spatial Magnitude Calculated from the Time-Based Vector- cardiogram after Drug Treatment of Anesthetized Dogs -	126
Table 42	Ratios of Magnitudes of the Waves to the QRS _m Spatial Magnitudes Calculated from the Time-Based Vector- cardiogram after Drug Treatment of Anesthetized Dogs -	127
Table 43	Differences in Ratios of Magnitude of Waves Between Pre-Treated and Drug-Treated Anesthetized Dogs Calculated from Time-Based Vectorcardiogram with Statistical Analysis -----	128

LIST OF TABLES (continued)

	Page
Table 44 Differences in Ratios of Magnitudes of Waves between Pre-Treated and Drug-Treated Anesthetized Dogs Calculated from Time-Based Vectorcardiogram with Statistical Analysis -----	129
Table 45 Summary of Significant Differences of the Ratios of Means of Magnitude between the Pre-Treated and Drug-Treated Anesthetized Dogs -----	130
Table 46 Spatial Angles of Each Wave to the QRS _m Vector Calculated from Time-Based Vectorcardiogram of Pre-treated Anesthetized Dog -----	131
Table 47 Spatial Angles of Each Wave to the QRS _m Vector Calculated from Time-Based Vectorcardiogram After Drug Treatment of Anesthetized Dog -----	132
Table 48 Spatial Angles of Each Wave to the QRS _m Vector Calculated from Time-Based Vectorcardiogram after Drug Treatment of Anesthetized Dog -----	133
Table 49 Differences of Spatial Angles to QRS _m Calculated from Time-Based Vectorcardiogram of Pre-Treated and Drug-Treated Anesthetized Dogs, with Statistical Analysis -----	134
Table 50 Differences of Spatial Angles to QRS _m Calculated from Time-Based Vectorcardiogram of Pre-Treated and Drug-Treated Anesthetized Dogs, with Statistical Analysis -----	135
Table 51 Heart Rates and Intervals Measured from Time-Based Vectorcardiogram on Pre-Treated Anesthetized Dogs -----	136
Table 52 Heart Rate and Intervals Measured from Time-Based Vectorcardiogram after Drug Treatment of Anesthetized Dogs -----	137
Table 53 Heart Rates and Intervals Measured from Time-Based Vectorcardiogram after Drug Treatment of Anesthetized Dogs -----	138

LIST OF TABLES (continued)

	Page
Table 54 Differences of Heart Rate and Intervals Measured from Vectorcardiogram of Pre-Treated and Drug-Treated Anesthetized Dogs, with Statistical Analysis -----	139
Table 55 Differences of Heart Rate and Intervals Measured from Time-Based Vectorcardiogram of Pre-Treated and Drug-Treated Anesthetized Dogs, with Statistical Analysis --	140
Table 56 Summary of Significant Differences of Intervals -----	141
Table 57 Summary of Significant Findings from the Analysis of Variance for Conditions -----	143
Table 58 Analysis of Variance for Lead I, Series II -----	144
Table 59 Analysis of Variance for Lead II, Series II -----	145
Table 60 Analysis of Variance for Lead III, Series II -----	146
Table 61 Analysis of Variance for Lead AVR , Series II -----	147
Table 62 Analysis of Variance for Lead AVL , Series II -----	148
Table 63 _a Analysis of Variance for Lead AVF , Series II -----	149
Table 63 _b Analysis of Waves in Lead AVF -----	149
Table 64 _a Analysis of Variance of Lead V_1 , Series II -----	150
Table 64 _b Analysis of Waves in Lead V_1 -----	150
Table 65 _a Analysis of Variance of Lead V_2 , Series II -----	151
Table 65 _b Analysis of Waves in Lead V_2 -----	151
Table 66 _a Analysis of Variance of Lead V_3 , Series II -----	152
Table 66 _b Analysis of Waves in Lead V_3 -----	152
Table 67 _a Analysis of Variance of Lead V_4 , Series II -----	153
Table 67 _b Analysis of Waves in Lead V_4 -----	153

LIST OF TABLES (Continued)

	Page
Table 68 Analysis of Variance of Lead V_5 , Series II -----	154
Table 69 Analysis of Variance of Lead V_6 , Series II -----	155
Table 70 Analysis of Variance of Intervals, Standard Electrocardiogram, Series II -----	156
Table 71 Analysis of Variance of Frontal Axis, Standard Electrocardiogram -----	157
Table 72 Analysis of Variance of QRS-ST-T Angles, Standard Electrocardiogram -----	157
Table 73 Summary of Analysis of Variance of Significant Conditions and Associated Waves, Vectorcardiogram Leads -----	158
Table 74 Analysis of Variance of Wave Angles in Frontal Lead of Vectorcardiogram, Series II -----	160
Table 75 _a Analysis of Variance of Wave Angles in Sagittal Lead of Vectorcardiogram, Series II -----	161
Table 75 _b Analysis of Waves in Sagittal Lead of Vectorcardiogram, Series II -----	161
Table 76 Analysis of Variance of QRS_i/QRS_m and QRS_t/QRS_m Magnitudes Calculated from the Time-Based Vectorcardiogram, Series II -----	163
Table 77 Analysis of Variance of Ratios of P, ST_a , ST_b , ST_c and T Spatial Magnitudes to the QRS_m Calculated from Time-Based Vectorcardiogram, Series II -----	164
Table 78 Analysis of Variance of Ratios of QRS_i and QRS_t to the QRS_m Vector Calculated from Time-Based Vector- cardiogram, Series II -----	165
Table 79 Analysis of Variance of Ratios of P, ST_a , ST_b , ST_c and T Waves to the QRS Vector Calculated from Time- Based Vectorcardiogram, Series II -----	166

LIST OF TABLES (continued)

	Page
Table 80 Analysis of Variance of Spatial Angles of the QRS _i and QRS _t with the QRS _m Spatial Vector Calculated from the Time-Based Vectorcardiogram, Series II -----	167
Table 81 Analysis of Variance of Spatial Angles of P, ST _a , ST _b , ST _c and T Spatial Vectors with the QRS _m Spatial Vector Calculated from the Time-Based Vectorcardiogram, Series II -----	168
Table 82 _a Analysis of Variance of Spatial Angles of QRS _i and QRS _t with the QRS _m Spatial Vector Calculated from the Time-Based Vectorcardiogram, Series II -----	169
Table 82 _b Analysis of Waves of Significant Conditions for the Calculated Spatial Angles from the Time-Based Vectorcardiogram -----	169
Table 83 Analysis of Variance of Spatial Angles of P, ST _a , ST _b , ST _c and T Spatial Vectors with the QRS _m Spatial Vector Calculated from Time-Based Vectorcardiogram, Series II -----	170
Table 84 Summary of Analyses of Variance of between Conditions and Associated Waves of Time-Based Vectorcardiogram Method, Series II -----	171
Table 85 Voltages in Millivolts of the Waves from Electro- cardiogram of Standard Clinical Limb Leads for the Six Conditions -----	174
Table 86 Voltages in Millivolts of the Waves from Electro- cardiogram of Standard Clinical Limb Leads for the Six Conditions -----	175
Table 87 Voltages in Millivolts of the Waves from Electro- cardiogram of Standard Clinical Limb Leads for the Six Conditions -----	176
Table 88 Voltages in Millivolts of the Waves from Electro- cardiogram of Standard Clinical Limb Leads for the Six Conditions -----	177

LIST OF TABLES (continued)

	Page
Table 89 _a Factorial Analysis of Voltage of the Waves from Standard Clinical Limb Leads -----	178
Table 89 _b Factorial Analysis of Voltage of the Waves from Standard Clinical Limb Leads -----	179
Table 89 _c Factorial Analysis of Voltage of the Waves from Standard Clinical Limb Leads -----	180
Table 90 _a Factorial Analysis of Voltage of the Waves from Standard Clinical Chest Leads -----	181
Table 90 _b Factorial Analysis of Voltage of the Waves from Standard Clinical Chest Leads -----	182
Table 91 _a Summary of Significant Findings from Factorial Analysis of Standard Electrocardiographic Leads -----	183
Table 91 _b Summary of Significant Findings from Factorial Analysis of Standard Electrocardiographic Leads -----	184
Table 91 _c Summary of Significant Findings from Factorial Analysis of Standard Electrocardiographic Leads -----	185
Table 92 Factorial Analysis of Heart Rate from Standard Electrocardiogram, Series III -----	187
Table 93 Factorial Analysis of P-R Interval from Standard Electrocardiogram, Series III -----	188
Table 94 Factorial Analysis of RR' Interval from Standard Electrocardiogram, Series III -----	189
Table 95 Factorial Analysis of the QRS Interval from Standard Electrocardiogram, Series III -----	190
Table 96 Factorial Analysis of Q-T Interval from Standard Electrocardiogram, Series III -----	191
Table 97 Factorial Analysis of QRS Axis in the Frontal Plane from Standard Electrocardiogram, Series III -----	192

LIST OF TABLES (continued)

	Page
Table 98 Factorial Analysis of ST Axis in the Frontal Plane from Standard Electrocardiogram, Series III -----	193
Table 99 Factorial Analysis of T Axis in Frontal Plane from Standard Electrocardiogram, Series III -----	194
Table 100 Factorial Analysis of Spatial QRS-T Angle from Standard Electrocardiogram, Series III -----	195
Table 101 Factorial Analysis of Spatial ST-T Angle from Standard Electrocardiogram, Series III -----	196
Table 102 _a Summary of Significant Comparisons of Intervals of Standard Electrocardiogram -----	197
Table 102 _b Summary of Significant Spatial Angles of Standard Electrocardiogram -----	198
Table 103 Factorial Analysis of QRS _m Vector's Angle in Frontal Lead from Vectorcardiogram -----	200
Table 104 Factorial Analysis of Angle of QRS _m Vector in Sagittal Lead from Vectorcardiogram -----	201
Table 105 Factorial Analysis of Angle of QRS _i Vector in the Frontal Lead from Vectorcardiogram -----	202
Table 106 Factorial Analysis of the Angle of the QRS _i Vector in the Sagittal Lead from Vectorcardiogram -----	203
Table 107 Factorial Analysis of the Angle of the QRS _t Vector in Frontal Lead from Vectorcardiogram -----	204
Table 108 Factorial Analysis of the Angle of the QRS _t Vector in the Sagittal Lead from Vectorcardiogram -----	205
Table 109 Summary of Significant Comparisons of Angles from Vectorcardiogram -----	206
Table 110 Factorial Analysis of Spatial Magnitude of QRS _m Vector Calculated from Time-Based Vectorcardiogram -----	209

LIST OF TABLES (continued)

	Page
Table 111 Factorial Analysis of Spatial Magnitude of T Vector Calculated from Time-Based Vectorcardiogram, Series III -----	210
Table 112 Factorial Analysis of P/QRS _m Ratios Calculated from Time-Based Vectorcardiogram, Series III -----	211
Table 113 Factorial Analysis of QRS _i /QRS _m Ratios Calculated from Time-Based Vectorcardiogram -----	212
Table 114 Factorial Analysis of QRS _t /QRS _m Ratios Calculated from Time-Based Vectorcardiogram -----	213
Table 115 Factorial Analysis of ST _a /QRS _m Ratios Calculated from Time-Based Vectorcardiogram -----	214
Table 116 Factorial Analysis of ST _b /QRS _m Ratios Calculated from Time-Based Vectorcardiogram -----	215
Table 117 Factorial Analysis of ST _c /QRS _m Ratios Calculated from Time-Based Vectorcardiogram -----	216
Table 118 Factorial Analysis of T/QRS _m Ratios Calculated from Time-Based Vectorcardiogram -----	217
Table 119 Summary of Significant Comparisons of Magnitudes and Ratios Calculated from Time-Based Vectorcardiogram ----	218
Table 120 Factorial Analysis of QRS _i -QRS _m Spatial Angle Calculated from Time-Based Vectorcardiogram -----	219
Table 121 Factorial Analysis of QRS _t -QRS _m Spatial Angle Calculated from Time-Based Vectorcardiogram -----	220
Table 122 Factorial Analysis of ST _a -QRS _m Spatial Angle Calculated from Time-Based Vectorcardiogram -----	221
Table 123 Factorial Analysis of ST _b -QRS _m Spatial Angle Calculated from Time-Based Vectorcardiogram -----	222
Table 124 Factorial Analysis of ST _c -QRS _m Spatial Angle Calculated from Time-Based Vectorcardiogram -----	223

LIST OF TABLES (continued)

	Page
Table 125 Factorial Analysis of T-QRS _m Spatial Angle Calculated from Time-Based Vectorcardiogram -----	224
Table 126 Summary of Significant Comparisons of Spatial Angles Calculated from Time-Based Vectorcardiogram ----	225
Table 127 Factorial Analysis of P Interval Calculated from Time-Based Vectorcardiogram -----	226
Table 128 Factorial Analysis of P-R Interval Calculated from Time-Based Vectorcardiogram -----	227
Table 129 Factorial Analysis of QRS Interval Calculated from Time-Based Vectorcardiogram -----	228
Table 130 Factorial Analysis of QT Interval Calculated from Time-Based Vectorcardiogram -----	229
Table 131 Factorial Analysis of RR' Interval Calculated from Time-Based Vectorcardiogram -----	230
Table 132 Summary of Significant Comparisons of Intervals Calculated from Time-Based Vectorcardiogram -----	231

APPENDIX

Table	Page
I. Measurements of Waves from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitude and Angles of the Pre-treated Anesthetized Dogs in Series I -----	272
II. Measurements of Waves from Time-Based Vectorcardiographic Leads Used in the Calculations of the Spatial Magnitude and Angles after Drug Treatment of Anesthetized Dogs in Series I -----	273
III. Measurements of Waves from Time-Based Vectorcardiographic Leads Used in the Calculations of the Spatial Magnitudes and Angles after Drug Treatment of Anesthetized Dogs in Series I -----	274
IV. Measurements of P Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	275
V. Measurements of QRS _m Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	276
VI. Measurements of QRS ₁ Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	277
VII. Measurements of QRS _t Wave from the Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs of Series III -----	278
VIII. Measurements of ST _a Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	279

APPENDIX (continued)

Table	Page
IX. Measurements of ST _b Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	280
X. Measurements of ST _c Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	281
XI. Measurements of T Wave from Time-Based Vectorcardiographic Leads Used in Calculation of the Spatial Magnitudes and Angles of the Anesthetized Dogs in Series III -----	282

LIST OF APPENDIX FIGURES

	Page
Fig. 1a Time-Based Vectorcardiogram: A Pre-Drug Record of 12.6 Kg Dog -----	283
Fig. 1b Time-Based Vectorcardiogram: A Record of the Same Dog after 500 mg Quinidine -----	284
Fig. 2a Time-Based Vectorcardiogram: A Pre-Drug Record of 12 Kg Dog -----	285
Fig. 2b Time-Based Vectorcardiogram: A Record of the Same Dog Illustrating a Rare "Digitalis Pattern" Obtained after 0.65 mg of Ouabain -----	286
Fig. 3 Time-Based Vectorcardiogram: A Record Obtained from a Normal Human -----	287

CHAPTER I

INTRODUCTION

Digitalis compounds were introduced in clinical practice more than a century and a half ago. Although these compounds were featured in one of the earliest known herbales in 1542, it was William Withering in 1785 who first gave a careful account of the effects of these preparations on dropsy. Withering did not classify these preparations as cardiac drugs, but he did suggest that they had a power over the heart. It was John Ferriar in 1799 who ascribed the primary action to the effect on the heart, with diuresis as a secondary role.

Probably no other class of drugs has been the subject of such extensive and thorough pharmacological investigation as the digitalis series. The dramatic effects caused by these compounds in the clinic by their ability to increase the force of contraction of the myocardium, thus increasing the stroke volume of the heart with a reduction of residual volume, has intrigued many a researcher. Even with the vast amount of literature available, only the gross manifestations of these effects on altered heart and tissue activity are well understood. The underlying mechanism of action of these compounds on cardiac function is still more or less obscure.

The effects of these and other drugs on the electrical activity of the heart has been largely descriptive. The amount of information available of an electrocardiographic nature has been limited because the development of theory and instrumentation has not provided an adequate system to furnish data for a critical evaluation of the electrical activity of the heart.

However, recent advances in theory have made possible the establishment of suitable "units" which adequately describe this electrical type data.

The present study was undertaken to devise a method and build an instrument suitable for the measurement and expression of data in appropriate electrical "units" as obtained in an electrocardiogram. The development of the vector concept for expression of these "units" in electrocardiography is the most rational and objective method for evaluating information in the form of directed electrical forces. Vectors as used in engineering have three dimensions; magnitude, direction, and sense (polarity). In a study of the electrical activity of the heart (electrocardiogram), the manifest electrical potential of the heart exists and changes each instant. Thus it can be described as a series of instantaneous spatial vectors, having the dimensions of magnitude, direction, and sense (polarity).

Some of the recent advances in clinical technique have been concerned with spatial electrical changes as derived from the human heart. However, these findings were not actually measured but were abstractions from a series of recordings. The application of the new method to be described here, will allow the separate calculation of the magnitude (voltage and polarity) and orientation electrical spatial vectors by actual measurements from the recorded graphs. Modifications of these vectors caused by digitalis compounds or other drugs then can be readily measured.

This study will add to the findings obtained by many investigations, which have centered mainly around three aspects of cardiac glycoside activity; namely, (a) the relation to the action on and metabolism of certain inorganic

ions (K, Ca, etc.), (b) effects on the physiological and chemical states of the protoplasm, and (c) the effects on the energy transformation in the heart, especially energy production concerned with the recovery phase of the cardiac cycle. This additional technique of study may provide new information leading to a better understanding of the underlying mechanism of action of these intriguing digitalis compounds.

CHAPTER II

REVIEW OF RELATED LITERATURE

In the course of an investigation of the effects of digitalis compounds on the spatial electrocardiogram of the dog, it is necessary to be familiar with vectorcardiographic methods. Hence this review of the literature will emphasize the vector concept and special interest will be given to this type of data.

The vector concept, as used in spatial electrocardiographic analysis, is nothing more than an integration and schematizing of instantaneous electrical force data. If such an electrical force, from the contracting heart, is at the center of a cylindrical volume conductor, (the chest), it would produce a distribution of potential on the surface of the cylinder similar to that which is encountered in the leads of the clinical electrocardiograph.

Even without this vector concept, the usefulness of the standard clinical electrocardiogram in clinical evaluation of cardiac abnormalities is well recognized (Harrison, 1954). However, many physiological conditions and certain drugs effect each standard electrocardiographic lead, in a manner which simulates the effects of organic abnormalities. These similarities, without the vector concept, are often evaluated with difficulty and unsatisfactorily. For example, the alteration of the T wave by such drugs as digitalis, and physiological variations in the same wave produced by hypokassemia and cardiac injury are very much the same (Harrison, 1954, Gold, et al., 1942, and Bellet, et al., 1950).

Recent advances in clinical methodology, using the standard clinical electrocardiograph, have been concerned with spatial electrical changes in the heart. Observations of the electrical changes have been visualized by using the vector concept from the standard clinical leads (Graettinger, et al., 1951; Grant, et al., 1951; Grishman, et al., 1952; Duchosal, et al., 1949; Mann, 1938; Schellong, 1936; Wilson, et al., 1938; Hollmann, et al., 1938, and Minot, 1938). A search of the literature does not provide data using the vector type analysis in the dog with G-strophanthin or other digitalis-like preparations. Further, there is only limited data, using vector analysis of the standard electrographic recordings, for the normal dog (Lombard and Witham, 1955, Dobbie, 1955).

Two other methods, termed "vector cardiograms" (Wilson and Johnston, 1938) and "timed vectocardiograms" (Selvester and Griggs, 1957), are noted in the literature. These methods have not been utilized for a study of digitalis preparation on the dog heart. However, a limited amount of data is available utilizing the vectorcardiographic method (Horan, Burch, and Cronvich, 1957).

If one accepts the concept that the ideal recorded observation of the electrical changes projected by a vector would be a series of recordings whose sum or integral will produce a cardiac vector at the moment of observation (instantaneous integral vector) (Grishman and Scherlis, 1952), we find, therefore, that the available methods evaluated in this light are of limited value.

The vector data that is available for the normal dog is that obtained by the method of Grant, et al., (1951). This method allows the estimation but not actual recording of the spatial vectors from the standard clinical electrocardiograms. The disadvantage of this method is that the values are not actual recording of vectors, but visual estimations taken from a number of electrocardiographic leads. However, it is possible to plot a frontal plane vector graph taken from the limb leads, but considerable error is introduced unless the leads are recorded simultaneously. Plotting these graphs is also very tedious and time-consuming.

The method termed "vectorcardiograms" (Wilson and Johnston, 1938) has overcome some of the disadvantages of the method of Grant (1951) because an actual graph of the electrical changes that occur in the frontal, sagittal and horizontal plane are recorded. One report using this method is found describing the "normal" dog (Horan, Burch and Cronvich, 1957). One disadvantage of this method is that these recordings often have the various major portions of the electrocardiograph cycle superimposed upon each other. With very elaborate equipment (Mann, 1938) these smaller waves can be separated so that their size and shape (P and T loops) can be determined. Even with such separation of the various complexes one still cannot determine information such as heart rate, irregularities in rhythm, and many of the clinically important time intervals.

The method termed "timed vectorcardiograms" (Selvester and Griggs, 1957) also has some disadvantages. Though these records give the progressive

electrical changes of a complete cycle occurring in a plane, they do not give the information necessary for the measurement and calculation of the relative spatial magnitudes and the spatial angles of the smaller deflections.

A new method, distinct from those described above, is introduced in this work for the study of G-strophanthin and digitoxin. This method uses a three dimensional type recording similar to that used in "timed vectorcardiograms." However, the introduction of the time dimensions will be such that the perpendicular height of a particular wave in each of three leads will give the X, Y and Z components of its spatial vector.

NORMAL DOG

This literature may be divided into two groups, those directly concerned with the description of the dog's electrocardiogram, and those obtained in a similar manner but used as controls for other experimental studies.

One of the first papers concerned with the description of the electrocardiogram of the dog was that of Katz, et al. (1934), who determined the electrocardiographic variation on three normal dogs, using only the three standard limb leads. Recordings were taken twice a week for a period of four weeks. These dogs were unanesthetized and trained to lie on their right side. Although no data was presented in their paper, they concluded that repeated electrocardiograms on normal dogs show significant variations. This variation was attributed to the mobility of the dog's heart.

In a later study of eight dogs by Mainzer and Krause (1937) it was concluded that records taken from the dog in a standing position were valueless, because of "electrical disturbance," while recordings obtained in the sitting position were almost as constant as the recordings obtained in man. A marked variation on different days was obtained with the animals lying either on their right or left side. This variation was correlated with the different degrees of rigidity of the mediastnum of each dog as noted by X-ray and postmortem examination. Though no records were presented, a general description of the major features of each of the three standard limb leads was given.

Lalich, et al., (1941) studied 24 normal unanesthetized dogs trained to lie on either the right or left side, using the three standard limb leads. Five of these dogs were examined on both sides. Although no detailed analysis was made, they did report that: the P waves showed changes in amplitude and direction in the same lead; that the T waves were variable in amplitude and direction; and that a variation in amplitude or disappearance of the Q and S waves occurred. The electrical axis, as calculated by Dieuaide's method (1935), had a variation of 70° in one dog (-65° to 10°), however, 60% of the data for the 24 animals fell between 50° and 75° . The shift in electrical axis was less than 15° for each dog from day to day and the T wave reversals were not related to the animal's position. They expressed the belief that each dog's electrocardiogram was characteristic even though day to day variation occurred in the various complexes.

In a study of three unanesthetized and fifty anesthetized normal dogs, Luisada, et al., (1944) reported a heart rate of 90 to 140 with respiratory arrhythmia present in all leads. The P waves were upright and "sharp," lasting 0.06 to 0.08 seconds while the P-R interval lasted 0.07 to 0.08 seconds. The S-T segment was often slightly displaced from the base line in the animals without anesthesia. The T waves were usually diphasic with a sharp upright phase, ending simultaneous with the second heart sound. The QT interval lasted from 0.20 to 0.24 seconds. No other data was given.

Peterson, et al., (1951) attempted to set up detailed criteria for the standard and augmented unipolar limb leads in a study of normal, untrained and unanesthetized young beagle dogs, in the supine position. They presented a table of intervals of the important complexes and a voltage measurement for each deflection or wave. An exception was the P wave which was measured only in lead II. A calculation of the electrical axis was made but no statistical analysis was presented. Their conclusion was that the variations in the serial electrocardiograms were more marked in dogs than in man, but were not so great as to preclude comparison with one another.

A "detailed" analysis of 62 electrocardiograms on 30 normal laboratory dogs on mongrel breed and indeterminate age was made by Horwitz, et al., (1953) with a direct writing machine. The standard limb leads and the augmented unipolar extremity leads were recorded with the dog in the supine position. The amplitudes of each wave in each lead was measured and expressed in millivolts along with the intervals of the important complexes,

measured in seconds. The minimum and maximum value for each series of measurements was tabulated with the statistical calculation of the mean and standard deviation. A series of 10 consecutive readings on the same dog was presented, but no attempt was made of a statistical nature to compare these results to the total group. They concluded by recommending that a mean of three tracings be taken at different times to reduce the effect of the occasional extreme values sometimes encountered.

Lombard and Witham (1955) published the first attempt to report vector type electrocardiographic data in the dog, using the standard clinical electrocardiograph. They reported the voltages of all the waves in the three standard limb leads and the six precordial leads. It should be pointed out that a modification of the routine placement of the precordial lead electrodes was made. They were all placed in a straight horizontal line at the level of the fourth intercostal space. Estimates of the direction of the vectors of the Q, ST deviation, and T waves were presented using the method of Grant (1950). Using this same method, they presented the angles between the deflection of the QRS and T, ST, and T. They concluded that there is no predictable relationship between the direction of the mean QRS vectors, R vectors, or the ST vectors which will define the normal tracing.

One study, using the vectorcardiographic method, was reported by Horan, et al. (1957). Recordings of the QRS sE -loop¹ (Baylet, 1943) projec-

1 sE is introduced to standardize nomenclature and symbolically represent the spatially oriented loops. The symbol E is used to indicate electric quantities of vectorial (\wedge) nature and the "s" to indicate that

tions in the frontal, left sagittal and horizontal planes in 34 "normal" mongrel dogs, anesthetized with pentobarbital, were reported. The equilateral tetrahedral reference lead system was used. The QRS \hat{sE} -loop was described as a long, narrow, and elliptical loop. Its deviation varied only slightly to the right, left, ventrad or dorsad from a strictly caudal orientation². For most of the dogs, the orientation of the maximal vector of the QRS \hat{sE} -loop lies in the fifth sextant of the triaxial reference system in both the anterior (frontal) and left sagittal plane projections. Similar configuration orientation of the P and T \hat{sE} -loops were often orientated in the second sextant on the triaxial reference system in both the anterior (frontal) and left sagittal plane projections. This indicates some negative T waves. T \hat{sE} -loops, which lie in both the fifth and second sextant of the triaxial reference systems, were described as discordant. Other T \hat{sE} -loops showing notching or irregularities were obtained, but no description or emphasis of these types was made by the authors.

these are spatial in orientation. Therefore P \hat{sE} -loop, QRS \hat{sE} -loop and T \hat{sE} -loop indicate the loops as they appear oriented in space, P \hat{E} -loop, QRS \hat{E} -loop and T \hat{E} -loop indicate the frontal plane projections of the respective spatial loops, unless otherwise stated.

2 Spatial orientation of the spatial vectocardiogram in the dog, as in man, is defined in the anatomic position except that in the dog the term "caudad" corresponds to inferior in man, "cephalad" to superior, "ventral" to anterior and "dorsal" to posterior. For the convenience of the readers who are more familiar with human terminology, the human convention will be used, with the understanding that the dog will be described as standing upright on his hind legs.

Literature Where Pre-treated Normal Dogs Were Used

Several authors reported control electrocardiographic recordings prior to artery ligation in the course of investigation of this effect on the electrocardiogram of the dog. Smith (1918) concluded, that the tracings were "fairly constant in conformation" with the T waves being small in all the leads and negative quite frequently. Extreme variation in the T waves were reported by Barnes and Mann (1934), but they concluded that unless the direction of the T waves was established in the control observations, conclusions drawn after coronary ligation might be confusing. Harris and Hussy (1936) with similar results reported "extreme variability of the so-called 'normal' tracing."

Betlach (1937) reported on controls of a series of four highly trained unanesthetized dogs used in a study of the effects of certain drugs and anesthetics on the electrocardiogram. They reported that variation from day to day in the three limb leads and Lead IV (Wolterth and Wood, 1932) was limited to that of the T wave. This variation could not be related to environmental factors although varying the position of the dogs did introduce additional changes in the records. Measurement of the amplitudes in millivolts of the P, R, and T waves and the intervals in seconds of the P-R and ST were given.

The electrocardiogram of normal dogs was reported by Barnes and Mann (1939) to vary greatly in respect to the pattern of the T waves. These were pretreated dogs used in an electrocardiographic study of experimental localized pericarditis. They concluded that the most stable electrocardiogram

of the dog is one which shows negativity of the T wave in all leads (I, II, III, and IV). No additional data was given.

Control electrocardiograms of 39 dogs were reported by Halkesgring and Wertenberger (1947) as pretreated animals used in a study of the effects of sulfonamide administration on cardiac function. These dogs were trained to lie on their right side while lead II was recorded on a Hindle #3 Electrocardiograph. In the dogs having "normal" electrocardiograms, the heart rate ranges from 62 to 141 per minute and the duration of the QRS ranged from 0.026 to 0.059 seconds. Fourteen of these dogs showed abnormalities in their control electrocardiograms such as sinus arrhythmia and slurred S waves. The T wave was variable with a negative T wave in lead II being common and not considered pathological.

A series of pretreated or control electrocardiograms on the dog was reported by Grollman, et al., (1952) in a study of malignant hypertension. The range and amplitude in millivolts of the P, Q, R, S, and T waves along with the deviation of the ST segment were tabulated. Their conclusions were that the dog has a vertical heart with T waves upright in leads II and III most of the time.

Electrocardiogram After Digitalis

Selenin (1912) observed, in morphinized dogs, an increase in the size of the T wave after the administration of digitoxin. The same observation was reported by Bickel and Pawlow (1913) with moderate doses of strophanthin and digestrophan, but with large doses there was a decrease in the height of the T wave. In the same year Rothberger and Winterberg found no

electrocardiographic changes with small doses and sometimes inversion of the T waves with large doses.

In a study of the relation between cardiac size and cardiac output per minute, Cohn and Stewart (1929) reported the effects of "therapeutic" doses of digifoline on the electrocardiogram of the dog. Although no details were given they do state that the T waves were constantly changing after digifoline. Negative T waves might change size or become positive; positive ones might become negative. These changes persisted for 24 to 48 hours, but the control form always was obtained after four days. The ventricular rate slowed for 2 or 3 hours after injection and returned to normal after 24 hours.

Brams (1929) studied the effects of "therapeutic" and "toxic" doses of various preparations of digitalis on dogs and cats. Although no data or graphs were reported he commented that "practically no change occurred in the electrocardiogram at any time." Constant lowering of the T wave did not occur and in no case was a negative T wave observed. He doubted that changes in the T wave could be used as a criterion of the action of digitalis compounds in the dog, as Pardee (1941) had suggested for the human.

A series of electrocardiograms on dogs were obtained by La Due (1942) in a study of myocardial necrosis and fibrosis occurring as a result of the administration of massive doses of the cardiac glycosides. Every animal in the series showed some electrocardiographic effects from these drugs. The only details presented in their paper were a series of graphs on one dog along with general descriptions of the changes. These were described as alterations in the shape of the T waves, alterations of the S-T

interval with slight depression to depression with "coving," and slight lengthening of the P-R interval. These T and ST changes seemed to occur spontaneously and could not be directly related to the appearance of myocardial necrosis or fibrosis. Large doses also produced arrhythmias.

Levine, et al., (1951) suggested that the "electrocardiographic pattern of digitalis" was produced by slowing of repolarization in the apical region. From a study on anesthetized dogs after the intravenous injection of lanatoside C, four types of evidence for this conclusion was presented. These are: (1) The digitalis pattern (depression of ST and flattening of T in the precordial leads and in VF), (2) absence of QT shortening, (3) abolition of the pattern by the acceleration of apical repolarization (this was accomplished by increasing the dog's temperature to 42 degrees centigrade by radiant heat), and (4) apical localization of ectopic beats produced by digitalis (this was concluded from the observation of qS configuration in VF and an R configuration in VR and VL).

The amount of literature providing electrocardiographic information for the dog is surprisingly limited, particularly in the study of digitalis compounds. This is even more limited when we look for vector concepts in interpretation of the electrocardiograms.

Even the meager experimental information on the "normal" dog which is available does not have direct relevance to the work to be described, wherein a completely new Time-Based vectorcardiographic analysis is to be made. Therefore a detailed analysis of Non-drug (control) dogs will be described.

A critical evaluation of the effects of digitalis compounds on the electrocardiogram of the dog is not found in the literature. The application of the new method, making use of vector concepts, is proposed. The application of the new instrument with the collection of actual numerical data and the use of methods of statistical evaluation of this data should provide a more adequate and quantitative description of the effects of drugs of this type in the dog. Such information may give some insight into the fundamental mechanism of action of these digitalis compounds.

CHAPTER III

METHODS AND MATERIALS

Experimental Animal: Adult mongrel "normal" dogs were used throughout these experiments. The unanesthetized dogs were trained to lie on their right side. The anesthetized dogs were lightly anesthetized with pentobarbital, 25-30 mg per Kg intraperitoneally, and placed on their right side.

The electrocardiographic electrodes were applied with REDUX (Sanborn) electrode paste and secured with electrode straps to shaved areas. These areas were shaved carefully in such a way that they outlined the position of the electrodes for repeated recordings.

The lead system used for recording the standard clinical electrocardiographic method was the usual one for the limb leads, and slight modifications were used for the precordial leads. Their positions were modified according to the method of Lombard and Withan (1955) for comparison with their data. They placed V_1 and V_2 at the level of the fourth intercostal space about 2 cm from the mid-line and V_6 placed in the same plane in the mid-axillary line. V_3 , V_4 , and V_5 were placed equidistant between V_2 and V_6 also on the same plane of the left side.

In the Vectorcardiographic method and the new Time-Based vectorcardiographic method the cube lead system of Grishman (1951) was used throughout. The electrode placement for this lead system is as follows:

(1) A-, B- and C+. One electrode with three cable connections is placed in the right posterior axillary line at the level of the first or second lumbar vertebra.

(2) A+. In the left posterior axillary line at the same level as 1.

(3) B+. In the right anterior axillary line at the same level as 1 and 2.

(4) C-. Over the right scapula in the right posterior axillary line. (See footnote 1 and 2).

See Figure I.

Recording Methods

Standard Clinical Electrocardiogram. The three bipolar leads (leads I, II, and III), augmented unipolar leads (leads AVR, AVL, and AVF), and unipolar leads (precordial leads V_1 to V_6 with modification) were recorded serially on a Sanborn single channel Viso Cardette.

1 The symbol - or + refers to the selected polarity of the electrode as compared with its mate.

2 For ease of the discussion, the dog is viewed as if standing upright on two hind legs.

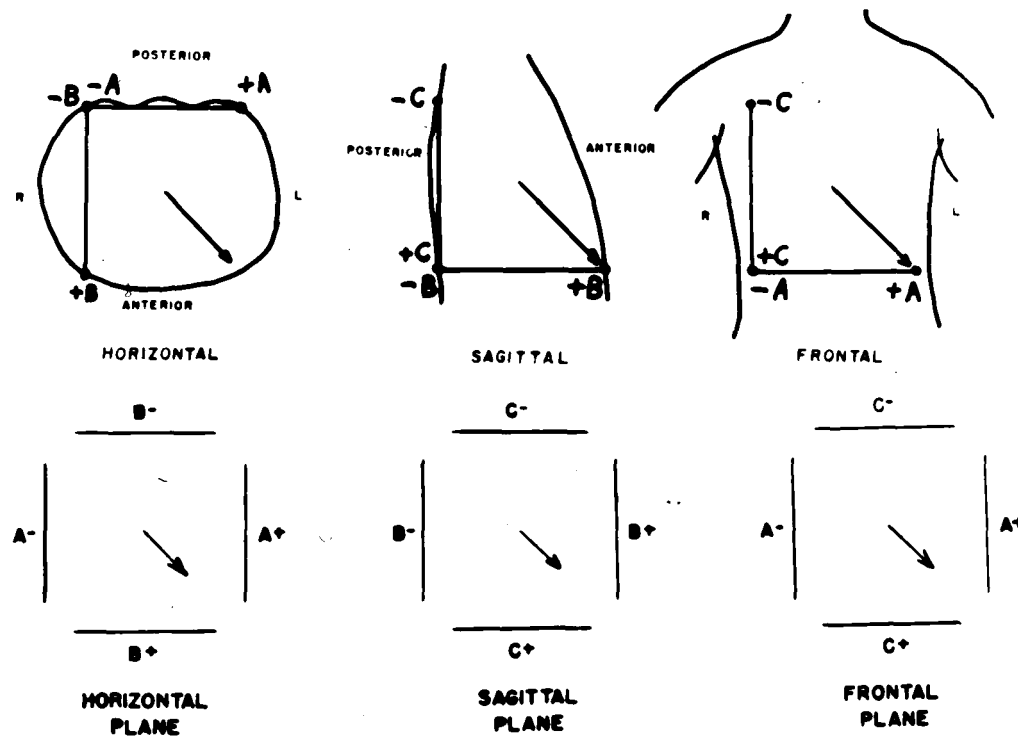


Figure 1—Schematic representation of the method of orthogonal bipolar lead formation. Leads A and B constitute the horizontal projection; B and C, the sagittal; A and C the frontal projection. Polarity is designated as positive or negative. Electrode location is shown on the appropriate body outline as described in text. The arrow points in the direction followed by the electrode beam when a positive charge is introduced during standardization.

The following measurement and analyses was made on each of these leads:

<u>Voltages</u>		<u>Intervals</u>	<u>Axis</u> ³	<u>Angles</u>
P	T	P	QRS	QRS-T
Q	ST	P-R	T	ST-T
R		QRS	ST	
S		QT		

The analysis of the axis of the QRS, T and ST in the frontal plane and the spatial angles between QRS and T, and ST and T were estimated according to the method of Grant and Estes (1950).

This method depends upon the principle that when a vector is perpendicular to the axis of one of the leads, it produces a net zero or a transitional deflection in that lead. If the vector is parallel to the axis of a lead then it writes its largest deflection in that lead. Thus by simply studying the enclosed areas of the deflection on the limb and chest leads (subtracting in one's mind's eye the positive area from the negative area when the deflection is bi-phasic) and deciding whether the net area is conspicuously biggest on one lead or conspicuously smallest (most nearly zero) on another, one knows instantly the spatial direction of the mean vector.

Vectorcardiogram. Recordings as used in this method are essentially the method of Wilson and Johnston (1938) using the lead system of Grishman (1951). Apparatus used in the method is the same apparatus designed and built for Time-Based Vectorcardiographic method, without the use of the

special sweep for the time-based recordings. The description of the apparatus will be presented in the next section under Time-Based Vectorcardiographic method. A block diagram of this apparatus is given in Figure II.

Permanent recordings were obtained by photographing the recording screen with a modified 35 mm Universal movie camera or a Polaroid oscillograph record camera (type 2514).

All the information obtained by the Vectorcardiograph recordings are also obtainable from the Time-Based Vectorcardiograms. However, it was thought desirable to run both methods in order to compare the new Time-Based Vectorcardiogram method to the previous work. A frontal, Saggital and Horizontal lead were recorded and the following measurements taken from these recordings:

<u>Voltage</u>	<u>Angles</u>
QRS _m	QRS _m
QRS _i	QRS _i
QRS _t	QRS _t

Time-Based Vectorcardiograms. This is essentially a new method and no commercial apparatus was available for this study. Figure III shows a block diagram of the components needed for the three dimensional type recordings obtained by this method.

The inputs to the apparatus from the 4 electrodes are controlled by the lead switch. This switch has 5 positions: (1) frontal lead, (2) sagittal lead (with vertical time dimension), (3) horizontal lead, (4) calibrate, and (5) additional sagittal lead with horizontal time dimension (used for additional clarification). With the lead switch in position 4, the calibrate

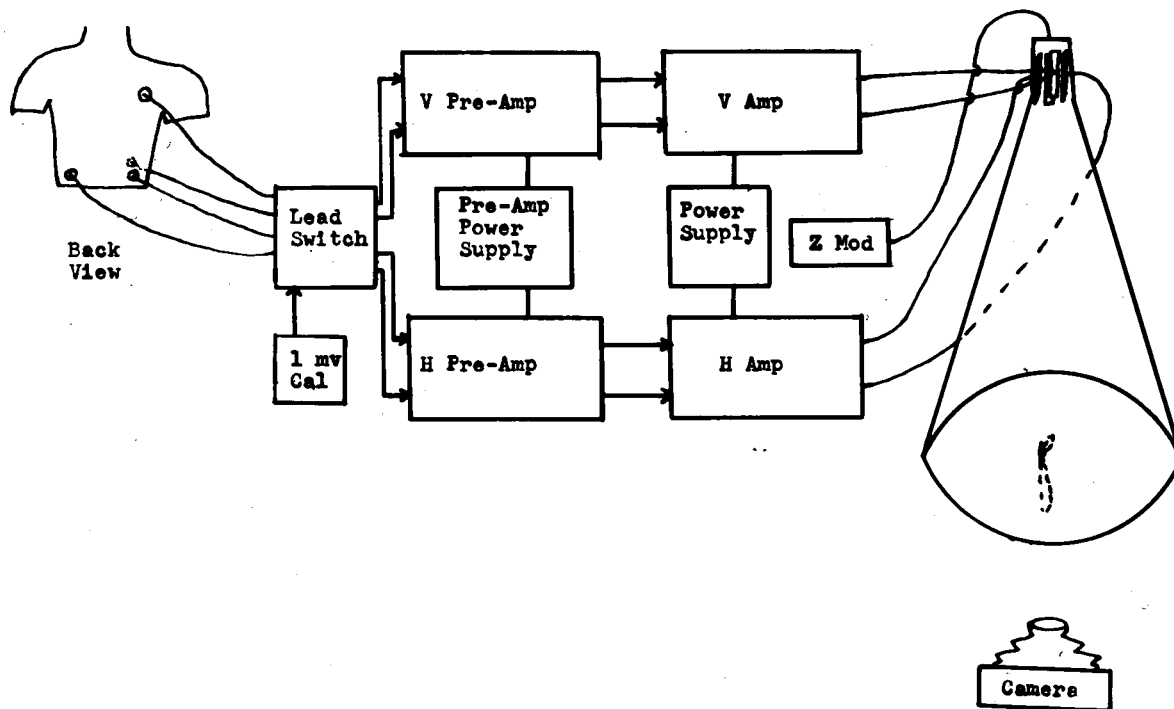


Figure II —Block diagram of VCG

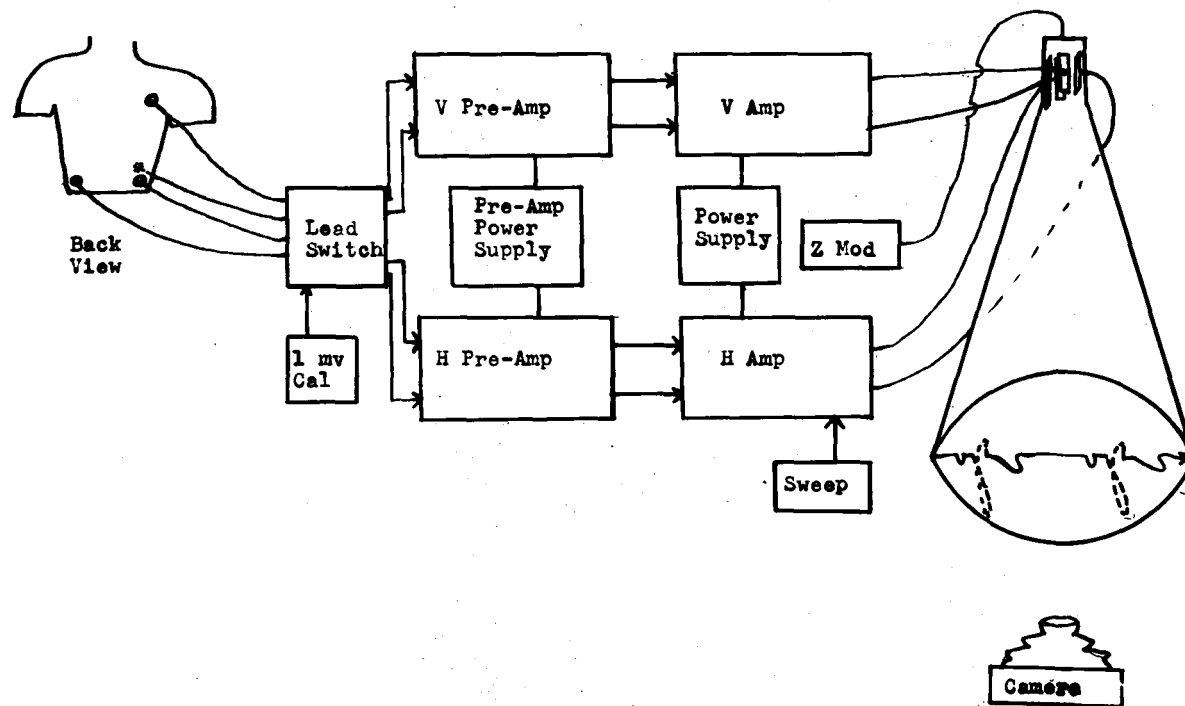


Figure III —Block diagram of Time-Based VCG

switch is introduced. This switch has four positions: (1) No signal (input grounded), (2) 1 mv introduced into the horizontal amplifier, (3) 1 mv introduced in the vertical amplifier, and (4) 1 mv signal introduced in both amplifiers simultaneously, for calibration. The two separate signals from the lead switch are then introduced in the horizontal and vertical pre-amplifiers respectively.

The pre-amplifiers were designed and built for this study. They are feed back, high impedance difference amplifiers with a fixed voltage gain of 100. The schematic diagram for this circuit is given in Figure IV. A special power supply, voltage regulated supply with DC current for the filaments, was designed for these pre-amplifiers. The circuit for this power supply is given in Figure V. The over-all performance of these different pre-amplifiers is DC to 30 kc with a rejection ratio of 1 to 300 with a $\pm 1-1/2$ volt signal.

The signal from each pre-amplifier is then introduced to the respective X and Y amplifiers of the Dumont Cathode-Ray Oscillograph (Type 340). An AC-DC switch determines if they are direct coupled or capacity coupled.

The horizontal (X) and vertical (Y) amplifiers are identical. They have a relative phase shift that will not exceed 3.5° below 10 kc for any X and Y amplitude control settings. Both these amplifiers have a sensitivity of 100 mv peak-to-peak full scale or 25 mv peak-to-peak volt/inch (8.5 mv rms/inch) nominal, and a frequency response that is DC to not down more than 30% at 100 kc.

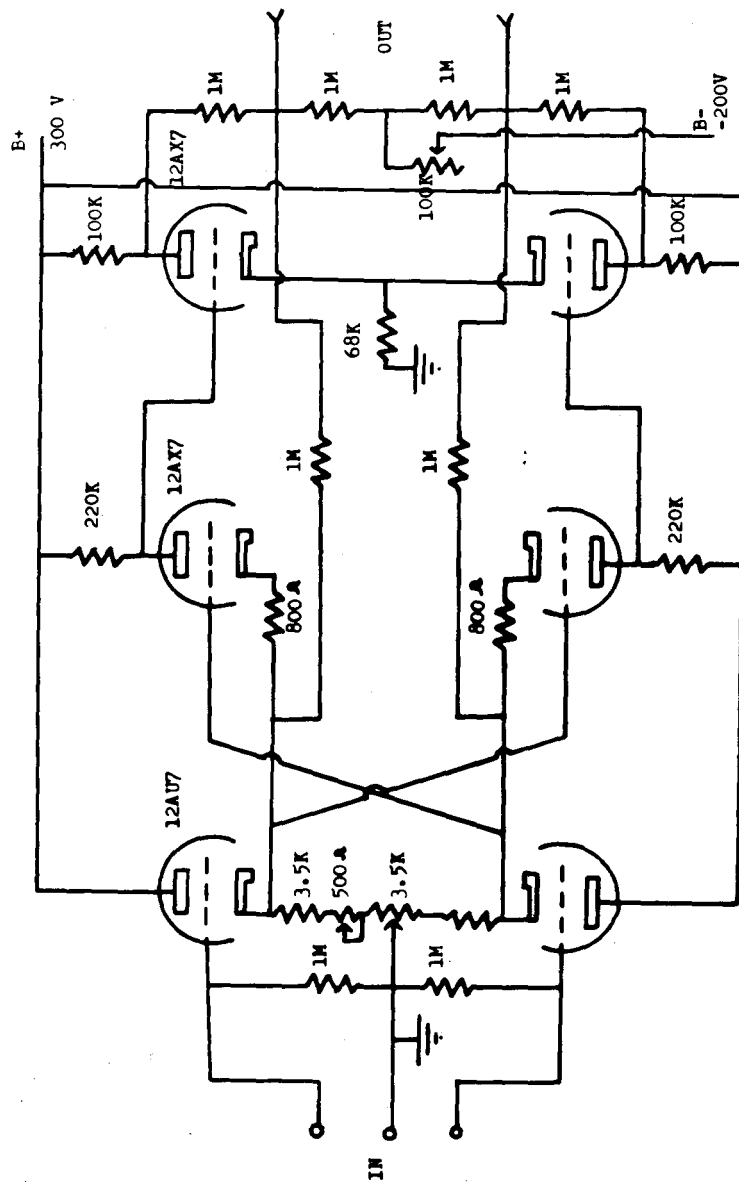


Fig. IV Preamplifier

The over-all performance of each pre-amplifier is DC to over 30 kc. However, it was found that junction potentials were produced between the electrodes, skin, and various other junction or connections which made DC recordings impractical, since these potential were sometimes as large as 15 mv. All the recordings were recorded with the AC-DC switch in the AC position, limiting the low frequency to 0.25 cps. (-6db). The upper limit of the frequency response also was limited because of muscle potentials and other high frequency interference. The usual upper limit of frequency used in clinical electrocardiographic instruments is about 45 to 60 cps (-6db). However, in the present study, there was a definite distortion of the records with this low upper limit of frequency response, so a higher frequency limit was chosen. Very satisfactory tracings were obtained with an upper frequency limitation of 2000 cps (-6db) and this frequency limit was regularly used.

The time dimension for each oscilloscope display was introduced by the addition of a mechanical sweep to the horizontal amplifier unit. The horizontal amplifier was modified so that the signal from the sweep would be added to the horizontal signal without distortion of either. This horizontal sweep was adjusted to 50 mm/second for photography.

Z intensity modulation of the beam was added by the introduction of a negative signal from a Lab-Tronic Inc. signal generator at 500 cps and a positive signal from a specially built generator at 30 cps. The negative signal blanked the tracing every 0.002 seconds and the positive signal intensified the tracing every 0.033 seconds.

Permanent records were made by photographing the oscillograph screen with either a polaroid oscillograph record camera (type 2614) or a modified continuous moving film 35 mm Universal movie camera. In the case of the 35 mm Universal camera the film speed was at the standard rate of speed, 25 mm per second. The sweep circuit was used only for visual observation and recording with the polaroid camera. The records from the moving film camera were preferred because a black tracing on a white background was obtained while the polaroid camera produced a white tracing on a black background.

CALCULATIONS. A record obtained with this apparatus gives the progressive electrical change that occurs in a plane similar but not identical to that used in "timed vectorcardiograms" (Selvester and Griggs, 1957). However, this method differs in that the time dimension in each of the three orthogonal leads is applied in such a way that each lead will have its time dimension perpendicular to the other two. A measurement of the perpendicular height of a particular deflection on each record would measure its X, Y, and Z components in space or its spatial vector. Figure VI shows an example.

Knowing the X, Y, and Z components of a vector, one can calculate the magnitude of the spatial vector, A, as follows:

$$A = \sqrt{X^2 + Y^2 + Z^2} \quad (1)$$

If one also knows the X, Y, and Z components of a second vector B, originating from the same origin as A, the magnitude of vector B can be calculated with formula 1.

In order to calculate these spatial angles the following steps must be taken. A line drawn from the terminal portions of two of these vectors

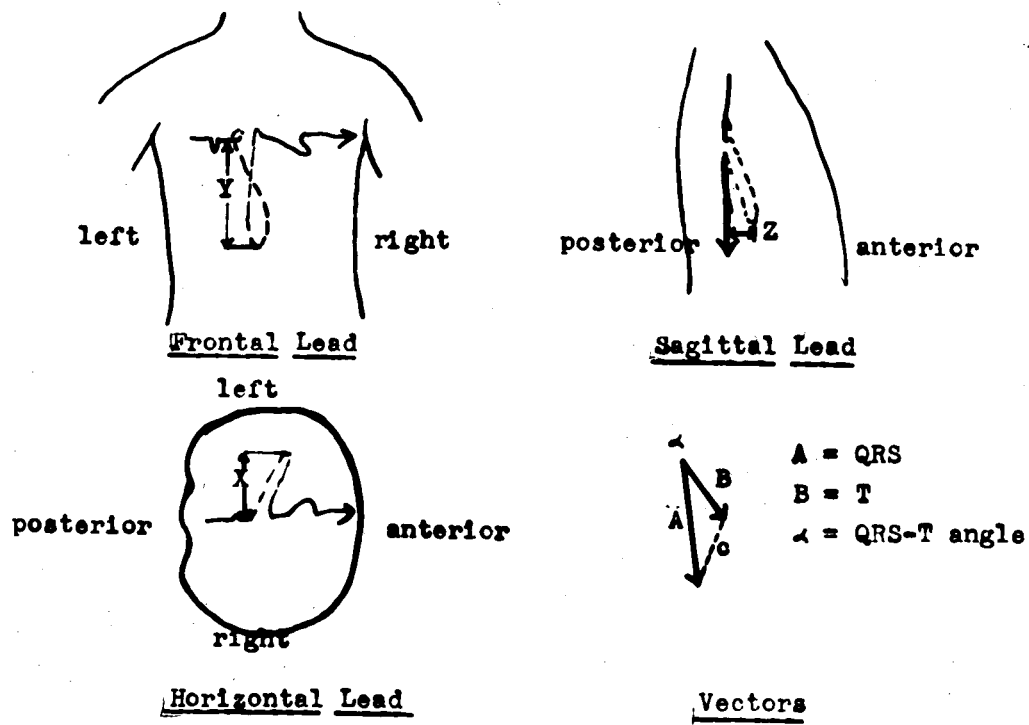


Figure VI --Time-Based VCG Leads with Measurement of Waves.

originating from the same point will form a triangle. The magnitude of this line, c , can be calculated:

$$c = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2 + (z_A - z_B)^2} \quad (2)$$

If three sides of a triangle are known one can calculate the angle, α , opposite the side c (formed with the two spatial vectors) by the law of Cosines:

$$\cos \alpha = \frac{A^2 + B^2 - c^2}{2AB} \quad (3)$$

α is the angle formed by the two measured instantaneous vectors from two electrocardiographic waves.

Measurements and Analysis: The procedures used in making the voltage measurements were essentially those used in clinical human electrocardiographic analysis (Lepeschkin, 1951). These rules can be applied also to our new method, with emphasis being placed on perpendicular measurements.

Three measurements were made on the QRS $\overset{\wedge}{sE}$ -loop wave: (1) QRS_m , or its maximal instantaneous vector, (2) QRS_i or its initial .006 instantaneous vector, and (3) QRS_t or its terminal 0.006 instantaneous vector.

A modification of the terminology of the ST-T wave was made when it became apparent that this wave is regularly quite different in the dog from that of the T wave in the human. In the human, the T wave (ST-T wave) is a smooth curve reflecting a gradual decent of activity, starting at the isoelectric base line, and does not contain any frequencies exceeding 5 cycles per second (Lepeschkin, 1951). On the other hand, in the dog, the T

wave does not have a smooth curve starting at the isoelectric base line, but rather has a deep notched ST-T wave, almost always starting above the base line. In order to adequately describe this wave in the dog it was necessary to subdivide the ST segment portion of the ST-T wave into three sections and to describe a separate T wave.

As shown in Figure VII, the ST_a deflection is determined by measuring the voltage that is produced at the end of the QRS complex. If the rule is followed (Lepeschkin, 1951), the end of the QRS complex is determined by the abrupt change of slope of the QRS to the gradual slope of the ST-T, then the ST_a is the measurement of the voltage of this junction. The ST_b wave is that portion of the ST segment which shows a tendency to return to the base line. The last portion of the ST segment, the ST_c wave, is the portion following ST_b , which usually tends to become positive in voltage and then usually returns to the base line before the actual T wave. The T wave is that portion of the graph from the notch ending the ST_c wave to the point of return to either the base line or the U wave.

(See Figure VII)

The Frontal, Sagittal and Horizontal leads were recorded serially. See Figure 8 for details of orientation for each recording. The following perpendicular voltage measurements were made on each lead:

<u>Voltage</u>			
P	QRS_m	ST_a	T
	QRS_i	ST_b	
	QRS_t	ST_c	

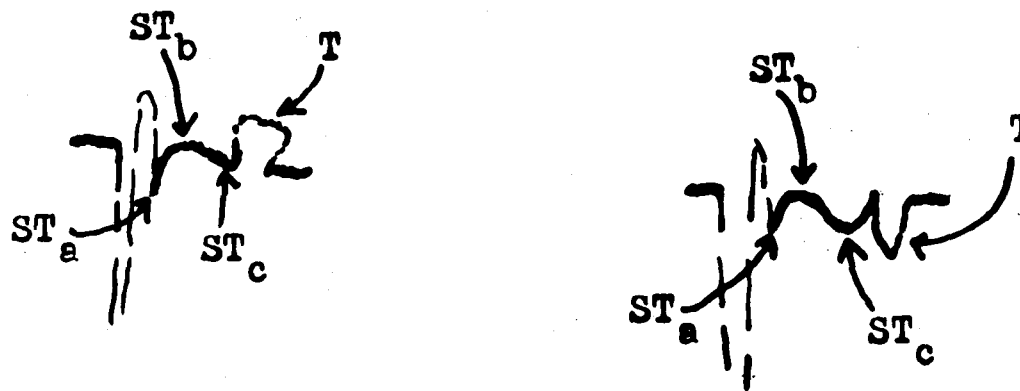


Figure VII --Measurement of ST-T Segment of Dog

From these measurements in each lead calculations using formula (1), following voltage magnitudes in space were made:

Spatial Magnitudes

P	QRS _m	ST _a	T
	QRS _i	ST _b	
	QRS _t	ST _c	

The following angles were calculated using the formulas (1), (2), and (3):

Spatial Angles

P-QRS	QRS _i -QRS	ST _a -QRS	T-QRS
	QRS _t -QRS	ST _b -QRS	
		ST _c -QRS	

From the records the following angles were measured:

Frontal Lead

QRS_m
QRS_i
QRS_t

Sagittal Lead

QRS_m
QRS_i
QRS_t

Measurements of the heart rate and the following intervals were tabulated:

Intervals

P
QRS [^] sE-loop
QT

DESIGN OF EXPERIMENTS AND STATISTICAL ANALYSIS

The general statistical analysis performed on most of the data taken from the different electrocardiographic tracings is based on the methods from

Batson (1957), Villars (1951), Teppet (1952) and Bennett and Franklin (1954).

The student "t" test is utilized where comparison of two means is made. Where more than two comparisons are indicated, analysis of variance is utilized. The major comparisons analyzed using the analysis of variance were:

- 1) Dogs.
- 2) Waves (voltages, spatial magnitudes, spatial angles and intervals of all the waves measured).
- 3) Conditions:
 - a) Non-Drug dog
 - b) after Low-Dose of drug
 - c) after High-Dose of drug

in the anesthetized and unanesthetized series of dogs. However, since we were not interested in the variations between dogs and knew that each electrocardiographic wave is different by definition, we limited the analysis to differences between conditions.

The level of significance is designated by a single plus (+) for a p (probability) value between 0.05 and 0.01, a double plus (++) for a p value between 0.01 and 0.001, and a triple plus (+++) for a p value less than 0.001.

"NORMAL" DOG. This data, obtained under the Non-Drug condition of each series, was described separately under two headings: unanesthetized "normal" dogs, and anesthetized "normal" dogs. A tabulation of the means, standard deviation and range of the data collected from the Non-Drug condition for each electrographic method is given. A statistical comparison of

the means of the values between these two groups of "normal" dogs is made using the student "t" test.

As used here, drug time refers to the interval of time between the administration of the digitalis drug and the recording of the electrocardiogram.

DRUG EXPERIMENTS. Three different series of experiments were undertaken using digitalis preparations. The first series was a study designed to determine if any marked characteristic changes occurred with varying doses of strophanthin G in dogs lightly anesthetized with pentobarbital. A second series of experiments was undertaken on trained unanesthetized dogs, thus eliminating the effect of anesthesia. A third series was designed to control the interval and effect of anesthesia.

SERIES I, ANESTHETIZED DOGS: A group of 7 dogs was studied under light pentobarbital anesthesia (30 mg./Kg., i.p.). Pre-drug (Non-Drug condition) recordings using each of the three electrocardiographic methods were taken. Doses of Strophanthin G between 0.25 and 1.0 mg were administered i.v. and serial electrocardiograms were taken at selected intervals of time after administration of the drug. These drug times varied between 1 and 24 hours.

The data from this series of experiments was statistically analyzed using the student's "t" test for paired experiments. The electrocardiograms from the pre-drug dogs (Non-Drug condition) were used as control and the differences obtained after administration of drug analyzed. The post-drug

electrocardiograms were divided into two groups, those with a drug time of 2 hours or less and those with a drug time of more than two hours. Each group was analyzed separately.

SERIES II, UNANESTHETIZED DOGS: Four dogs were trained to lie on their right side and submit quietly to electrocardiographic recordings. Two recordings with each of the three methods were taken on two different days for the Non-Drug condition. Data for the Low-Dose condition was obtained by taking serial recordings on different days during a period of daily oral administration of 0.1 mg digitoxin. The dose and recording schedule is given in Table 1. Data for the High-Dose condition was obtained from the same set of dogs after an administration of 1 mg digitoxin per day. A recovery period of three months was allowed between the two dose series.

Analysis of variance was used to analyze the data obtained from these drug studies. Three main sources of error were separated, that resulting from differences between dogs, between waves, and between conditions. The means squares used for the calculation of the F ratio were taken following the directions from the tables of the components of variance according to Villars (1951) for Two Factors with w-fold Replication and Three Factors with w-fold Replication. Our primary interest is in the conditions variance. This variance is composed of the Non-Drug, Low-Dose and High-Dose conditions. These conditions were further analyzed by use of the Least Standard Deviation (LSD) method (Villars, 1951).

TABLE 1
DOSE AND ELECTROCARDIOGRAM RECORDING SCHEDULE
FOR SERIES II

Day	Low Dose		High Dose	
	Dose (mg)	Recording	Dose (mg)	Recording
1		+		+
2		+	1	+
3	0.4		1	
4	.1	+	1	
5	.1	+	1	
6	.1		1	
7	.1	+	1	
8	.1		1	
9	.1	+	1	
10	.1		1	
11	.1		1	
12	.1		1	+
13	.1		1	
14	.2	+ ^a	1	
15	.2		1	+
16	.2		1	
17	.2	+		+
18	.2			
19	.2			
20	.2			
21	.2			
22	.4			
23		+		
24				

Digitoxin was given orally.

Plus signs indicate day on which recording was taken by the three methods.

a Indicates that only Dog #15 recording was obtained on that day.

SERIES III, ANESTHETIZED DOGS WITH CONTROL ANESTHESIA: This group of experiments was specially designed to utilize the advantages of the Factorial method of statistical analysis (Batson, 1951 and 1953). Five dogs were anesthetized with pentobarbital (30 mg./Kg., I.P.) and studied. Six conditions were selected and electrocardiographic recordings for each method taken during each condition. Details of these conditions are presented in the results.

The advantages of the factorial statistical method are the simplification and shortening of the arithmetic involved. However, only the differences in the conditions are studied by this method.

The procedure used is simple. The error term used for calculation of the F ratio is the variance of all of the data. The mean squares for each of the comparisons is calculated as follows: (1) sum of squares (SS) - obtained by squaring the difference of sums of the columns to be compared. (2) The degree of freedom (DF) used for calculation of mean square (MS) is the sum of first group's co-efficients squared, times the number of values in the first group. This is added to the sum of the second group co-efficients squared times the number of values in the second group, to give the appropriate degree of freedom.

The data of the spatial magnitudes, derived from the Time-Based Vectorcardiogram, were transformed into ratios, using the QRS_m spatial voltage as 100. Such ratios would tend to eliminate variations in field distortions, electrode and skin resistances and have been suggested for routine electrocardiograph analysis by Lepeschkin (1951). This transformation is

possible, unique and especially useful in analyzing data from this method because the actual magnitude of each wave in space is calculated independently regardless of its orientation in space. This eliminates the errors in the magnitudes of the waves obtained with other methods whose magnitudes of the waves change with spatial orientation.

CHAPTER IV

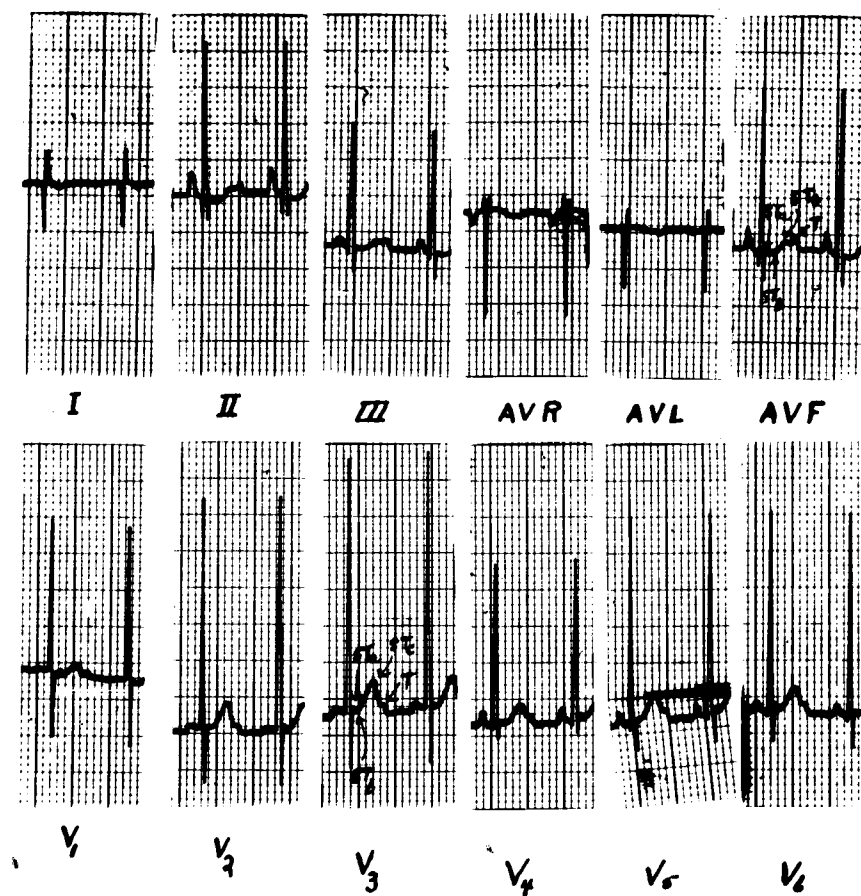
RESULTS

"NORMAL" DOG

A statistical description of the electrocardiograms of the pre-treated ("normal" adult) dogs is given for each of the three methods. One of the methods, the Time-Based vectorcardiographic method, is new and no previous data is presented in the literature. Further, not all of the standard clinical electrocardiographic leads have been described statistically and only scanty vectorcardiographic data is available. These pre-treated dogs are separated into two groups and separate descriptive statistical analysis of these "normal" dogs given. One group contains 8 electrocardiograms with each method from 4 unanesthetized trained dogs and the second 18 electrocardiograms from 13 dogs anesthetized with pentobarbital, 30 mg/Kg.

Standard Clinical Method: The means, standard deviations, and ranges of the voltages for all the waves of the 12 standard clinical electrocardiographic leads are given in Tables 2a and 2b for the unanesthetized trained dogs and in Tables 3a and 3b for the anesthetized dogs. For typical records see Figures VIII and IX.

Table 4 has the means, standard deviation, and range of values for the heart rates, intervals, and axes of the various waves for the unanesthetized dogs and Table 5, similar values for the anesthetized dogs.



Dog 21

DOG 21

FIGURE VIII

STANDARD ELECTROCARDIOGRAM: A CONTROL RECORD OF ANESTHETIZED DOG

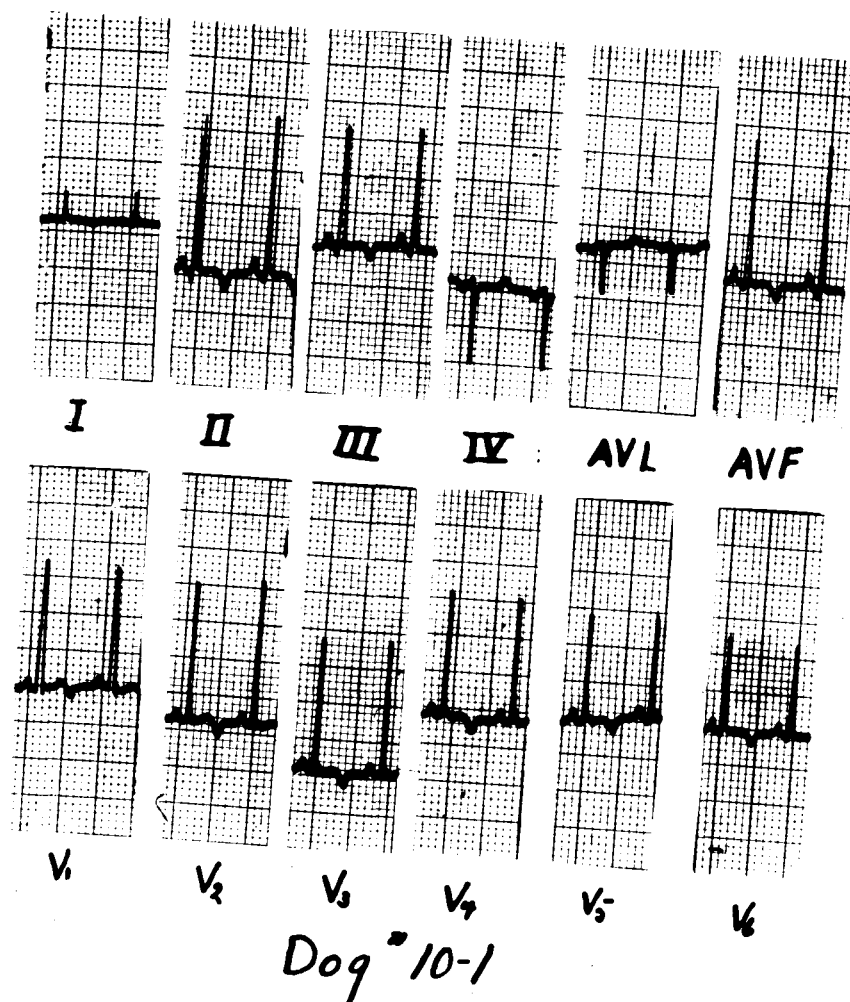
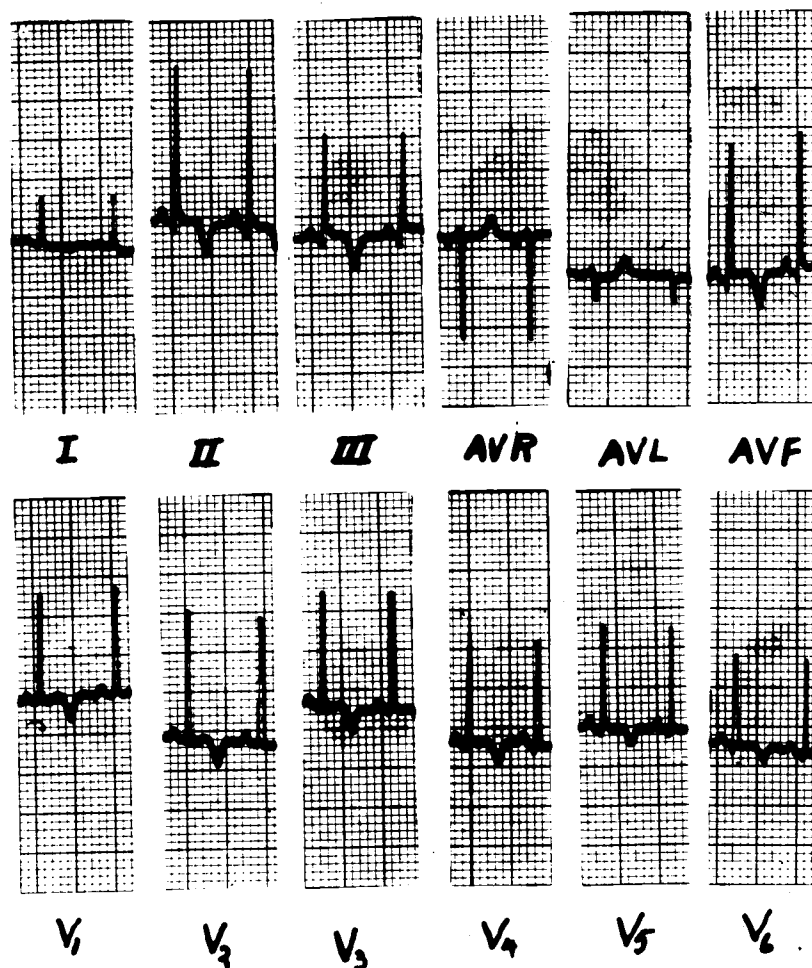


FIGURE IXa

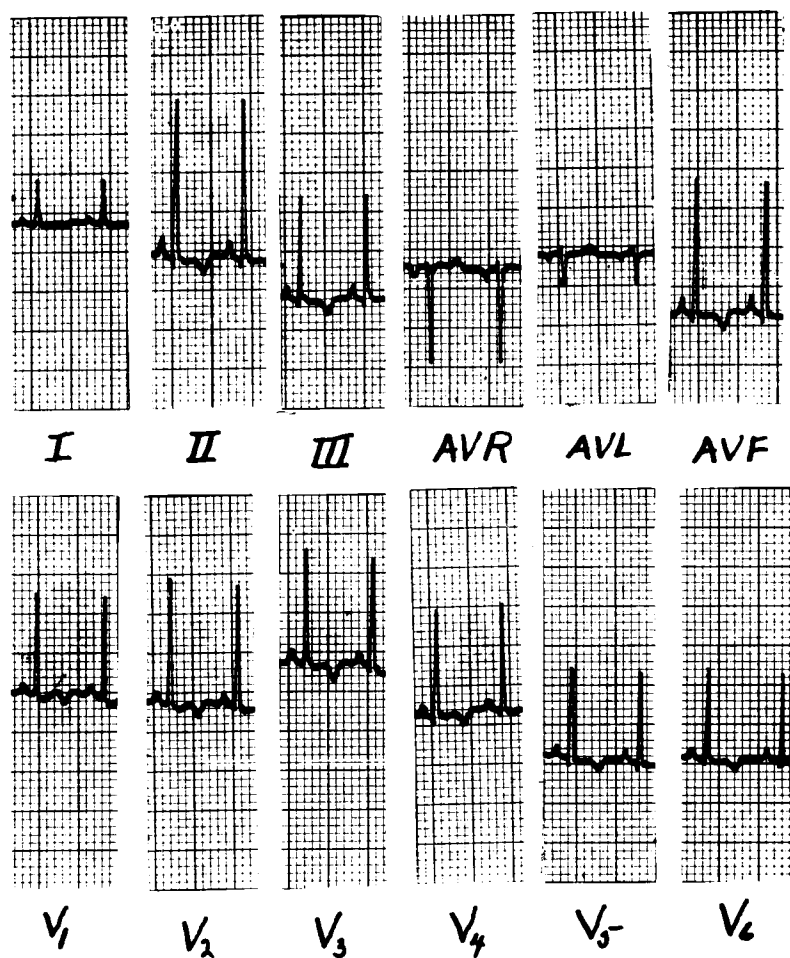
STANDARD ELECTROCARDIOGRAM: A CONTROL RECORD OF ANESTHETIZED DOG



Dog *10-2

FIGURE IXb

STANDARD ELECTROCARDIOGRAM: A RECORD OF THE SAME ANESTHETIZED DOG
ONE HOUR AFTER 0.25 mg OUABAIN



Dog # 10-3

FIGURE IXc

STANDARD ELECTROCARDIOGRAM: A RECORD OF THE SAME ANESTHETIZED DOG
FOUR HOURS AFTER 0.25 mg OUABAIN

TABLE 2a

MEANS OF VOLTAGE MEASUREMENTS OF THE WAVES FROM THE
LIMB LEADS - STANDARD ELECTROCARDIOGRAM

Wave		Limb Leads					
		I	II	III	AVR	AVL	AVF
P	Mean	.03	.11	.09	.07	.04	.11
	S.D.*	±.02	±.02	±.07	±.04	±.04	±.04
	Range	.01-.05	.08-.12	.03-.19	.02-.12	.01-.12	.08-.12
Q	Mean	.10	.21	.12	.12	.09	.17
	S.D.	±.13	±.10	±.07	±.07	±.09	±.10
	Range	0-.39	.10-.35	0-.22	.02-.21	0-.24	.01-.29
R	Mean	.57	1.09	.78	.80	.46	.93
	S.D.	±.24	±.41	±.30	±.30	±.43	±.39
	Range	.22-.85	.67-1.82	.40-1.22	.12-1.12	.17-1.18	.34-1.49
S	Mean	0	.08	.13	.19	.10	.09
	S.D.	± 0	±.08	±.17	±.42	±.18	±.12
	Range	0-.02	0-.21	0-.48	0-1.23	0-.46	0-.31
T	Mean	.01	.08	.02	-.03	.03	.02
	S.D.	±.10	±.08	±.10	±.15	±.06	±.10
	Range	-.20-.05	-.22-.26	-.10-.18	-.26-.11	-.06-.12	-.15-.13
ST	Mean	0	0	0	0	.01	-.0
	S.D.	±.03	±.05	± 0	±.02	±.02	±.03
	Range	0-.08	-.03-.02	-.02-.03	-.02-0	0-.06	-.02-.02

This group of dogs was trained and unanesthetized.

All the measurements are in millivolts (standardization of
1 cm = 1 mv.)

Means - 8 electrocardiograms on 4 dogs.

* Standard Deviation.

TABLE 2b

MEANS OF VOLTAGE MEASUREMENTS OF THE WAVES FROM THE
CHEST LEADS - STANDARD ELECTROCARDIOGRAM

Wave		Chest Leads					
		V ₁	V ₂	V ₃	V ₄	V ₅	V ₆
P	Mean	.05	.04	.05	.05	.04	.03
	S.D.*	±.03	±.02	±.04	±.03	±.02	±.02
	Range	0-.08	.01-.07	.01-.10	.02-.10	.01-.08	.01-.05
Q	Mean	.01	.03	.03	.02	.02	.04
	S.D.	±.01	±.02	±.03	±.02	±.02	±.03
	Range	0-.03	0-.08	0-.08	0-.06	0-.05	.01-.10
R	Mean	.91	.97	.97	.90	.93	.91
	S.D.	±.28	±.21	±.20	±.20	±.13	±.16
	Range	.62-1.20	.71-1.22	.64-1.23	.60-1.19	.74-1.12	.72-1.18
S	Mean	.09	.10	.08	.06	.06	.07
	S.D.	±.08	±.10	±.07	±.05	±.06	±.05
	Range	0-.19	0-.24	0-.16	0-.15	.02-.18	.02-.19
T	Mean	.11	.08	.10	.10	.05	.05
	S.D.	±.11	±.12	±.08	±.07	±.10	±.10
	Range	.01-.32	-.12-.26	.02-.74	.02-.20	-.12-.14	-.10-.22
ST	Mean	0	0	0	0	.01	.01
	S.D.	±.06	±.04	± 0	±.01	±.01	±.01
	Range	-.05-.02	-.02-.03	-.01-.02	-.01-.03	-.02-.03	0-.02

This group of dogs was trained and unanesthetized.

All the measurements are in millivolts (standardization of
1 cm = 1 mv.)

Means - 8 electrocardiograms on 4 dogs.

* Standard Deviation.

TABLE 3a

MEANS OF VOLTAGE MEASUREMENTS OF WAVES OF LIMB LEADS,
ANESTHETIZED DOG - STANDARD ELECTROCARDIOGRAM

Wave		I	II	III	AVR	AVL	AVF
P	Mean	.25	.19	.14	.07	.07	.23
	S.D.*	±.08	±.10	±.06	±.05	±.05	±.08
	Range	.09-.49	.02-.37	.02-.23	.02-.20	-.02-.20	.05-.38
Q	Mean	.11	.16	.11	.11	.05	.17
	S.D.	±.12	±.12	±.10	±.08	±.07	±.11
	Range	0-.41	0-.41	0-.30	0-.28	0-.27	0-.40
R	Mean	.46	1.76	1.52	1.23	.66	1.87
	S.D.	±.18	±.78	±.50	±.52	±.30	±.67
	Range	.20-.75	.27-3.28	.76-2.57	.01-2.25	.12-1.26	.90-3.27
S	Mean	.06	.10	.11	.04	.07	.12
	S.D.	±.24	±.12	±.13	±.07	±.10	±.14
	Range	0-1.00	0-.33	0-.36	0-.22	0-.28	0-.42
T	Mean	-.01	.04	.02	.06	-.01	-.07
	S.D.	±.07	±.30	±.33	±.16	±.09	±.26
	Range	-.15-.10	-.62-.49	-.37-1.03	-.34-.22	-.12-.19	-.59-.41
ST	Mean	.01	.01	0	0	-.01	0
	S.D.	±.02	±.05	±.21	±.21	±.02	±.31
	Range	-.05-.05	-.20-.15	-.09-.12	-.10-.09	-.08-.02	-.10-.19

All the measurements are in millivolts (standardization of
1 cm = 1 mv.)

Means - 18 electrocardiograms on 13 dogs.

Pentobarbital anesthesia, 30 mg/Kg.

* Standard Deviation.

TABLE 3b

MEANS OF VOLTAGE MEASUREMENTS OF WAVES OF CHEST LEADS,
ANESTHETIZED DOG - STANDARD ELECTROCARDIOGRAM

Wave		V ₁	V ₂	V ₃	V ₄	V ₅	V ₆
P	Mean	.10	.13	.14	.18	.17	.15
	S.D.*	±.06	±.06	±.06	±.04	±.05	±.04
	Range	0-.20	.02-.23	.01-.23	.10-.25	.11-.28	.07-.21
Q	Mean	0	0	.01	.06	.13	.23
	S.D.	± 0	± 0	±.02	±.07	±.10	±.17
	Range	0-0	0-0	0-.07	0-.27	.02-.32	.05-.53
R	Mean	1.59	2.33	2.42	1.82	1.57	1.25
	S.D.	±.61	±.57	±.69	±.64	±.69	±.40
	Range	.28-2.33	1.00-3.07	.97-3.65	.01-3.62	.70-2.90	.50-2.78
S	Mean	.47	.29	.22	.08	.08	.05
	S.D.	±.39	±.29	±.26	±.11	±.13	±.10
	Range	0-1.20	0-.79	0-.76	0-.40	0-.46	0-.40
T	Mean	.14	.03	.02	-.06	0	.02
	S.D.	±.24	±.33	±.33	±.23	±.23	±.21
	Range	-.17-.63	-.50-.66	-.45-.73	-.50-.35	-.43-.39	-.32-.38
ST	Mean	.04	.05	.04	.17	.02	.01
	S.D.	±.10	±.14	±.13	±.08	±.04	±.04
	Range	-.14-.30	-.16-.32	-.11-.29	-.16-.18	.03-.10	-.05-.14

All the measurements are in millivolts (standardization of
1 cm = 1 mv.)

Means - 18 electrocardiograms on 13 dogs.

Pentobarbital anesthesia, 30 mg/Kg.

* Standard Deviation.

TABLE 4

MEANS OF HEART RATE, INTERVALS, AXES AND ANGLES FROM
STANDARD ELECTROCARDIOGRAMS OF UNANESTHETIZED
NORMAL DOGS

	Heart Rate Beats/ Minute	Intervals/			
		P-R	Q-T	RR'	QRS
Mean	70	.15	.24	.76	.03
S.D.*	±33	±.03	±.02	±.08	± 0
Range	33 - 113	.13 - .20	.21 - .26	.68 - .89	.03 - .03
N**	8	8	8	8	8

	Axes//, Frontal Plane				
	QRS	T	ST ₀	S-T ₊	ST-
Mean	71°	54°	No	60°	-100°
S.D.	±12°	±78°	Wave	±42°	
Range	50° - 85°	-130° - 100°		30° - 90°	
N	8	8	5	2	1

	Spatial Angles//			
	QRS-T		ST-T	
	+ T Waves	- T Waves		
Means	21°	152°	No	60°
S.D.	±18°	±49°	Wave	±62°
Range	0° - 45°	95° - 180°		10° - 130°
N	5	3	5	3

/ Intervals in seconds.

// Axes and angles in degrees.

* Standard Deviation.

** Number of Observations.

TABLE 5

MEANS OF THE HEART RATE, INTERVALS, AXES, AND ANGLES FROM
ANESTHETIZED DOGS - STANDARD ELECTROCARDIOGRAM

	Heart Rate Beats/ Minute	Intervals \neq			
		P-R	QRS	QT	RR $^{\circ}$
Mean	150	.09	.03	.218	.423
S.D.*	± 31	$\pm .01$	$\pm .00$	$\pm .044$	$\pm .109$
Range	94 - 210	.08 - .11	.03 - .04	.16 - .36	.288 - .600
N**	18	18	18	18	18

	Axes $\neq\neq$, Frontal Plane					
	QRS	T +	T -	ST $_o$	ST -	ST +
Mean	79 $^{\circ}$	87 $^{\circ}$	-95 $^{\circ}$	No	-92 $^{\circ}$	74 $^{\circ}$
S.D.	$\pm 14^{\circ}$	$\pm 16^{\circ}$	$\pm 6^{\circ}$	Wave	$\pm 18^{\circ}$	$\pm 30^{\circ}$
Range	65 $^{\circ}$ - 125 $^{\circ}$	60 - 100 $^{\circ}$	-88 $^{\circ}$ - -105 $^{\circ}$		-75 $^{\circ}$ - -120 $^{\circ}$	30 - 115 $^{\circ}$
N	18	10	8	5	5	8

	Spatial Angles $\neq\neq$				
	QRS-T		ST-T	-ST	+ST
	+ T	- T			
Mean	27 $^{\circ}$	173 $^{\circ}$	No	146 $^{\circ}$	9 $^{\circ}$
S.D.	$\pm 29^{\circ}$	$\pm 4^{\circ}$	Wave	$\pm 37^{\circ}$	$\pm 25^{\circ}$
Range	5 $^{\circ}$ - 70 $^{\circ}$	85 $^{\circ}$ - 180 $^{\circ}$		85 $^{\circ}$ - 170 $^{\circ}$	5 $^{\circ}$ - 20 $^{\circ}$
N	10	8	5	8	5

\neq Intervals in seconds.

$\neq\neq$ Axes and angles in degrees.

* Standard Deviation.

** Number of Observations.

Anesthesia - Pentobarbital, 30 mg/Kg.

A statistical comparison of the voltages using the "t" test analysis was made for each wave, comparing the unanesthetized with the anesthetized dogs. Tables 6a and 6b give the differences in the means, "t" values, and significance of these comparisons for the two groups of dogs. A summary of these analyses shows that the voltage of the P wave in the anesthetized group of dogs is significantly larger (0.1% level) in leads I, V_5 , and V_6 . The R waves in leads V_5 and V_6 are significantly greater in the anesthetized group of dogs, and the Q wave in the same group is larger in lead V_6 .

Statistical comparison of the differences of means from the same two groups of dogs for the heart rates and the electrocardiographic intervals is presented in Table 7. The heart rates of the anesthetized dogs is significantly higher (0.1% level) than those of the unanesthetized dogs. The P-R and RR' intervals were significantly shorter (0.1% level) in the anesthetized dogs.

Vectorcardiograms: Typical QRS \hat{sE} -loop projections in the frontal, sagittal, and horizontal plane leads are given in Figures X, XI, and XII. Most of the QRS \hat{E} -loops in the frontal plane lead are long narrow ellipses. The sagittal plane \hat{E} -loops are also ellipses, but are usually less narrow. The QRS \hat{E} -loop in the horizontal plane lead (Figures X, XI, and XII) are usually of small magnitude indicating a thin \hat{sE} -loop orientated very vertically. A counter clockwise inscription of the tracing was found in all the frontal plane projections while a clockwise inscription was found in all the sagittal plane lead projections in both groups of dogs. The horizontal plane projections were usually very small and the rotation was in either

TABLE 6a

MEAN DIFFERENCES OF VOLTAGE AND STATISTICAL COMPARISONS
OF UNANESTHETIZED AND ANESTHETIZED DOGS -
STANDARD ELECTROCARDIOGRAM

Wave		I	II	III	AVR	AVL	AVF
P	Mean Diff. t* Sig.**	.22 10.9 (2) +++	.08 <1	.05 <1	0 <1	.03 <1	.12 <1
Q	Mean Diff. t Sig.	.01 <1	.05 <1	.01 <1	.01 <1	.04 <1	.16 <1
R	Mean Diff. t Sig.	.11 1.1 -	.67 <1	.74 <1	.43 <1	.20 <1	.96 <1
S	Mean Diff. t Sig.	.06 1.1 -	.02 <1	.02 <1	.16 <1	.03 <1	.03 <1
T	Mean Diff. t Sig.	.02 <1	.04 <1	0 <1	.09 <1.	.04 <1	.18 <1
S-T	Mean Diff. t Sig.	.01 <1	.01 <1	0 <1	0 <1	.02 <1	0 <1

Mean differences are in millivolts.

(1) Unanesthetized group of dogs - voltage larger.

(2) Anesthetized group of dogs - voltage larger.

* "t" test

** Significance

TABLE 6b

MEAN DIFFERENCES OF VOLTAGE AND STATISTICAL COMPARISONS
OF UNANESTHETIZED AND ANESTHETIZED DOGS -
STANDARD ELECTROCARDIOGRAM

Wave		V ₁	V ₂	V ₃	V ₄	V ₅	V ₆
P	Mean Diff. t* Sig.**	.05 1	.09 1	.09 1	.13 1	.13 9.2 (2) +++	.12 ⁽²⁾ 10.0 +++
Q	Mean Diff. t Sig.	.01 1	.03 1	.02 1	.04 1	.11 1	.19 ⁽²⁾ 4.63 +++
R	Mean Diff. t Sig.	.68 1	1.36 1	1.45 1	.92 1	.64 3.78 (2) ++	.34 ⁽²⁾ 2.09 +
S	Mean Diff. t Sig.	.38 1	.19 1	.14 1	.02 1	.02 1	.02 1
T	Mean Diff. t Sig.	.03 1	.05 1	.08 1	.16 1	.05 1	.03 1
S-T	Mean Diff. t Sig.	.04 1	.05 1	.04 1	.17 1	.01 1	.01 1

Mean differences are in millivolts.

(1) Unanesthetized group of dogs - voltage larger.

(2) Anesthetized group of dogs - voltage larger.

* "t" test

** Significance

TABLE 7

MEAN DIFFERENCES IN MILLIVOLTS OF HEART RATES AND
INTERVALS AND STATISTICAL COMPARISON OF
UNANESTHETIZED AND ANESTHETIZED DOGS -
STANDARD ELECTROCARDIOGRAM

	Heart Rate Beats/ Minute	Intervals		
		P-R	Q-T	RR'
Difference in Means	80	.06	.02	.44 ⁽¹⁾
t*	5.71 ⁽²⁾	6.0 ⁽¹⁾	1.66 ⁽¹⁾	11.28 ⁽¹⁾
Sig.**	+++	+++		+++

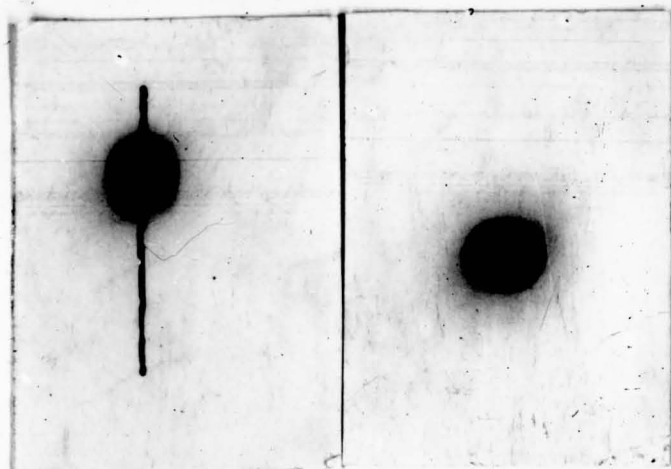
Mean differences in millivolts (standardization of
1 cm = 1 mv.)

(1) Unanesthetized group of dogs has high mean.

(2) Anesthetized group of dogs has high mean.

* "t" test

** Significance



frontal horizontal

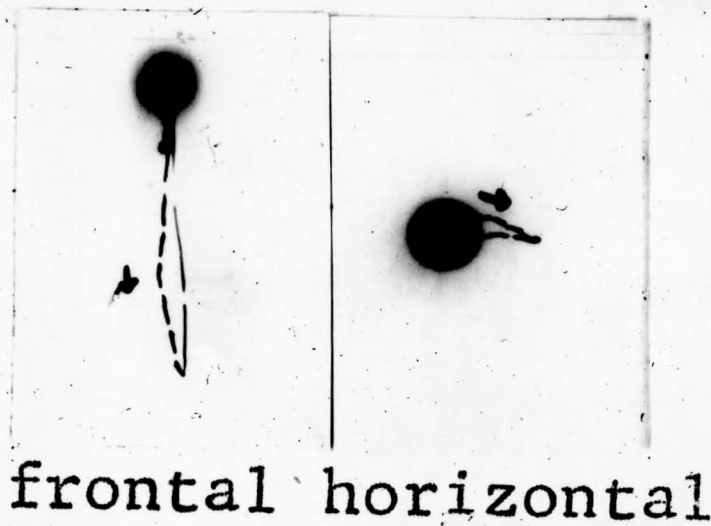


1 mv sagittal

DOG 11

FIGURE X

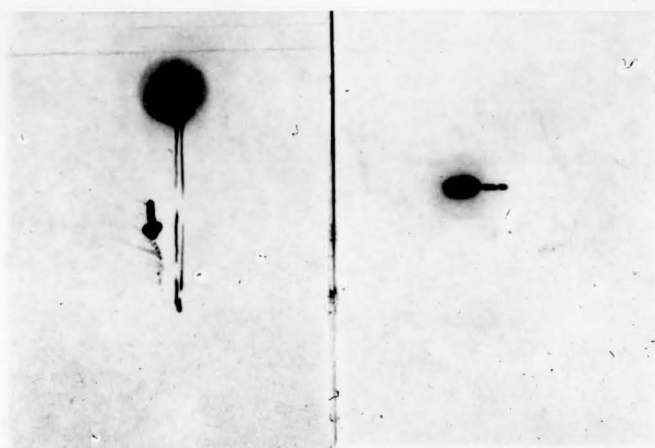
VECTOCARDIOGRAM: QRS sE-LOOP WITH A TERMINAL CEPHALIC INSCRIPTION



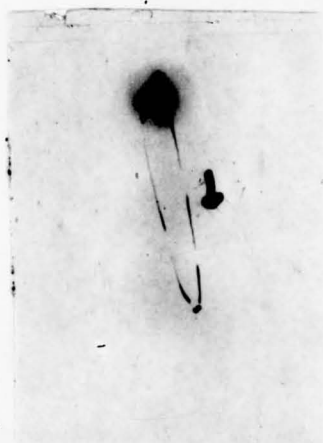
1 mv sagittal
DOG 14

FIGURE XI

VECTOCARDIOGRAM: QRS [^]SE-LOOP WITH ONLY A CAUDAL INSCRIPTION



frontal horizontal



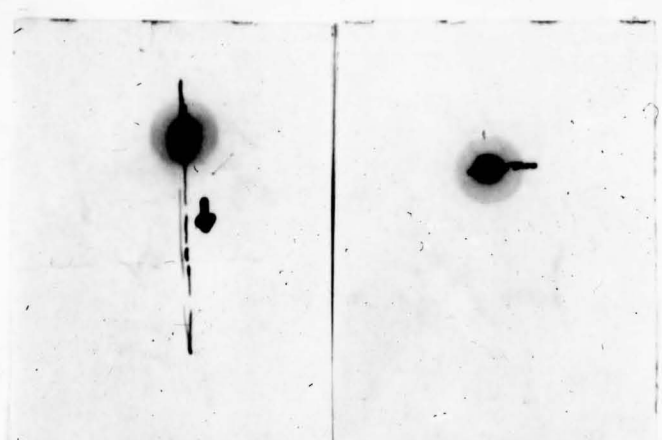
1 mv sagittal

DOG 19

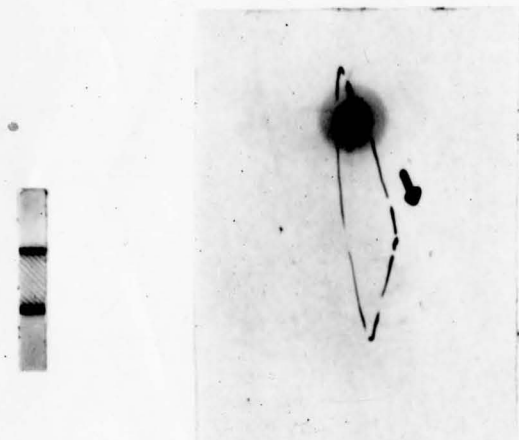
FIGURE XII

VECTOCARDIOGRAM: QRS $\overset{\wedge}{sE}$ -LOOP WITH ONLY A CAUDAL INSCRIPTION

AFTER PERIODICALLY ANESTHESIA



frontal horizontal



1 mv sagittal

DOG 21-1

FIGURE XIIIa
 VECTORCARDIOGRAM: A COUNTERCLOCKWISE ROTATION OF THE QRS \vec{E} -LOOP
 AFTER PENTOBARBITAL ANESTHESIA
 VECTORCARDIOGRAM: \wedge NARROW THIN QRS \vec{E} -LOOP IN FRONTAL LEAD,
 \wedge MORE OVOID \vec{E} -LOOP IN SAGITTAL LEAD IMMEDIATELY
 AFTER PENTOBARBITAL ANESTHESIA



1 mv

sagittal

DOG 21-2

FIGURE XIIIb

VECTOCARDIOGRAM: AFTER THREE HOURS UNDER PENTOBARBITAL ANESTHESIA A COUNTER CLOCKWISE ROTATION OF THE QRS \hat{E} -LOOP OCCURRED SO THAT A MORE OVOID QRS \hat{E} -LOOP WAS INSCRIBED IN THE FRONTAL LEAD AND A THIN QRS \hat{E} -LOOP INSCRIBED IN THE SAGITTAL LEAD

direction depending on whether the frontal plane loops were oriented slightly to the right or to the left. An isolated but interesting observation was obtained with dog #21 (see Figure XIIIa and XIIIb). Vectorcardiographic recordings taken during the first recording period gave a QRS \hat{sE} -loop projection in the frontal plane that was long and very narrow and a sagittal plane lead projection \hat{E} -loop that was more ovoid. Recordings from the second period or three hours later showed a clockwise rotation of the QRS \hat{sE} -loop resulting in a thicker ellipse being found in the frontal plane projection and the very thin ellipse being found in the sagittal plane projection, indicating a clockwise rotation in the electrical axis.

Two major types of QRS \hat{sE} -loops may be described, depending on whether the QRS_t vector has a caudal or a cephalad inscription. In 8 dogs the QRS_t vector had a caudal inscription, and in 9 dogs the QRS_t vector had a cephalad inscription. See Figures X and XI for examples. The initial inscription of each of these types of QRS \hat{sE} -loops is slower until the maximum instantaneous vector is reached, then there is a more rapid phase, followed by a terminal slowing. Most of the QRS \hat{sE} -loops are slightly open. In those loops which have a QRS_t vector with a cephalad inscription, the slowing is found in the terminal inscription where the potential is returning to the zero point. Many of the QRS \hat{sE} -loops show an additional irregularity or marked slowing at the portion of the loop just before the maximal instantaneous vector is reached.

The magnitude and direction of the maximal mean instantaneous vector in the frontal and right sagittal plane projections are given in

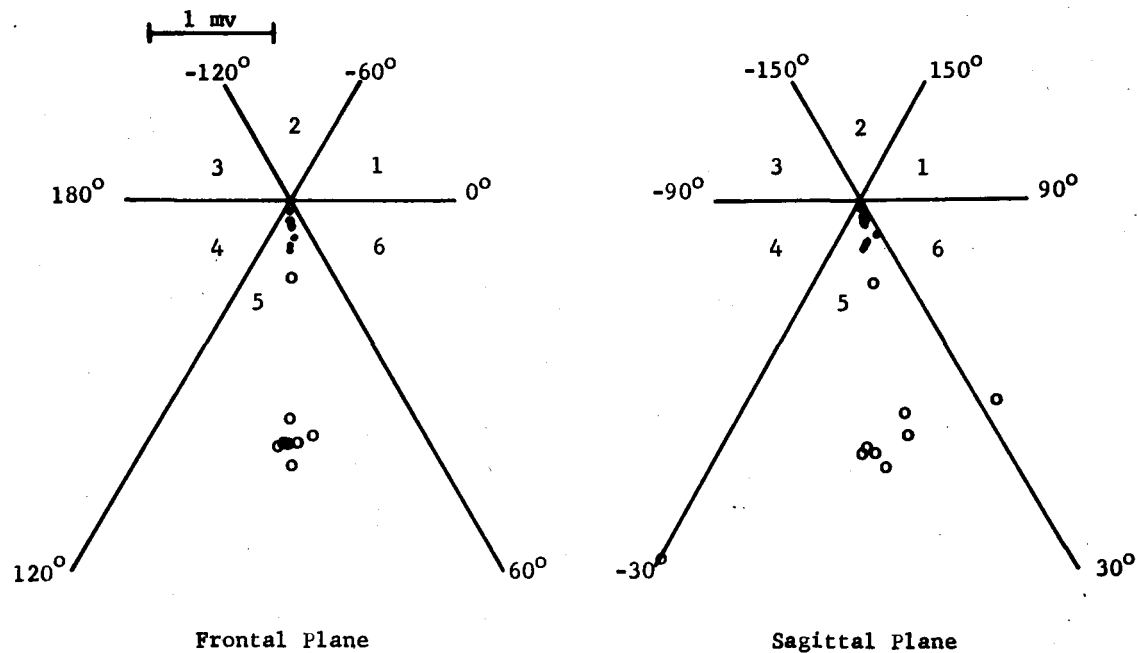


Figure XIV - Magnitude and direction of the maximal mean instantaneous vectors of the frontal and right sagittal plane projections of 8 QRS sE-loops (circles) and 8 T sE-loops (dots) on triaxial reference frames. These measurements are from 4 unanesthetized dogs. Numbers indicate the sextents for each plane.

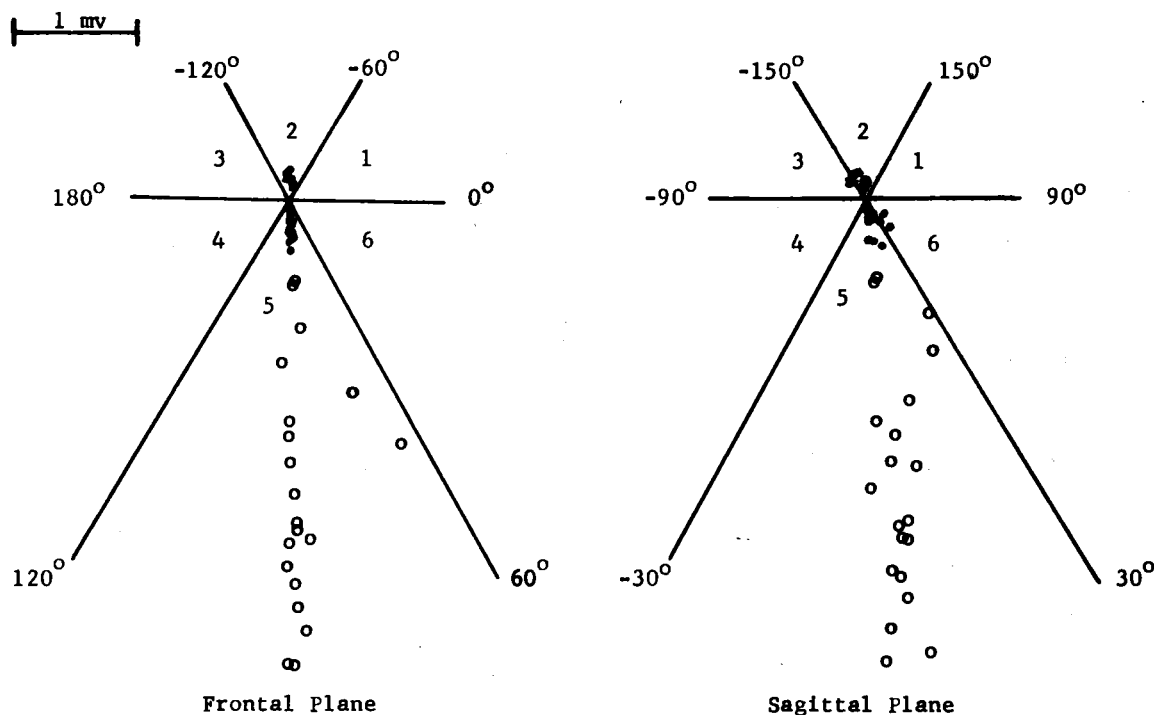


Figure XV - Magnitude and direction of the maximal mean instantaneous vectors in the frontal and right sagittal plane projections of 19 QRS sE-loops (circles) and 19 T sE-loops (dots) on a triaxial reference frame. This group of dogs was anesthetized with pentobarbital, 30 mg/Kg. Numbers indicate the sextent for each plane.

Figure XIV for the anesthetized dogs and in Figure XV for the unanesthetized trained dogs, using the triaxial reference frame (Horan, et al, 1957). The circles in Figures XIV and XV give the maximal vector of the QRS \hat{sE} -loop and the dots the maximal vector of the T \hat{E} -loops. All of the maximal QRS \hat{E} -loops vectors lie in the fifth sextant in both the frontal and right sagittal plane projections in both series of dogs. The maximal T \hat{E} -loops (Figure XIV) of the unanesthetized trained dogs all lie in the fifth sextant in both plane projections indicating they all had positive T waves. The maximal T \hat{E} -loops of the anesthetized dogs (Figure XV) show a greater variation. In the frontal plane projection, 10 of the maximal T \hat{E} -loops were in the fifth sextant and 9 of the maximal T \hat{E} -loops in the second sextant. In the sagittal plane projection 8 maximal T \hat{E} -loops are in the fifth sextant with 2 maximal T \hat{E} -loops in the sixth sextant, indicating positive T waves. Of the remaining 9 T \hat{E} -loops in the sagittal plane projection, 7 maximal T \hat{E} -loops lie in the second sextant and 2 maximal T \hat{E} -loops lie in the third sextant indicating negative T \hat{sE} -loops.

All of the P and T loops were very narrow ellipses in both series.

Time-Based Vectorcardiograms. Figures XVI and XVII show two typical recordings obtained from the three regular leads and a fourth lead showing a right sagittal projection with a horizontal time dimension. This method as can be seen, gives the same scalar information as the standard clinical method and also the vector information obtained in the vectorcardiograms in only three leads where the other two methods require 15 leads and two different recorders.

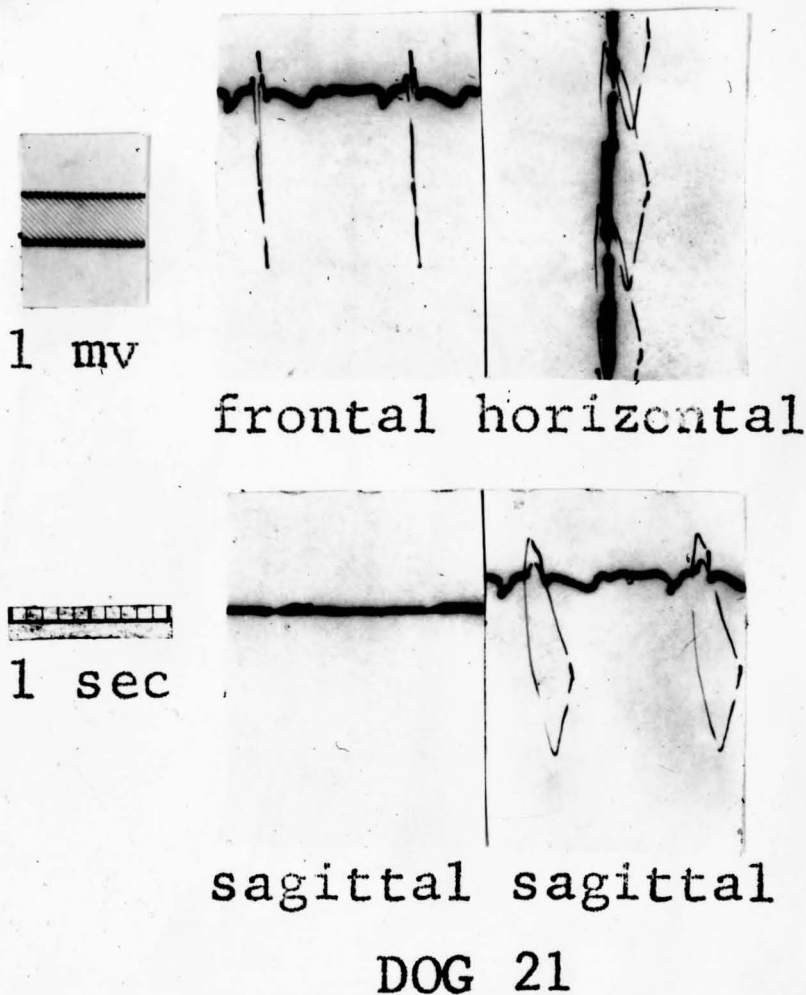


FIGURE XVI

TIME-BASED VECTORCARDIOGRAM: A TYPICAL RECORD SHOWING A QRS \hat{sE} -LOOP
 WITH A TERMINAL CEPHALAD INSCRIPTION.
 DOG ANESTHETIZED WITH PENTOBARBITAL.

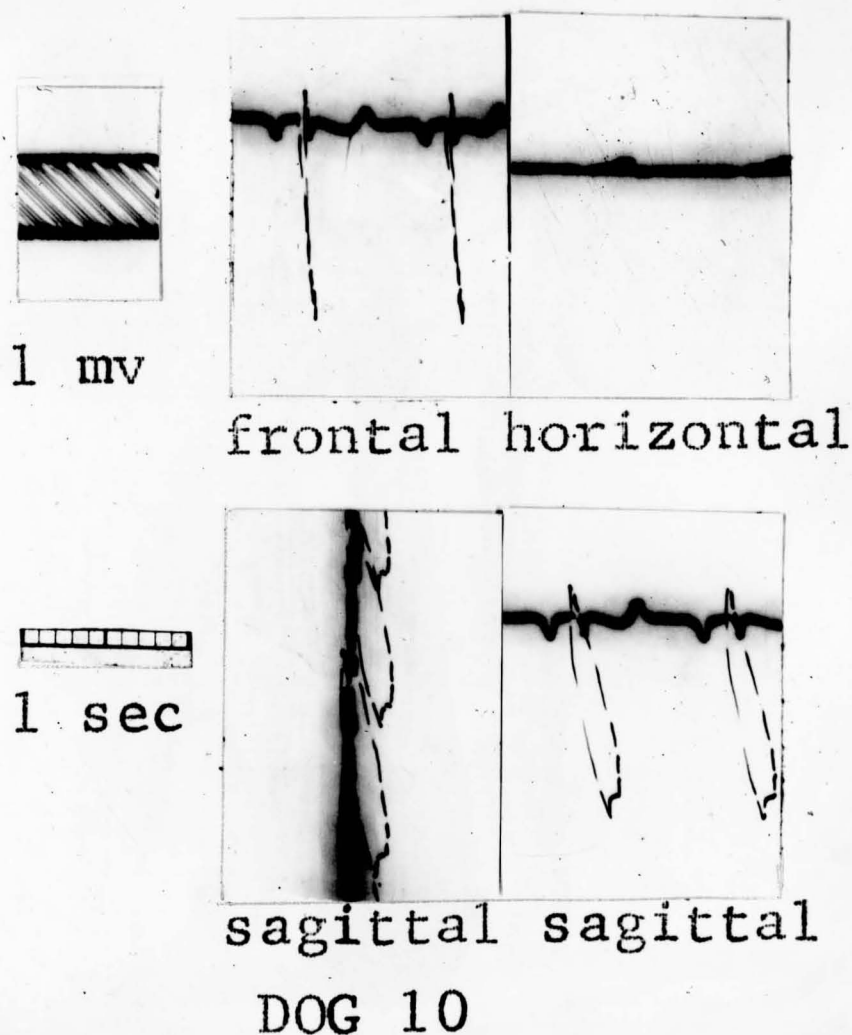


FIGURE XVIIa

TIME-BASED VECTORCARDIOGRAM: A TYPICAL RECORD SHOWING A
 QRS sĖ-LOOP WITH A TERMINAL CEPHALAD INSCRIPTION.
 DOG ANESTHETIZED WITH PENTOBARBITAL.

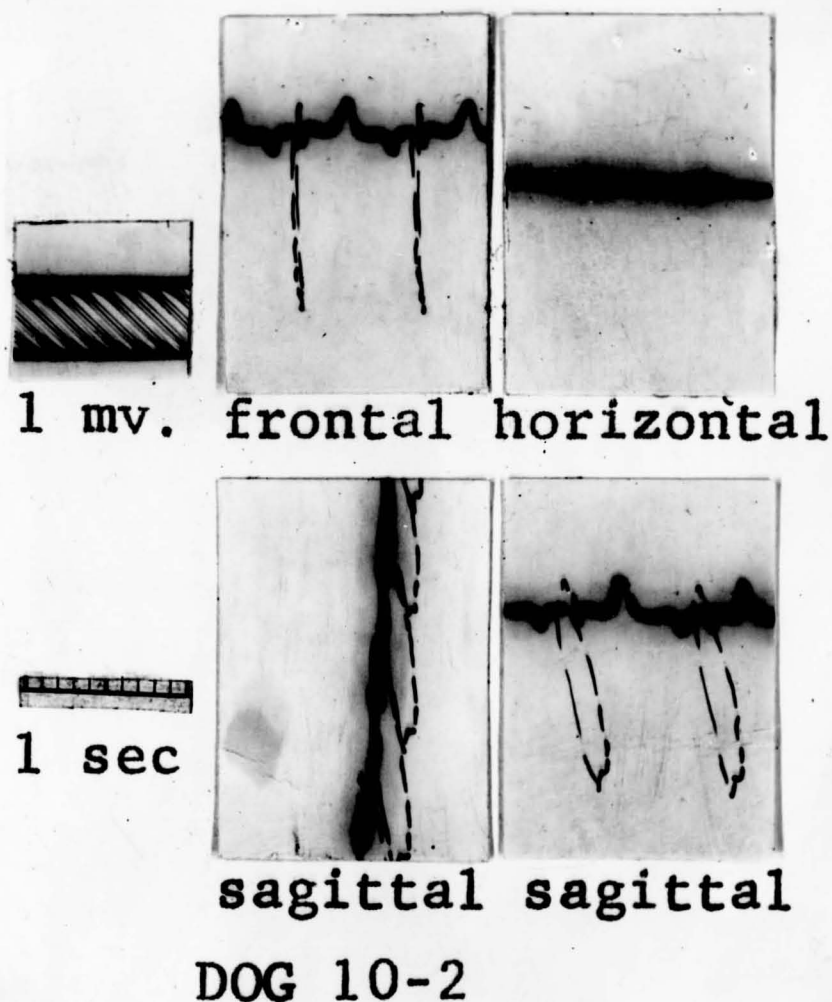


FIGURE XVIIb

TIME-BASED VECTORCARDIOGRAM: A RECORD OF THE SAME
ANESTHETIZED DOG ONE HOUR AFTER 0.25 MG OUABAIN

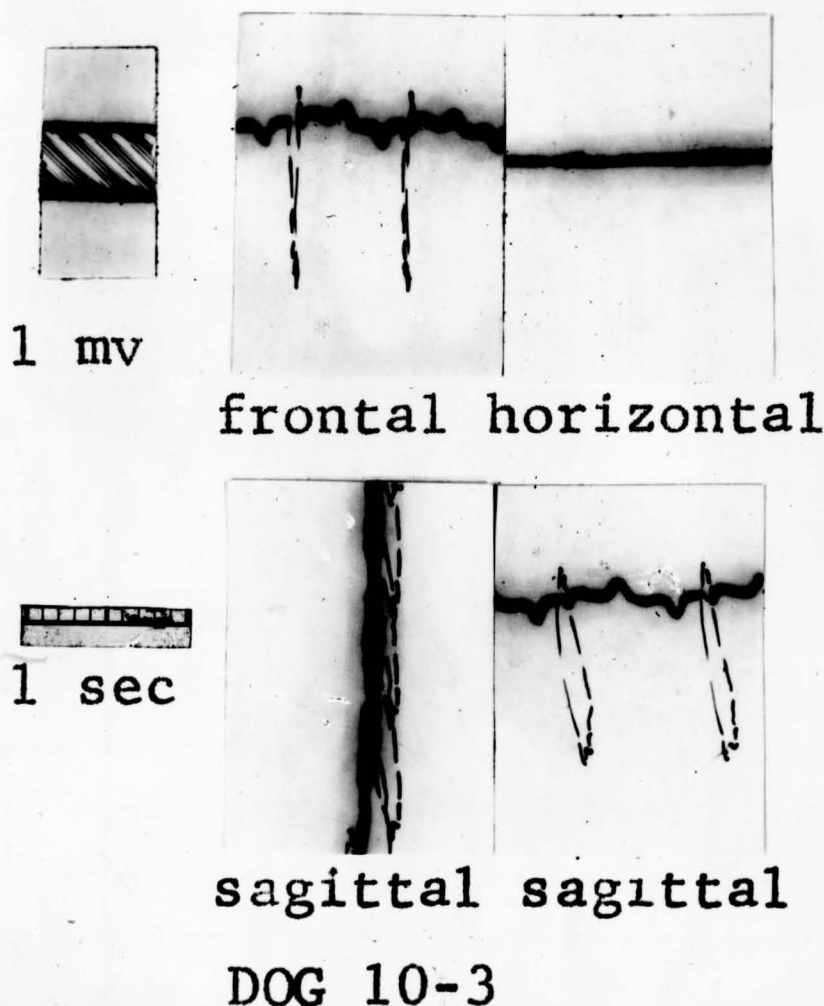


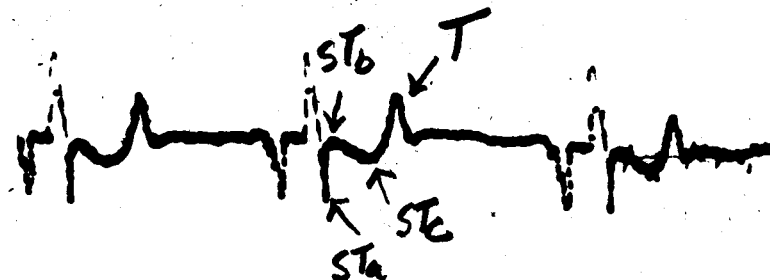
FIGURE XVIIc

TIME-BASED VECTORCARDIOGRAM: A RECORD OF THE SAME
ANESTHETIZED DOG FOUR HOURS AFTER 0.25 MG OUABAIN

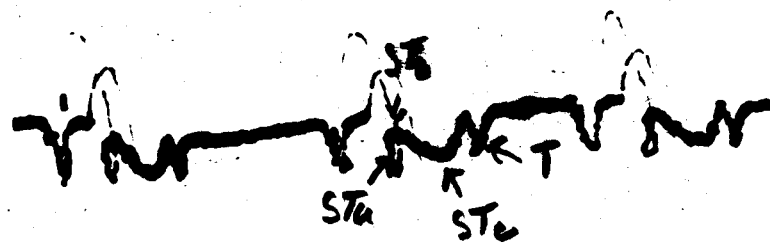
The P wave in the frontal lead is downward or positive in voltage and non-existent or very small in the sagittal and horizontal leads indicating a narrow, very thin vertical P \hat{sE} -loop. Such waves are rather sharply pointed and sometimes tent shaped in the frontal lead. Following the P wave is an isoelectric portion corresponding to the P-R interval in the standard scalar recordings. The general description of the QRS \hat{sE} -loop projection in each lead is similar to that described using the vectorcardiographic method except that these QRS \hat{E} -loops will be open corresponding to the duration of the QRS deflection plus any ST deviation. This difference is due to the time dimension superimposed on the horizontal amplitude dimension. The QRS \hat{E} -loops inscription, here, as in the vectorcardiograms, show a slower downward inscription or positive voltage until the maximal voltage is reached, a more rapid return to zero or to a negative voltage, with a final slower return to the base line or zero voltage.

From Figure XVI, it can be seen that the ST-T wave or \hat{sE} -loops are considerably different in the dog, from that described for the human. Figure XVIII shows some examples of the ST-T wave from the dog marked with the suggested terminology. Similarly, Figure XIX shows that these divisions of the ST-T wave can be seen in the standard clinical recordings, though they are not so clearly defined.

Because the P, QRS, and T \hat{sE} -loops are shaped as narrow ellipses, and are oriented in a very caudad direction, the horizontal plane projections of these loops are usually very small. As a consequence the P, QRS, and ST-T



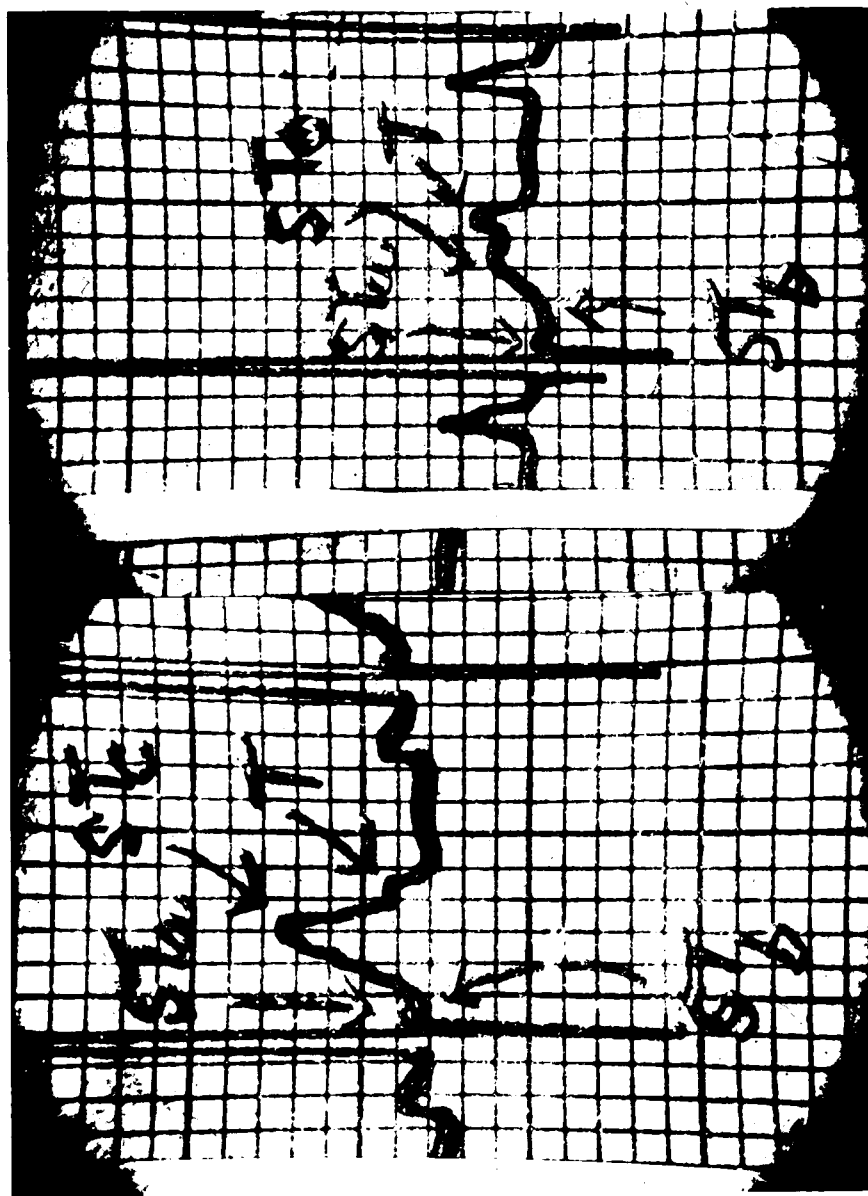
a frontal lead



a sagittal lead

FIGURE XVIII

TIME-BASED VECTORCARDIOGRAM: SAMPLE RECORDS ILLUSTRATING THE FOUR DIVISIONS OF THE ST-T WAVE. THESE TRACINGS ARE HIGH AMPLICATION RECORDINGS

V₃

AVF

FIGURE XIX

STANDARD ELECTROCARDIOGRAMS: SAMPLE RECORDS ILLUSTRATING
THE FOUR DIVISIONS OF THE ST-T WAVE

waves, from the horizontal lead in the time-based vectorcardiographic method, will have very small deflections for most dogs.

The angles of the projection of the spatial QRS_m , QRS_1 , and QRS_t instantaneous vector in the horizontal and sagittal leads are measured in degrees. Table 8 gives the angles of the frontal plane leads and Table 9 similar angles for the sagittal plane lead. Since two types of $QRS_{s\hat{E}}$ -loops exist, one which has a caudal orientation of the QRS_t vector and the other which has a cephalad orientation, two descriptions are necessary. Analysis using the "t" test comparing the differences of these angles is given in Table 10. Summary of the significant comparisons shows that the QRS_m vector angle in the frontal plane is smaller in the anesthetized dogs, the QRS_1 vector angle in the frontal plane is smaller in the same group of dogs.

Means, standard deviations, and ranges of the spatial voltage of the P, QRS_m , QRS_1 , QRS_t , ST_a , ST_b , ST_c and T instantaneous spatial vectors have been calculated using formula (1), page 28. These voltage magnitudes for the unanesthetized dogs are given in Table 11 and for the anesthetized dogs in Table 12. A statistical comparison between the two groups using the "t" test is given in Table 13. A summary of the significant results shows that only the P waves voltage are different, the voltage of the P wave in the anesthetized group being larger than the unanesthetized dogs.

Calculations of the angles of the QRS_1 - QRS_m , QRS_m - QRS_t , P- QRS_m , ST_a - QRS_m , ST_b - QRS_m , ST_c - QRS_m , and T- QRS_m , using formulas (1), (2), and (3), are given in Table 14 for the unanesthetized dogs and in Table 15 anesthetized dogs. Here again two separate descriptions of the QRS_t - QRS_m angle are

necessary because of the two types of QRS sE^A-loops. Statistical comparisons using the "t" test comparing the two groups are given in Table 16. Summarizing these comparisons, none of these angles show any differences between the two groups of dogs.

TABLE 8

MEANS OF MEASURED ANGLES IN THE FRONTAL AND SAGITTAL LEADS
OF UNANESTHETIZED DOGS - TIME-BASED
VECTOCARDIOGRAMS

	QRS _m -F	QRS _m -S	QRS ₁ -F	QRS ₁ -S	QRS _T -F		QRS _T -S	
					-	+	-	+
Mean	90°	9°	91°	13°	-89°	89°	-174°	16°
S.D.*	± 2°	± 11°	± 2°	± 12°	± 2°	± 7°	± 5°	± 10°
Range	87°- 93°	0°- 34°	88°- 95°	0°- 40°	-87°- -91°	84°- 94°	-166°- -178°	9°- 24°
N**	8	8	8	8	6	2 (1 dog)	6	2 (1 dog)

F - Frontal Lead

S - Sagittal Lead

Angles in degrees

* Standard Deviation

** Number of observations

TABLE 9

MEANS OF MEASURED ANGLES IN THE FRONTAL AND SAGITTAL LEADS
OF ANESTHETIZED DOGS - TIME-BASED
VECTORCARDIOGRAMS

	QRS _m -F	QRS _m -S	QRS ₁ -F	QRS ₁ -S	QRS _T -F		QRS _T -S	
					-	+	-	+
Mean	86°	8°	87°	13°	-90°	87°	-165°	0°
S.D.*	± 7°	± 7°	± 6°	± 7°	± 9°	± 3°	± 17°	± 1°
Range	70°- 91°	2°- 29°	70°- 95°	3°- 30°	-70°- -112°	84°- 90°	-125°- -180°	0°- -0°
N**	19	19	19	19	15	4	15	4

F - Frontal Lead

S - Sagittal Lead

Angles in degrees

Anesthesia, pentobarbital 30 mg/Kg.

* Standard Deviation

** Number of observations; 19 electrocardiograms on 13 dogs.

TABLE 10

ANALYSIS OF CHANGES IN MEANS OF ANGLES IN THE
FRONTAL AND SAGITTAL LEADS OF UNANESTHETIZED
AND ANESTHETIZED DOGS - TIME-BASED
VECTORCARDIOGRAMS

Wave	Plane	Mean of Angle		Changes in Mean	"t" Test	Signifi- cance
		Anesthetized Dog	Unanesthetized Dog			
QRS _m	F	86°	90°	4°	2.29	+
QRS _m	S	8°	9°	1°	< 1	
QRS _i	F	87°	91°	4°	2.58	++
QRS _i	S	13°	13°	0°	< 1	
QRS _t	F	-90°	-89°	1°	< 1	
QRS _t [†]	F	87°	89°	2°	< 1	
QRS _t	S	-165°	-174°	9°	1.88	
QRS _t [†]	S	0°	16°	16°	2.25	

F - Frontal Lead

S - Sagittal Lead

Angles in degrees

TABLE 11
 MEANS OF CALCULATED SPATIAL MAGNITUDES OF
 WAVES FROM UNANESTHETIZED DOGS
 TIME-BASED VECTORCARDIOGRAM

	P	QRS _m	QRS ₁	QRS _t	ST _a	ST _b	ST _c	T
Mean	.16	1.74	1.25	.61	.14	.06	.24	.28
S.D.*	±.09	±.46	±.36	±.28	±.05	±.03	±.12	±.12
Range	.05- .33	.63- 2.08	.62- 1.43	.26- .99	.03- .18	.02- .10	.04- .43	.07- .45
N**	8	8	8	8	8	4***	8	8

Voltage in millivolts.

* Standard Deviation.

** Number of observations; 8 electrocardiograms on 4 dogs.

*** Wave not present in four observations.

TABLE 12

MEANS OF CALCULATED SPATIAL MAGNITUDES OF
WAVES FROM ANESTHETIZED DOGS FROM
TIME-BASED VECTORCARDIOGRAMS

	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
Mean	.33	2.33	1.61	.68	.20	.06	.26	.29
S.D.*	±.19	±.94	±.59	±.41	±.17	±.06	±.15	±.16
Range	.09- .88	.60- 3.62	.45- 2.28	.27- 2.03	0- .42	0- .20	0- .56	.08- .65
N**	19	19	19	19	19	19	19	19

Voltage in millivolts.

Anesthesia, Pentobarbital 30mg/Kg.

* Standard Deviation.

** Number of observations; 19 electrocardiograms on 13 dogs.

TABLE 13

ANALYSIS OF CHANGES OF MEANS OF SPATIAL MAGNITUDES
OF THE WAVES FROM UNANESTHETIZED AND ANESTHETIZED
DOGS - TIME-BASED VECTORCARDIOGRAM

Wave	Means of Magnitudes		Difference of Means	"t" Test	Signifi- cance
	Anesthetized Dogs	Unanesthetized Dogs			
P	.33	.16	.17	3.15	+++
QRS _m	2.33	1.74	.59	1.02	
QRS _i	1.61	1.25	.36	△ 1	
QRS _t	.68	.61	.07	△ 1	
ST _a	.20	.14	.06	1.05	
ST _b	.06	.06	0	△ 1	
ST _c	.26	.24	.02	△ 1	
T	.29	.28	.01	△ 1	

Magnitudes in millivolts.

TABLE 14

MEANS OF CALCULATED SPATIAL ANGLES OF WAVES TO THE QRS
MAXIMAL VECTOR FROM UNANESTHETIZED DOGS -
TIME-BASED VECTORCARDIOGRAM

Angle	QRS _m - QRS _i	QRS _m -QRS _t		QRS _m - T	(5=no wave) QRS _m -ST	QRS _m - P	(5=no wave) ST-T
		+QRS _t	-QRS _t				
		+	-				
Mean	6°	12°	169°	7°	8°	7°	28°
S.D.*	±4°	±9°	±5°	±8°	±18°	±5°	±48°
Range	1°- 11°	5°- 18°	163°- 176°	0°- 25°	5°- 51°	2°- 19°	85°- 0°
N**	8	2 (1 dog)	6	8	3	8	3

Angle	QRS _m -ST _a		QRS _m -ST _b		(4=no wave)	QRS _m -T
	+ST _a	-ST _a	+ST _b	-ST _b	QRS _m -ST _c	
Mean	7°	171°	11°	NO Wave	8°	8°
S.D.	±7°	-	±12°		±11°	±9°
Range	1°- 17°	- to 171°	5°- 27°	- -	1°- 34°	1°- 31°
N	7	1	4	4	8	8

Angles in degrees.

* Standard Deviation.

** Number of observations.

TABLE 15

MEANS OF CALCULATED SPATIAL ANGLES OF WAVES TO THE QRS MAXIMAL
VECTOR FROM ANESTHETIZED DOGS - TIME-BASED
VECTOCARDIOGRAM

	P-QRS _m	QRS _i - QRS _m	QRS _t - QRS _m		ST _a - QRS _m	ST _b - QRS _m		
			- QRS _t	+ QRS _t		+ ST _b	- ST _b	None
Mean	9°	8°	165°	9°	12°	13°	172°	
S.D.*	±6°	±5°	±20°	±3°	±15°	±6°	±4°	
Range	3° - 21°	0° - 17°	98° - 178°	5° - 11°	0° - 50°	6° - 45°	169° - 177°	
N**	19	19	15	4	19	8	5	6

	ST _c - QRS			T - QRS		
	+ ST _c	- ST _c	None	- T	- T	
Mean	22°	140°	No wave	14°	169°	
S.D.	±15°	±26°		±14°	±9°	
Range	3° - 50°	125° - 170°		5° - 44°	152° - 170°	
N	14	3	2	10	9	

Angles in degrees.

Anesthesia - Pentobarbital 30 mg./Kg.

* Standard Deviation.

** Number of observations.

+ or - indicates whether wave was positive (+) or
negative (-) in voltage.

TABLE 16

ANALYSIS OF DIFFERENCES OF MEANS OF SPATIAL ANGLES
FOR ANESTHETIZED AND UNANESTHETIZED DOGS FROM
THE TIME-BASED VECTORCARDIOGRAM

Spatial Angles	Means of Angles		Difference of Means	"t" Test	Significance
	Anesthetized Dogs	Unanesthetized Dogs			
$QRS_m - QRS_i$	8°	6°	2°	< 1	
$QRS_m - QRS_t^-$	165°	169°	4°	< 1	
$QRS_m - QRS_t^+$	9°	12°	3°	< 1	
$QRS_m - P$	9°	7°	2°	1.83	
$QRS_m - ST_a$	12°	7°	5°	1.16	
$QRS_m - ST_b$	13°	11°	2°	< 1	
$QRS_m - ST_c$	22°	8°	12°	1.85	
$QRS_m - T$	14°	8°	6°	1.11	

Angles in degrees.

- indicates a negative voltage for that wave.

+ indicates a positive voltage for that wave.

The measurement of the intervals in seconds, of the P, P-R, QRS, QT, and RR', which are not obtainable with standard vector loop methods, are given in Table 17 for the unanesthetized dogs, and Table 18 for the anesthetized dogs. Statistical comparisons using the "t" test of the two groups of data are given in Table 19. Summarizing these significant comparisons shows that the P-R interval in the anesthetized dogs is shorter and the QT interval in the anesthetized dogs is also shorter.

TABLE 17

MEANS OF MEASURED HEART RATE AND INTERVALS OF UNANESTHETIZED
DOGS - TIME-BASED VECTORCARDIOGRAM

	P	P-R	QRS	QT	RR'
Mean	.03	.13	.025	.21	.75
S.D.*	±.01	±.03	±.011	±.02	±.30
Range	.02- .05	.10- .20	.024- .030	.18- .24	.51- 1.44
N**	8	8	8	8	8

Intervals in seconds.

* Standard deviation.

** Number of observations.

TABLE 18

MEANS OF MEASURED HEART RATE AND INTERVALS OF ANESTHETIZED
DOGS - TIME-BASED VECTORCARDIOGRAM

	P	P-R	QRS	QT	RR'
Mean	.0353	.082	.027	.189	.387
Standard Deviation	$\pm .078$	$\pm .013$	$\pm .014$	$\pm .028$	$\pm .091$
Range	.02- .05	.07- .11	.022- .04	.160- .230	.268- .692

Intervals in seconds.

Anesthesia - Pentobarbital, 30 mg/Kg.

Means - 19 electrocardiograms on 13 dogs.

TABLE 19

ANALYSIS OF DIFFERENCES IN MEANS OF THE INTERVALS BETWEEN UNANESTHETIZED
AND ANESTHETIZED DOGS - TIME-BASED VECTORCARDIOGRAM

Intervals	Means of Intervals		Changes in Means	"t" Test	Signifi- cance
	Anesthetized Dogs	Unanesthetized Dogs			
P	.035	.030	.005	<1	
P-R	.082	.130	.058	5.27	+++
QRS	.027	.025	.002	<1	
QT	.189	.210	.021	22.1	+++
RR'	.387	.750	.363	1.10	

Intervals in seconds.

DRUG STUDIES - SERIES I - ANESTHETIZED DOGS

Varying doses of strophanthin G between 0.25 and 1.0 mg were administered i.v. to 7 dogs anesthetized with pentobarbital (30 mg/Kg i.p.). Electrocardiograms using the three methods were taken before administration of the drug and at selected intervals of time after the administration of the drug.

Standard Clinical Method: The voltage measurements of the waves in the twelve standard clinical electrocardiographic leads for the pre-treated dogs are given in Tables 20a, 20b and 20c. Similar voltage measurements, dose of drug, and drug time after treatment, are given in Tables 21a, 21b, 21c, 21d, 21e, and 21f for each dog.

Two separate analysis of the treated dogs were made, those where drug time was 2 hours or less, and those where drug time was more than 2 hours. Tables 22a, 22b, 22c, 22d, 22e, and 22f give the differences of voltage, differences of means between pretreated and treated state for each dog, standard deviation, standard error, and significance for the recordings taken 2 hours or less after drug administration. Tables 23a, 23b, 23c, 23d, 23e, and 23f give similar data for the recordings taken more than 2 hours after drug administration.

A summary of the significant comparisons from Tables 22a, 22b, 22c, 22d, 22e, and 22f is given in Table 24. These are for the recordings taken with a drug time of 2 hours or less. The analysis shows that the P wave in the AVF lead is increased in voltage after administration of the drug. The voltage of the R waves is decreased in leads AVF, V_1 , V_2 , V_3 , V_4 , and V_5 .

TABLE 20a

AMPLITUDES OF WAVES FROM STANDARD ELECTROCARDIOGRAMS
OF PRE-TREATED ANESTHETIZED DOGS

Dog No.	Lead I						Lead II					
	P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-1	.06	-	.21	.02	.02	-.05	.32	.18	1.08	.33	.10	-.20
8-1	-.10	-	.21	1.00	.10	0	.20	.10	.27	.22	.20	-
10-1	.02	.04	.36	0	-.05	0	.18	.17	2.13	0	-.26	0
12-1	.02	.05	.27	0	.03	0	.29	.09	1.71	.08	-.14	-.02
13-1	.16	.12	.66	0	-.03	.02	.28	.12	1.42	-	-.23	-.10
14-1	.08	-	.67	0	-.15	0	.20	0	2.30	-	-.20	.04
19-1	.07	-	.37	-	.06	.03	.32	.09	2.28	-	-.09	.02

Dog No.	Lead III						Lead AVR					
	P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-1	.22	.03	.76	.26	.10	.12	.20	.02	.58	.10	.08	-.10
8-1	.30	.30	1.31	.21	.11	-	.02	-	.01	-	.12	-
10-1	.20	.10	1.70	0	-.21	.02	.10	.08	1.20	0	-.16	0
12-1	.26	.03	1.31	.04	-.13	-.02	.15	.06	1.00	.02	-.10	0
13-1	.12	0	.50	0	-.08	-.03	.19	.11	1.05	0	-.10	-.07
14-1	.37	0	1.57	0	-.06	.02	.21	0	1.50	0	-.18	.05
19-1	.12	.22	1.82	-	-.10	-	.18	.02	1.37	-	-.12	-

Amplitudes in millivolts
Anesthesia - 30 mg/Kg Pentobarbital

TABLE 20b

AMPLITUDES OF WAVES FROM STANDARD ELECTROCARDIOGRAMS
OF PRE-TREATED ANESTHETIZED DOGS

Dog No.	Lead AVL						Lead AVF					
	P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-1	.09	.01	.30	.18	.01	-.02	.25	.10	.90	.21	.11	.19
8-1	.20	.27	1.14	.12	.02	-	.16	.20	.91	.20	.11	-
10-1	.08	.03	.62	0	-.09	.02	.21	.11	2.08	0	-.21	.01
12-1	.12	-	.62	.02	-.05	0	.30	.08	1.59	.08	-.11	0
13-1	.01	0	.12	.02	-.03	-.02	.23	.07	1.00	0	-.24	-.09
14-1	.10	0	.52	0	-.07	.01	.23	0	2.12	0	-.09	.04
19-1	.02	.14	.73	-	-.03	-	.22	.20	2.31	-	-.17	-

Dog No.	Lead V ₁						Lead V ₂					
	P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-1	.09	0	1.05	.72	.09	.11	.10	0	1.90	.71	-.14	-.12
8-1	.08	-	1.32	.37	.25	-	.09	-	1.79	.28	.04	-
10-1	.16	0	1.80	.08	-.13	.11	.11	0	1.91	0	-.20	.06
12-1	.13	0	1.37	.37	±.15	.05	.17	-	2.00	.21	±.11	-.02
13-1	.07	0	1.02	.36	-.05	-.05	.11	0	1.00	.33	-.05	.04
14-1	.20	0	1.82	0	-.06	.30	.23	0	2.40	0	-.50	.28
19-1	.10	-	1.83	1.20	.38	-	.15	-	2.80	.28	+.14	-
											-.20	

Amplitudes in millivolts
Anesthesia - 30 mg/Kg Pentobarbital

TABLE 20c

AMPLITUDES OF WAVES FROM STANDARD ELECTROCARDIOGRAMS
OF PRE-TREATED ANESTHETIZED DOGS

Dog No.	Lead V ₃						Lead V ₄					
	P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-1	.19	.01	1.51	.32	-.18	-.11	.21	.04	.91	.11	0	-.12
8-1	.12	.06	1.68	.20	-.15 +.06	-	.13	.11	1.10	.12	+.07	-
10-1	.13	0	1.85	0	-.22	.02	.15	.03	1.70	0	-.20	.03
12-1	.16	0	2.00	.20	-.13	0	.18	0	1.81	.11	-.09	-
13-1	.12	0	.97	.20	-.05	-.05	.10	.05	1.00	0	-.10	0
14-1	.18	.02	2.51	0	-.30	.16	.23	.02	2.10	0	-.21	.10
19-1	.18	.07	2.49	.03	-.15	-	.20	.18	1.82	.02	-.12	-

Dog No.	Lead V ₅						Lead V ₆					
	P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-1	.18	.05	.72	.16	.02	0	.17	.09	.62	.11	.06	-.05
8-1	.11	.30	.70	.10	-.05	-	.13	.32	.50	.10	-.06	-
10-1	.12	.07	1.42	0	.15	0	.18	.07	1.30	0	-.18	0
12-1	.18	.10	.90	.05	-.07	0	.18	.09	.90	.05	.03	0
13-1	.20	.04	.89	0	-.05	-.02	.20	.20	.77	0	-.04	-.04
14-1	.28	.02	1.48	0	-.10	.02	.15	.05	1.10	0	-.05	0
19-1	.13	.25	1.36	.04	-.05	-	.07	.32	1.08	.09	-.04	-

Amplitudes in millivolts
Anesthesia - 30 mg/Kg Pentobarbital

TABLE 21a

AMPLITUDE OF WAVES FROM STANDARD ELECTROCARDIOGRAM
AFTER DRUG-TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time* in Hours	Wt. in Lbs.	Lead I						Lead II					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5**	24	12	.09	0	.08	.35	.17	0	.15	.04	.35	.44	.36	.34
8-2	.25	1	12	-.10	0	.31	1.18	.06	0	.16	.08	.20	.14	.23	0
8-3	.25	4	12	-.10	0	.25	1.08	.14	0	.18	.07	.20	.22	.19	-.02
10-2	.25	1	20	.04	0	.73	0	-.07	-.06	.17	.16	1.99	0	-.40	0
10-3	.25	4	20	.06	0	.53	0	-.03	-.02	.17	.11	1.93	0	-.24	-.09
12-2	.25	1.5	14	0	.13	.31	0	.01	0	.29	.18	1.12	.17	.10	-.18
13-2	1 mg.	2	16	.10	.08	.50	0	-.03	-.02	.20	.05	1.08	.02	-.22	-.19
14-2	.5	1	20	.09	0	.60	0	-.10	.02	.36	0	1.95	0	±.05	-.05
14-3		6.5	20	.03	.07	.57	0	-.04	0	.40	0	1.18	0	.15	.05
14-4		7.5	20	.03	.05	.58	0	-.05	0	.56	0	1.28	0	.13	.09
19-2	.50	4.5		.03	.07	.31	-	-	-	.28	.20	1.82	-	.10	-

Amplitude in millivolts

Drug - G-strophanthin, given i.v.

Anesthesia - 30 mg/Kg Pentobarbital

*Interval of time between administration of drug and recordings.

**Dose given i.m. in this experiment.

TABLE 21b

AMPLITUDE OF WAVES FROM STANDARD ELECTROCARDIOGRAM
AFTER DRUG-TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time* in Hours	Wt. in Lbs.	Lead III						Lead AVR					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5**	24	12	†.10	0	.57	.11	.17	-.09	.12	0	.12	.28	.29	.10
8-2	.25	1	12	.27	.40	1.38	.16	.17	0	.05	0	.12	0	.11	0
8-3	.25	4	12	.23	.37	1.30	.15	.10	-.03	.03	0	.10	.49	.10	.07
10-2	.25	1	20	.13	.15	.13	0	-.41	.08	.13	.10	1.18	0	-.23	0
10-3	.25	4	20	.15	.12	1.26	0	-.18	-.03	.16	.10	1.21	0	-.12	-.03
12-2	.25	1.5	14	.27	.10	.67	.01	.09	-.19	.20	.18	.70	.01	.03	-.10
13-2	1 mg.	2	16	.05	.01	.38	0	-.10	-.07	.19	.08	.86	0	-.06	-.05
14-2	.5	1	20	.27	0	1.03	0	.12	.10	.11	0	.37	0	.14	.03
14-3		6.5	20	.32	0	.60	0	.20	.15	.22	0	.84	0	.03	.02
14-4		7.5	20	.32	0	.57	0	.21	.10	.30	0	.80	0	.06	.03
19-2	.50	4.5		.19	.12	1.36	-	.02	-	.14	.14	1.08	-	.02	.02

Amplitudes in millivolts

Drug - G-strophanthin given i.v.

Anesthesia - 30 mg/Kg Pentobarbital

*Interval of time between administration of drug and recordings.

**Dose given i.m. in this experiment.

TABLE 21c

**AMPLITUDE OF WAVES FROM STANDARD ELECTROCARDIOGRAM
AFTER DRUG-TREATMENT OF ANESTHETIZED DOGS**

Dog No.	Dose in Mg.	Time* in Hours	Wt. in Lbs.	Lead AVL						Lead AVF					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5**	24	12	-.05	.01	.47	0	0	0	.12	0	.46	.30	.22	.12
8-2	.25	1	12	.05	.36	1.31	.10	.05	0	.20	.21	.80	.15	.20	0
8-3	.25	4	12	.14	.39	1.20	.04	-.06	.04	.20	.24	.82	.30	.12	-.03
10-2	.25	1	20	.03	.05	.33	0	-.20	.10	.19	.12	1.73	0	-.40	.05
10-3		4		.03	.04	.40	0	-.12	0	.18	.05	1.75	0	-.18	-.04
12-2	.25	1.5	14	.10	0	.16	0	.03	-.08	.27	.12	.89	.11	.08	-.12
13-2	1 mg.	2	16	.01	0	.09	.06	.02	-.02	.21	.05	.75	.05	-.10	-.08
14-2	.5	1	20	.25	0	1.39	0	-.03	.03	.40	0	1.71	0	.13	.10
14-3	.5	6.5	20	.07	0	.22	0	.12	.05	.45	0	.93	0	.22	.16
14-4		7		.10	0	.17	.03	.12	.05	.46	0	1.02	0	.25	.15
19-2	.50	4.5		.02	.03	.53	-	.01	.02	.26	.17	1.76	-	.04	-

Amplitudes in millivolts

Drug - G-strophanthin given i.v.

Anesthesia - 30mg/Kg Pentobarbital

*Interval of time between administration of drug and recordings.

**Dose given i.m. in this experiment.

TABLE 21d

**AMPLITUDE OF WAVES FROM STANDARD ELECTROCARDIOGRAM
AFTER DRUG-TREATMENT OF ANESTHETIZED DOGS**

Dog No.	Dose in Mg.	Time* in Hours	Wt. in Lbs.	Lead V ₁						Lead V ₂					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5**	24	12	†.10	0	.86	.65	.23	.16	.02	0	.81	.71	.32	.23
8-2	.25	1	12	.07	0	1.12	.42	.30	-.05	.09	-	1.40	.31	.20	0
8-3	.25	4	12	.07	0	.94	.60	.21	.16	.07	0	1.21	.42	.10	.12
10-2	.25	1	20	.10	0	1.33	0	-.29	.04	.10	0	1.63	.03	-.30	.02
10-3		4		.12	0	1.23	0	-.18	-.10	.12	0	1.56	0	-.17	-.08
12-2	.25	1.5	14	.18	0	1.09	.40	.29	-.29	.17	0	1.49	.33	.17	-.31
13-2	1 mg.	2	16	.05	0	.65	.40	-.07	-.07	.11	0	1.00	.40	-.05	-.10
14-2	.5	1	20	.23	0	1.27	.09	.04	.13	.28	0	2.22	0	-.20	.12
14-3	.5	6.5	20	.14	.03	.73	.10	.14	-.19	.20	0	1.39	0	†.06	0
14-4		7		.19	0	.81	.08	†.05	0	.21	0	1.45	0	-.12	0
19-2	.50	4.5		.21	-	.65	1.81	.43	-.23	.22	-	1.28	.88	.42	-.10

Amplitude in millivolts

Drug - G-strophanthin given i.v.

Anesthesia - 30 mg/Kg Pentobarbital

*Interval of time between administration of drug and recordings.

**Dose given i.m. in this experiment.

TABLE 21e

AMPLITUDE OF WAVES FROM STANDARD ELECTROCARDIOGRAM
AFTER DRUG-TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time* in Hours	Wt. in Lbs.	Lead V ₃						Lead V ₄					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5**	24	12	.05	0	.56	.55	.35	.21	.08	.03	.39	.31	.25	.11
8-2	.25	1	12	.12	.06	1.40	.20	.12	.07	.20	.14	1.10	.07	.11	.06
8-3		4		.11	.08	1.30	.30	.13	.14	.16	.17	.88	.20	.10	.03
10-2	.25	1	20	.12	.09	1.48	0	-.31	0	.13	.10	1.34	0	-.25	0
10-3		4		.15	0	1.37	0	-.23	-.04	.12	.10	1.38	0	-.16	-.06
12-2	.25	1.5	14	.20	0	1.45	.30	.20	-.23	.17	.04	1.16	.21	.14	-.19
13-2	1 mg.	2	16	.17	0	.86	.27	-.06	-.10	.20	0	.80	0	-.06	-.06
14-2	.5	1	20	.30	0	2.12	0	-.09	.10	.31	.02	1.63	0	-.04	.02
14-3		6.5		.23	0	1.22	0	.12	.05	.30	.01	1.05	0	.12	.05
14-4		<		.27	0	1.30	0	.10	.05	.31	0	1.18	0	.14	.10
19-2	.5	4.5		.28	.09	2.36	.18	.20	.05	.37	.13	2.16	-	.16	-.03

Amplitude in millivolts

Drug - G-strophanthin given i.v.

Anesthesia - 30 mg/Kg Pentobarbital

*Interval of time between administration of drug and recordings.

**Dose given i.m. in this experiment.

TABLE 21f

**AMPLITUDE OF WAVES FROM STANDARD ELECTROCARDIOGRAM
AFTER DRUG-TREATMENT OF ANESTHETIZED DOGS**

Dog No.	Dose in Mg.	Time* in Hours	Wt. in Lbs.	Lead V ₅						Lead V ₆					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5**	24	12	.07	.03	.37	.22	.17	.09	.09	.03	.22	.20	.14	.07
8-2	.25	1	12	.16	.28	.66	.10	.07	0	.15	.31	.56	.07	.06	0
8-3		4		.14	.30	.70	0	.05	0	.12	.34	.50	0	.01	-.02
10-2	.25	1	20	.14	.10	1.32	0	-.20	0	.11	.11	1.22	0	-.20	0
10-3		4		.15	.05	1.21	0	-.15	-.04	.18	.11	1.12	0	-.17	-.03
12-2	.25	1.5	14	.15	.16	.64	.10	.07	-.09	.14	.17	.70	.05	.06	-.06
13-2	1 mg.	2	16	.12	.05	.70	0	-.09	-.05	.15	.11	.63	0	-.06	.03
14-2	.5	1	20	.27	.01	1.23	0	.08	.08	.26	.03	1.04	0	.03	.02
14-3		6.5		.27	0	.82	0	.12	.05	.26	.04	.53	0	.12	.05
14-4		<		.21	0	.80	0	.16	.09	.21	.05	.64	0	.14	.09
19-2	.5	4.5		.24	.16	1.89	-	.05	-.02	.13	.27	1.33	-	-.05	.02

Amplitude in millivolts

Drug - G-strophanthin given i.v.

Anesthesia - 30 mg/Kg Pentobarbital

*Interval of time between administration of drug and recordings.

**Dose given i.m. in this experiment.

TABLE 22a

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead I						Lead II					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
8-2	.25	1	12	0	0	.10	.18	-.04	0	-.04	-.02	-.07	-.08	.03	-
10-2	.25	1	20	.02	-.04	.37	0	-.02	-.06	-.01	-.01	-.14	0	-.14	0
12-2	.25	1.5	14	-.02	.07	.04	0	-.02	0	0	.09	-.59	.09	.24	-.16
13-2	1.0	2	16	-.06	-.04	-.16	0	0	-.04	-.08	-.07	-.34	.02	-.01	-.09
14-2	.5	1	20	.01	0	-.07	0	.05	.02	.16	0	-.35	0	.15	-.09
Mean Differences				-.01	-.002	.056	.036	-.006	.024	-.006	-.002	-.298	.006	.054	-.068
Standard Deviation				.032		.402	.08	.032	.112	.092		.21		.147	.068
Standard Error				.019		.179	.035	.019	.050	.041		.168		.066	.030
"t" Test				<1	<1	<1	1.01	<1	<1	<1	<1	1.77	<1	<1	2.27
Significance															

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: 2 hours or less

TABLE 22b

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead III						Lead AVR					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
8-2	.25	1	12	-.03	.10	.07	-.05	.06	0	.03	-	.11	0	-.01	0
10-2	.25	1	20	-.07	.05	-1.57	0	-.20	.06	.03	.02	-.02	0	-.07	0
12-2	.25	1.5	14	-.01	.07	-.64	-.03	.22	-.17	.05	.12	-.30	-.01	.13	-.10
13-2	1.0	2	16	-.07	.01	-.12	0	-.02	-.04	0	-.03	-.19	0	.04	.02
14-2	.5	1	20	-.10	0	-.54	0	.18	.08	-.10	0	-.13	0	.32	-.02
Mean Differences				-.052	.046	-.56	.016	.048	-.014	.002	.022	-.106	-.002	.082	-.02
Standard Deviation				.042	.041	.635	.020	.168	.099		.057	.157		.151	.046
Standard Error				.019	.018	.283	.008	.075	.044		.022	.070		.067	.020
"t" Test				2.73	2.56	1.97	2.00	<1	<1	<1	1.00	1.51	<1	1.22	1.00
Significance															

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: 2 hours or less

TABLE 22c

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead AVL						Lead AVF					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
8-2	.25	1	12	-.15	.11	.13	-.02	.03	0	.04	.01	-.11	-.04	.09	0
10-2	.25	1	20	.05	.02	.29	0	-.11	.08	-.02	.01	-.25	0	-.19	.04
12-2	.25	1.5	14	-.02	0	.46	-.02	.08	-.08	-.03	-.04	-.70	.03	.19	-.12
13-2	1.0	2	16	0	0	-.03	-.04	.05	0	-.02	-.02	-.25	-.05	.14	.01
14-2	.5	1	20	.15	0	.87	0	.04	.02	.17	0	-.41	0	.22	.06
Mean Differences				.006	.026	.34	-.016	.018	.004	.108	-.008	-.344	-.012	.09	-.002
Standard Deviation				.109	.047	.344	.017	.074		.084	.014	.232	.033	.163	
Standard Error				.049	.021	.154	.008	.033		.038	.006	.104	.015	.073	
"t" Test				< 1	2.24	2.20	2.00	< 1	< 1	2.84	1.33	3.31	< 1	1.23	< 1
Significance										+		+			

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: 2 hours or less

TABLE 22a

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead V ₁						Lead V ₂					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
8-2	.25	1	12	-.01	0	-.20	.05	.05	-.05	0	-	-.39	.03	.16	0
10-2	.25	1	20	-.06	0	-.47	-.08	-.16	-.07	-.01	0	-.28	+.03	-.10	-.04
12-2	.25	1.5	14	.05	0	-.28	.03	.44	-.24	0	0	-.51	-.12	.28	-.29
13-2	1.0	2	16	-.02	0	-.37	-.04	-.02	.02	0	0	0	.07	0	-.05
14-2	.5	1	20	.03	0	-.55	.09	.10	-.17	.05	0	-.20	0	.30	-.16
Mean Differences				-.002	0	-.37	.01	.082	-.102	.008	0	-.276	.002	.128	-.108
Standard Deviation						.141		.222	.102			.193		.174	.118
Standard Error						.063		.099	.046			.086		.078	.053
"t" Test				<1	<1	5.87	<1	<1	2.22	<1	<1	3.21	<1	1.64	2.04
Significance						++						+			

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: 2 hours or less

TABLE 22c

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead V ₃						Lead V ₄					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
8-2	.25	1	12	0	0	-.28	0	.27	.07	.07	.03	0	.05	.04	.06
10-2	.25	1	20	-.01	.09	-.37	0	-.09	-.02	-.02	.07	-.36	0	-.05	-.03
12-2	.25	1.5	14	.04	0	-.55	.10	.33	-.23	-.01	.04	-.65	.10	.23	-.19
13-2	1.0	2	16	.05	0	-.11	.07	-.01	-.05	.10	-.05	-.20	0	.04	-.06
14-2	.50	1	20	.12	-.02	-.39	0	.21	-.06	.08	0	-.47	0	.17	-.08
Mean Differences				.04	.014	-.34	.034	.142	-.058	.044	.018	-.336	.01	.086	-.06
Standard Deviation				.051		.161	.049	.182	.109	.055	.045	.248		.112	.09
Standard Error				.023		.072	.022	.081	.049	.025	.020	.111		.050	.040
"t" Test				1.73	<1	4.72	1.55	1.75	1.21	1.76	<1	3.03	<1	1.72	1.50
Significance						++						+			

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: 2 hours or less

TABLE 22f

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead V ₅						Lead V ₆					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
8-2	.25	1	12	.05	-.02	-.04	0	.12	0	.02	-.01	.06	-.03	.12	0
10-2	.25	1	20	-.02	-.03	-.10	0	-.35	0	-.07	-.04	-.18	0	-.02	0
12-2	.25	1.5	14	-.03	.06	-.26	.05	-.14	-.09	-.04	.08	-.20	0	.03	-.06
13-2	1.0	2	16	-.08	+.01	-.19	0	-.04	-.03	-.05	-.09	-.14	0	-.02	-.07
14-2	.50	1	20	-.01	-.01	-.25	0	.18	.06	.11	-.02	-.06	0	.08	.02
Mean Differences				-.018	.002	-.178	.01	-.046	-.012	-.006	-.016	-.104	-.006	.038	-.022
Standard Deviation				.046		.095		.210	.054		.062	.106		.062	.04
Standard Error				.021		.042		.093	.024		.028	.047		.028	.019
"t" Test				< 1	< 1	4.24	< 1	< 1	< 1	< 1	< 1	2.21	< 1	1.36	< 1
Significance						+									

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: 2 hours or less

TABLE 23a

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead I						Lead II					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5	24	12	.03	0	-.13	.33	.15	-.05	-.16	-.14	-.73	.11	.26	.54
8-3	.25	4	12	0	0	.13	.08	.04	0	-.02	-.03	-.07	0	-.01	-.02
10-3	.25	4	20	.04	-.04	.17	0	.02	-.02	-.01	-.06	-.20	0	.02	-.09
14-3	.5	6.5	20	-.05	.07	-.10	0	-.11	0	.20	0	-1.12	-	.35	.01
14-4	.5	7.5	20	-.05	-.05	-.09	0	-.10	0	-.36	0	-1.02	0	.33	.05
19-2	.5	4.5		-.04	.07	-.06	0	-.06	-.03	-.04	.11	-.46	0	.19	-.02
Mean Differences				-.01	-.008	-.01	.07	-.01	-.017	-.065	-.02	-.60	.018	.19	.078
Standard Deviation				.035	.026	.129	.13		.20	.172	.077	.428	.446	.141	.223
Standard Error				.014	.011	.053	.05		.08	.070	.031	.172	.182	.057	.091
"t" Test				<1	<1	<1	1.40	<1	<1	<1	<1	3.49	<1	3.33	<1
Significance												+		+	

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: More than 2 hours

TABLE 23b

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead III						Lead AVR					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5	24	12	-.12	-.03	-.19	-.15	.07	-.21	-.08	-.02	-.46	.18	.21	.20
8-3	.25	4	12	-.07	.07	-.01	-.06	-.01	-.03	.01	0	.09	.49	-.02	.07
10-3	.25	4	20	-.05	.02	.34	0	+.03	-.05	.06	.02	.01	0	.04	-.03
14-3	.5	6.5	20	-.05	0	-.97	0	.26	.13	.01	0	-.66	0	.21	-.03
14-4	.5	7.5	20	-.05	0	-1.00	0	.27	.08	.09	0	-.70	0	.24	-.02
19-2	.5	4.5		.07	-.10	-.46	-	.12	-	-.04	.12	-.29	0	.14	.02
Mean Differences				-.045	-.007	-.38	-.035	.123	-.013	.008	.02	-.335	.112	.137	.035
Standard Deviation				.062	.055	.534	.061	.118	.118	.05	.05	.332	.163	.333	.089
Standard Error				.025	.022	.218	.025	.048	.048		.02	.136	.067	.135	.036
"t" Test				1.80	<1	1.74	1.40	2.56	<1	<1	1.00	.246	.167	1.01	<1
Significance															

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: More than 2 hours

TABLE 23c

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead AVL						Lead AVF					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5	24	12	-.14	0	.17	-.18	-.01	.02	-.13	-.10	-.44	.09	.11	.07
8-3	.25	4	12	-.06	.12	.06	-.08	-.08	.02	.04	.04	-.19	.10	.01	-.03
10-3	.25	4	20	-.05	.01	-.22	0	-.03	-.02	-.03	-.06	-.33	0	.03	-.05
14-3	.5	6.5	20	-.03	0	-.30	0	.19	.04	.22	0	-1.19	0	.31	.04
14-4	.5	7.5	20	0	0	-.35	.03	.19	.04	.23	0	-1.10	0	.34	.11
19-2	.5	4.5		0	-.11	-.20	-	.04	.02	.04	-.03	-.55	0	.21	-
Mean Differences				-.047	.003	-.14	-.038	.05	.02	.062	-.025	-.617	.03	.168	.023
Standard Deviation				.052		.208	.079	.363	.022	.450	.05	.437	.05	.448	.06
Standard Error				.021		.085	.032	.148	.009	.183	.020	.178	.204	.182	.024
"t" Test				2.23	<1	1.64	1.19	<1	2.22	<1	<1	3.47	1.50	<1	<1
Significance													+		

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time - More than 2 hours

TABLE 23d

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead V ₁						Lead V ₂					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5	24	12	-.19	0	-.19	-.07	.14	.05	-.08	0	.09	0	.46	.35
8-3	.25	4	12	-.01	0	-.38	.23	-.04	.16	-.02	0	-.58	.14	.06	.12
10-3	.25	4	20	-.04	0	-.47	-.08	-.05	-.21	.01	0	-.35	0	.03	-.14
14-3	.5	6.5	20	-.06	.03	-1.09	.10	.20	-.49	-.03	0	-1.01	0	.56	-.28
14-4	.5	7.5	20	-.01	0	-1.01	.08	.11	-.30	-.02	0	-.95	0	+.38	-.28
19-2	.5	4.5		.11	0	-1.18	.61	.05	-.23	.07	0	-1.52	.60	.62	-.10
Mean Differences				-.033	.005	-.72	.145	.068	-.335	.012	0	-.917	.123	.352	.055
Standard Deviation				.098		.426	.258	.100	.237	.05	0	.410	.240	.248	.247
Standard Error				.040		.174	.105	.040	.097	.020	0	.167	.097	.101	.101
"t" Test				<1	<1	4.13	1.38	1.70	3.45	<1	<1	5.49	1.27	3.45	<1
Significance						++			+			++		+	

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: More than 2 hours

TABLE 23e

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead V ₃						Lead V ₄					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5	24	12	-.14	-.01	-.95	.23	.53	.32	-.13	-.01	-.32	.20	.25	.23
8-3	.25	4	12	-.01	.02	-.28	.10	.07	.14	.03	.06	.22	.08	.03	.03
10-3	.25	4	20	.02	0	-.48	0	-.01	-.06	-.03	.07	-.32	0	+.04	-.09
14-3	.5	6.5	20	.05	-.02	-.29	0	.42	-.11	.07	-.01	1.05	0	.33	-.05
14-4	.5	7.5	20	.09	-.02	-1.21	0	.40	-.11	.08	-.02	-.92	0	.35	0
19-2	.5	4.5		.10	.02	-.13	.14	.35	-.05	.17	-.05	.34	-.02	.28	-.03
Mean Differences				.018	-.001	-.557	.078	.293	.022	.032	.007	.008	.043	.213	.015
Standard Deviation				.088	-	.428	.095	.214	.173	.106	.047	.679	.084	.142	.112
Standard Error				.036	-	.175	.039	.087	.070	.043	.019	.277	.021	.058	.045
"t" Test				<1	<1	3.18	2.00	3.37	<1	<1	<1	<1	2.05	3.67	<1
Significance						+		+						+	

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: More than 2 hours

TABLE 23f

**AMPLITUDE DIFFERENCES OF WAVES FROM STANDARD ELECTROCARDIOGRAM
BETWEEN PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISONS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Lead V ₅						Lead V ₆					
				P	Q	R	S	T	S-T	P	Q	R	S	T	S-T
7-3	.5	24	12	-.11	.02	-.35	.06	.15	.09	-.08	-.06	-.40	.09	.08	.12
8-3	.25	4	12	.03	0	0	-.10	.10	0	-.01	.02	0	-.10	.07	-.02
10-3	.25	4	20	.03	-.02	-.21	0	-.30	-.04	0	-.04	-.18	0	+.01	-.03
14-3	.5	6.5	20	-.01	-.20	-.66	0	.22	.03	.11	-.01	-.57	0	.17	.05
14-4	.5	7.5	20	-.07	-.02	-.68	0	.26	.07	.06	0	-.46	0	.19	.09
19-2	.5	4.5		.11	-.09	.53	-.04	-.10	-.02	.06	-.05	.25	-.09	-.01	-.02
Mean Differences				-.003	-.058	-.228	-.013	.088	.022	.023	-.023	-.227	-.017	.085	.032
Standard Deviation					.075	.454	.053	.020	.051	.067	.031	.031	.070	.081	.064
Standard Error					.031	.185	.022	.008	.021	.027	.013	.013	.029	.033	.026
"t" Test				<1	1.87	1.23	<1	1.10	1.05	<1	1.77	17.4	<1	2.58	1.23
Significance												+++		+	

Differences in millivolts
Pre-Treated - Treated (Paired Experiments)
Drug Time: More than 2 hours

TABLE 24

SUMMARY OF SIGNIFICANT DIFFERENCES OF VOLTAGE MEANS
OF THE STANDARD ELECTROCARDIOGRAM WAVES
OF DRUG TIMES OF TWO HOURS OR LESS

	Lead	Changes in Mean	"t" Test	Significance
P Wave	AVF	.11	2.84	+
R Wave	AVF	-.34	3.31	+
	V ₁	-.37	5.87	+ +
	V ₂	-.28	3.21	+
	V ₃	-.34	4.72	+ +
	V ₄	-.34	3.03	+
	V ₅	-.18	4.24	+

Table 25 gives a summary of the significant results of voltage changes from Tables 23a, 23b, 23c, 23d, 23e, and 23f where drug time is more than two hours. The voltage of the R waves is decreased in leads II, AVF, V_1 , V_2 , V_3 and V_6 after drug administration. The ST segment is elevated in V_1 and the voltage of the T waves is increased in leads II, V_2 , V_3 , V_4 and V_6 .

Measurement of the heart rate, the intervals, axes, and spatial angles of the dog's electrocardiograms before treatment with the drug is given in Table 26, and after treatment with the drug, in Table 27. Analysis of the differences of the measurements from these two tables is given in Table 28 for recordings with a drug time of two hours or less, and in Table 29 for a drug time of more than two hours.

Summarizing in Table 30 the significant results of Table 28 shows that the QT interval is smaller and the QRS axis in the frontal plane is slightly less vertical after drug administration. Table 31 summarizes the significant results from Table 29. Here again the QT interval is decreased after drug treatment.

TABLE 25

SUMMARY OF SIGNIFICANT DIFFERENCES OF MEANS
OF VOLTAGE FROM STANDARD ELECTROCARDIOGRAM WAVES WITH DRUG TIMES
OF MORE THAN TWO HOURS

	Lead	Changes in Mean	"t" Test	Significance
R Wave	II	-.60	3.49	+
	AVF	-.62	3.47	+
	V ₁	-.72	4.13	+ +
	V ₂	-.92	5.49	+ +
	V ₃	-.56	3.18	+
	V ₆	-.23	17.4	+ + +
T Wave	II	.19	3.33	+
	V ₂	.35	3.45	+
	V ₃	.29	3.37	+
	V ₄	.21	3.67	+
	V ₆	.09	2.58	+
ST Wave	V ₁	-.34	3.45	+

TABLE 26

HEART RATE, INTERVALS, AXES AND ANGLES
FROM STANDARD ELECTROCARDIOGRAM OF PRE-TREATED ANESTHETIZED DOGS

Dog No.	Heart Rate beats/ minute	Intervals*		
		P-R	QRS	Q-T
7-1	160	.09	.03	.232
8-1	160	.08	.03	.191
10-1	145	.08	.03	.24
12-1	155	.09	.04	.240
13-1	150	.10	.03	.192
14-1	135	.11	.03	.220
19-1	94	.12	.03	.240

Dog No.	Heart Rate Beats/ minute	Axes - Frontal Plane**		
		QRS	S-T	T
7-1	160	80°	-120°	65°
8-1	160	125°	115°	65°
10-1	145	79°	90°	105°
12-1	155	80°	-90°	-100°
13-1	150	74°	80°	110°
14-1	135	75°	80°	60°
19-1	94	65°	80°	-80°

Dog No.	Heart Rate beats/ minute	Angles**	
		QRS-T	ST-T
7-1	160	18°	170°
8-1	160	70°	50°
10-1	145	175°	170°
12-1	155	180°	10°
13-1	150	175°	170°
14-1	135	25°	85°
19-1	94	170°	180°

* Intervals in seconds.

** Axes and angles in degrees.

Anesthesia: 30 mg/Kg Pentobarbital.

TABLE 27

HEART RATE, INTERVALS, AXES AND ANGLES
FROM STANDARD ELECTROCARDIOGRAM AFTER DRUG TREATMENT
OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate beats/ minute	Intervals			Axes-Frontal Plane			Angles	
					P-R	QRS	Q-T	QRS	T	S-T	QRS-T	ST-T
7-3	.5*	24	12	125	.11	.04	.236	95°	55°	-125°	50°	140°
8-2	.25	1	12	135	.09	.04	.182	120°	75°	65°	65°	5°
8-3		4		125	.10	.03	.208	130°	65°	60°	65°	5°
10-2	.25	1	20	155	.07	.03	.204	75°	-95°	100°	180°	170°
10-3		4		180	.09	.03	.196	78°	-100°	-100°	170°	0°
12-2	.25	1.5	14	163	.09	.03	.192	75°	95°	-90°	30°	175°
13-2	1.0	2	16	145	.11	.03	.180	65°	-85°	-85°	140°	5°
14-2	.5	1	20	155	.10	.03	.190	70°	145°	90°	80°	25°
14-3		6.5		195	.10	.03	.180	72°	100°	100°	29°	0°
14-4		7		188	.12	.03	.180	65°	115°	100°	60°	15°
19-2	.5	4.5		198	.09	.03	.17	80°	90°	-	30°	-

Intervals in seconds.

Axes and angles in degrees.

Drug - G. Strophanthin. given i.v.

Anesthesia - 30 mg./Kg. Pentobarbital.

* Dose of drug given i.m. in this experiment.

TABLE 28

DIFFERENCES IN HEART RATES, INTERVALS, AXES AND ANGLES
FROM STANDARD ELECTROCARDIOGRAM OF PRE-TREATED AND DRUG-TREATED
ANESTHETIZED DOGS WITH STATISTICAL COMPARISON

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate beats/ minute	Intervals			Axes			Angles	
					P-R	QRS	Q-T	QRS	S-T	T	QRS-T	ST-T
7-3	.5*	24	12	-35	.03	.01	-.045	-30°	5°	-10°	32°	-30°
8-3	.25	4	12	-35	.02	0	.017	5°	-55°	0	-5°	-45°
10-3	.25	4	20	35	.01	0	-.04	1°	-110°	25°	-5°	170°
14-3	.5	6.5	20	60	-.01	0	-.040	-3°	12°	20°	4°	-85°
14-4	.5	7.5	20	45	.01	0	-.040	-10°	20°	55°	35°	-70°
19-2	.5	4.5		104	-.03	0	-.070	15°	-80°	170°	-140°	-180°
Mean Differences				29	.005	-	-.036	-4°	-45	43	-13	-40
Standard Deviation				54.7	.02	-	.029	15.2	73.2	66	62	115
Standard Error				22.3	.008	-	.0118	6.2	29.9	27	25	47
"t" Test				1.30	< 1	< 1	3.05	< 1	1.49	1.59	< 1	< 1
Significance							+					

Intervals in seconds.

Axes and angles in degrees.

Drug: G. Strophanthin - given i.v.

Anesthesia: 30 mg./Kg. Pentobarbital.

*Dose of drug given i.m. in this experiment.

TABLE 29

DIFFERENCES IN HEART RATE, INTERVALS, AXES AND ANGLES
FROM STANDARD ELECTROCARDIOGRAM OF PRE-TREATED AND DRUG-TREATED
ANESTHETIZED DOGS WITH STATISTICAL COMPARISONS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate beats/minute	Intervals			Axes			Angles	
					P-R	QRS	Q-T	QRS	S-T	T	QRS-T	ST-T
8-2	.25	1	12	-25	.01	.01	-.009	-5°	-50°	10°	-5°	-45°
10-2	.25	1	20	10	-.01	0	-.036	-4°	10°	170°	-5°	0
12-2	.25	1.5	14	8	0	-.01	-.058	-5°	165°	0	-150°	165°
13-2	1.0	2	16	-5	.01	0	-.120	-9°	165°	-165°	-35°	-165°
14-2	.50	1	20	20	-.01	0	-.032	-5°	10°	85°	55°	60°
Mean Differences				1.6	.004	0	-.051	-5.6	60	10	-28	3
Standard Deviation							.0134	1.7	97.4	123	76	
Standard Error							.006	.7	43	55	34	
"t" Test				<1	<1	<1	8.50	8.00	1.40	<1	<1	<1
Significance							+	+				

Intervals in seconds.

Axes and angles in degrees.

Drug: G. Strophanthin. given i.v.

Anesthesia: 30 mg./Kg. Pentobarbital.

Drug times: 2 hours or less.

TABLE 30

SUMMARY OF SIGNIFICANT DIFFERENCES OF MEANS OF INTERVALS,
AXES OF STANDARD ELECTROCARDIOGRAM

	Comparison	Differences in Mean	"t" Test	Significance
Interval	Q-T	-.051 sec.	8.50	+ +
Axis	QRS	-5.6°	8.00	+ +

Drug Time: 2 hours or less.

TABLE 31

SUMMARY OF SIGNIFICANT DIFFERENCES OF MEANS OF
INTERVALS, AXES AND ANGLES OF
STANDARD ELECTROCARDIOGRAM

	Comparison	Differences in Mean	"t" Test	Significance
Interval	Q-T	-.04	3.05	+

Drug Time: More than 2 hours.

Vectorcardiograms: Only the angles of the QRS_m , QRS_1 and QRS_t instantaneous vectors were measured in the frontal and sagittal leads for analysis of the drug effects. The other measurable information is more easily obtained in the time-based vectorcardiographic method. Difficulties previously mentioned like superimposed QRS, P and T $\overset{\Delta}{sE}$ -loops make separation, identification, and measurements difficult.

The measurements of these angles in degrees is given in Table 32 for the pre-treated dog, Table 33 for the drug-treated dog with drug time of 2 hours or less, and Table 34 for the drug-treated dog with a drug time of more than 2 hours.

Using the "t" test, analysis of this data for the differences in spatial angles, from the pre-treated and drug-treated dogs, is given in Table 35 for drug times of 2 hours or less, and Table 36 for the drug times of more than 2 hours. Analysis shows that there are no significant differences between these two conditions with a drug time of 2 hours or less. Summary of differences with a drug time of more than 2 hours is given in Table 36a. Analysis of these two conditions with a drug time of more than two hours shows that the axis of the QRS and QRS_1 vector in the sagittal plane has a larger angle or a more anterior orientation after the administration of the drug.

TABLE 32
 ANGLES OF WAVES FROM VECTORCARDIOGRAM LEADS
 OF PRE-TREATED ANESTHETIZED DOGS

Dog No.	QRS _m		QRS ₁		QRS _t	
	F	S	F	S	F	S
7	70°	12°	70°	22°	-112°	-152°
8	90°	8°	87°	20°	-90°	-154°
10	87°	6°	87°	16°	-100°	-125°
12	91°	7°	89°	10°	-85°	-174°
13	82°	29°	95°	6°	-70°	-157°
14	88°	5°	94°	25°	-88°	-1°
19	7°	90°	90°	8°	0°	7°

Angles in degrees.

F = Frontal lead.

S = Sagittal lead.

TABLE 33

ANGLES OF WAVES FROM VECTORCARDIOGRAM LEADS
AFTER DRUG TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS _m		QRS _i		QRS _t	
				F	S	F	S	F	S
8	.25	1	12	88°	47°	86°	15°	-90°	-140°
10	.25	1	20	87°	9°	87°	16°	-90°	-136°
12	.25	1.5	14	91°	7°	88°	10°	-88°	-175°
13	1.0	2	16	85°	4°	90°	19°	-87°	-150°
14	.5	2	20	87°	90°	9°	18°	-99°	-158°

Angles in degrees.

F = Frontal lead; S = Sagittal lead.

Drug Times: 2 hours or less.

TABLE 34

ANGLES OF WAVES FROM VECTORCARDIOGRAM LEADS
AFTER DRUG TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS _m		QRS _i		QRS _t	
				F	S	F	S	F	S
7	.50	24	12	86°	8°	87°	8°	-98°	-173°
10	.25	4	20	90°	5°	90°	9°	-90°	-172°
14	.5	6.5	20	86°	1°	100°	24°	-88°	0°
14	.5	7.5		89°	-1°	105°	6°	-105°	176°
19	.25	4.5	15	90°	4°	90°	5°	90°	-5°

Angles in degrees.

F = Frontal lead; S = Sagittal lead.

Drug Times: More than 2 hours.

TABLE 35

DIFFERENCES OF ANGLES OF WAVES FROM VECTORCARDIOGRAM LEADS
OF PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS,
WITH STATISTICAL COMPARISON

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS _m		QRS _i		QRS _t	
				F	S	F	S	F	S
8	.25	1	12	2°	-39°	1°	5°	0°	14°
10	.25	1	20	0	-3°	0°	-1°	10°	-11°
12	.25	1.5	14	0	0	1°	0°	-3°	-1°
13	1.0	2	16	-3°	25°	5°	-13°	-17°	7°
14	.5	2	20	1°	-4°	2°	7°	187°	-157°
Mean Differences				0	-4.3	1.8	-.40	35.4	-29.6
Standard Deviation				1.9	2.28	1.9	7.8	85.3	71.8
Standard Error				.85	10.2	.85	3.48	38.1	32.1
"t" Test				0	<1	2.12	<1	<1	<1
Significance									

Angles in degrees.

Drug Times: 2 hours or less.

TABLE 36

DIFFERENCES OF ANGLES OF WAVES FROM VECTORCARDIOGRAM LEADS
OF PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS
WITH STATISTICAL COMPARISON

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS _m		QRS _i		QRS _t	
				F	S	F	S	F	S
7	.50	24	12	16°	4°	17°	14°	14°	-21°
10	.25	4	20	-3°	1°	-3°	7°	10°	1°
14	.50	6.5	20	-2°	4°	-6°	1°	176°	177°
14	.50	7.5		-1°	6°	-11°	19°	193°	5°
19	.25	4.5	15	0°	3°	0°	3°	0°	
Mean Differences				2°	3.6	-.6	8.8	78.7	23
Standard Deviation				7.9	1.7	10.1	6.5	97	88.5
Standard Error				3.53	.76	4.51	2.9	43.3	39.5
"t" Test				<1	4.74	<1	3.03	1.81	<1
Significance					+ +		+		

Angles in degrees.

Drug Times: More than 2 hours.

TABLE 36a

SUMMARY OF SIGNIFICANT DIFFERENCES OF AXES FROM VECTORCARDIOGRAM

	Changes in Mean	"t" Test	Significance
QRS Axis Sagittal Plane	3.6	4.74	+ +
QRS _i Axis Sagittal Plane	8.8	3.03	+

Drug Time: More than 2 hours.

Time-Based Vectorcardiograms:

The results of the calculation of the spatial magnitudes of the waves using formula (1) (Page 28) are given in Table 37 for the pre-treated dog, in Table 38 after drug treatment with a drug time of 2 hours or less, and in Table 39 after drug treatment with a drug time of more than 2 hours.

The ratios of these spatial magnitudes to the QRS_m spatial magnitude were calculated. Table 40 gives these ratios for the pre-treated dog, Table 41 gives these ratios after drug treatment with a drug time of 2 hours or less, and Table 42 gives these ratios after drug treatment with a drug time of more than two hours. The differences of the ratios between the pre-treated dogs before and after treatment were analyzed. Table 43 gives the differences of the ratios and analysis for the drug times of more than 2 hours. Table 45 summarizes the significant results. The P wave is smaller, the ST_a wave is larger, and the T wave is smaller after the drug with a drug time of more than two hours.

The calculated spatial angles of each wave to the QRS maximal vector using formulas (1), (2) and (3) are given in Table 46 for the pre-treated dog, Table 47 after drug treatment with a drug time of 2 hours or less, and in Table 48 after drug treatment with a drug time of more than 2 hours. The differences between the pre-treatment and drug treatment for each dog is given in Table 49 with a drug time of 2 hours or less, and in Table 50 for a drug time of more than two hours. Summarizing these analyses

shows that no comparisons of the angles were statistically different after drug treatment as compared to pre-treated values.

Measurements of the heart rate and intervals from the time-based vectorcardiographic leads are given in Table 51 for the pre-treated dogs, Table 52 after drug treatment with a drug time of 2 hours or less, and in Table 53 after drug treatment with a drug time of more than 2 hours. The differences between the pre-treated and drug treatment for each drug time was calculated. Table 54 gives the analysis of these differences for the drug time of 2 hours or less, and Table 55 gives the analysis of these differences for the drug time of more than two hours. A summary of the significant comparisons is given in Table 56. Only the QT interval is significantly different. It is longer in duration after administration of the drug with a drug time of 2 hours or less.

TABLE 37

SPATIAL MAGNITUDES OF WAVES CALCULATED FROM TIME-BASED
VECTOCARDIOGRAPHIC LEADS OF THE
PRE-TREATED ANESTHETIZED DOGS

Dog No.	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
7	.35	1.57	1.52	.74	.11	0	.17	.32
8	.23	1.86	1.16	.75	.04	0	.05	.16
10	.21	2.52	1.86	.58	.23	0	.17	.30
12	.41	2.66	1.89	.47	0	.13	.05	.33
13	.20	1.02	1.22	.41	.04	0	.03	.22
14	.88	3.18	2.05	1.19	.40	.10	.25	.32
19	.47	3.58	2.17	2.03	.61	.08	.31	.32

Magnitude in millivolts.

TABLE 38

SPATIAL MAGNITUDES OF WAVES CALCULATED FROM TIME-BASED
VECTORCARDIOGRAPHIC LEADS AFTER DRUG TREATMENT
OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
8	.25	1	12	.17	.96	.81	.43	.076	-	.089	.191
10	.25	1	20	.25	2.39	1.85	.40	.233	.020	.045	.530
12	.25	1.5	14	.50	1.64	1.18	.58	.355	.383	-	.305
13	1.0	2	16	.22	1.15	1.21	.47	.040	.080	.182	.058
14	.5	2	20	.82	2.61	1.63	.28	.351	.161	.318	.270

Magnitude in millivolts.

Drug Times: 2 hours or less.

Drug: G Strophanthin, given i.v.

TABLE 39

SPATIAL MAGNITUDES OF WAVES CALCULATED FROM TIME-BASED
VECTORCARDIOGRAPHIC LEADS AFTER DRUG TREATMENT
OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
7	.5*	24	12	.23	1.22	.86	.56	-	.040	.220	.265
10	.25	4	20	.28	2.46	1.72	.59	.163	.160	.071	.357
14	.5	6.5	20	.72	1.80	.97	.26	.030	-	.045	.253
14	.5	7.5		.69	1.84	1.03	.20	.100	-	.110	.254
19	.25	4.5	15	.53	2.40	1.75	1.43	.226	.050	.304	.363

Magnitudes in millivolts.

Drug Times: More than 2 hours.

Drug: G Strophanthin, given i.v.

* Dose of drug given i.m. in this experiment.

TABLE 40

RATIOS OF MAGNITUDES OF EACH WAVE TO THE QRS_m
 SPATIAL MAGNITUDES CALCULATED FROM THE TIME-BASED VECTORCARDIOGRAM
 OF PRE-TREATED ANESTHETIZED DOGS

Dog No.	P	QRS_m	QRS_i	QRS_t	ST_a	ST_b	ST_c	T
7-1	18.3	100	81.1	35	8.3	-	8.7	19.4
8-1	12.4	100	62.4	40.3	2.2	-	2.9	8.5
10-1	8.3	110	73.8	23.0	9.2	-	6.5	11.9
12-1	15.4	100	71.1	17.7	-	4.9	1.9	12.6
13-1	19.6	100	119.6	40.2	4.1	-	2.7	21.7
14-1	27.1	110	64.5	37.4	12.6	3.1	7.7	10.1
19-1	13.1	110	60.6	56.7	17.0	2.2	8.5	8.9

TABLE 41

RATIOS OF MAGNITUDE OF EACH WAVE TO THE QRS_m
 SPATIAL MAGNITUDE CALCULATED FROM TIME-BASED VECTORCARDIOGRAM
 AFTER DRUG TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
8	.25	1	12	17.7	100	84.4	44.8	7.9	-	9.3	19.9
10	.25	1	20	10.5	100	77.4	16.7	9.7	.8	1.9	22.2
12	.25	1.5	14	30.5	100	72.0	35.4	21.6	23.4	-	18.6
13	1.0	2	16	19.1	100	105.0	40.9	3.5	7.0	15.8	7.4
14	.5	2	20	31.4	100	62.5	10.7	13.4	6.2	11.8	10.3

QRS magnitude x 100.

Drug Times: 2 hours or less.

Drug - G Strophanthin, given i.v.

TABLE 42

RATIOS OF MAGNITUDES OF THE WAVES TO THE QRS_m
 SPATIAL MAGNITUDES CALCULATED FROM THE TIME-BASED VECTORCARDIOGRAM
 AFTER DRUG TREATMENT OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P	QRS_m	QRS_1	QRS_t	ST_a	ST_b	ST_c	T
7	.50*	24	12	18.9	100	70.5	45.9	-	3.3	18.3	21.7
10	.25	4	20	11.4	100	69.9	24.0	6.6	6.5	2.9	14.5
14	.50	6.5	20	40.0	100	53.9	14.4	1.7	-	2.5	14.1
14	.50	7.5		37.5	100	56.0	10.9	5.4	-	6.0	13.8
19	.25	4.5	15	22.1	100	72.9	59.6	9.4	2.1	12.7	15.1

QRS magnitude x 100.

Drug Times: More than 2 hours.

Drug - G Strophanthin, given i.v.

* Dose of drug given i.m. in this experiment.

TABLE 43

DIFFERENCES IN RATIOS OF MAGNITUDE OF WAVES BETWEEN PRE-TREATED
AND DRUG-TREATED ANESTHETIZED DOGS CALCULATED FROM TIME-BASED
VECTORCARDIOGRAM WITH STATISTICAL ANALYSIS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P	QRS _m	QRS ₁	QRS _t	ST _a	ST _b	ST _c	T
8	.25	1	12	-5.3	-	-26.3	-4.5	-5.7	0	-6.4	-11.4
10	.25	1	20	-2.2	-	-3.6	6.3	-.5	-.8	4.6	-10.3
12	.25	1.5	14	-15.1	-	-.9	-17.7	-21.6	-18.5	1.9	-6.0
13	1.0	2	16	.5	-	14.4	-.6	.6	-7.0	-13.1	14.3
14	.5	2	20	-4.3	-	2.0	26.7	-.8	-3.1	-4.1	-.2
Mean Differences				-5.3		-2.88	1.8	-5.6	-5.9	-3.4	-2.7
Standard Deviation				6.9		14.8	15.9	±9.3	±7.6	±7.0	±10.5
Standard Error				3.08		6.61	7.1	±4.15	±3.39	±3.13	4.69
"t" Test				1.72		< 1	< 1	1.35	2.01	1.09	<1
Significance											

Drug Times: Less than 2 hours.

TABLE 44

DIFFERENCES IN RATIOS OF MAGNITUDES OF WAVES BETWEEN PRE-TREATED
AND DRUG-TREATED ANESTHETIZED DOGS CALCULATED FROM TIME-BASED
VECTORCARDIOGRAM WITH STATISTICAL ANALYSIS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
7	.50*	24	12	0.5	-	10.6	-10.9	8.3	-3.3	-9.6	-2.3
10	.25	4	20	-3.1	-	3.9	-1.0	2.6	-6.5	3.6	-2.6
14	.50	6.5	20	-12.9	-	10.6	23	10.9	3.1	5.2	-4.0
14	.50	7.5		-10.4	-	8.5	26.5	7.2	3.1	1.7	-3.7
19	.25	4.5	15	-13.2	-	-12.3	-2.9	7.6	0.1	-4.2	-6.2
Mean Differences				-7.9		4.26	6.9	7.3	-.7	-.7	-3.8
Standard Deviation				6.0		9.7	16.7	6.0	4.2	6.1	1.6
Standard Error				2.68		4.33	7.46	2.68	1.86	2.72	.71
"t" Test				2.95		.98	.92	2.72	.38	.26	5.35
Significance				+				+			+ ÷

Drug Times: More than 2 hours.

TABLE 45

SUMMARY OF SIGNIFICANT DIFFERENCES OF THE RATIOS
OF MEANS OF MAGNITUDE BETWEEN THE
PRE-TREATED AND DRUG-TREATED ANESTHETIZED DOGS

Wave*	Differences in Means	"t" Test	Significance
P	-7.9	2.95	+
ST _a	7.3	2.72	+
T	-3.8	5.36	+ +

- indicates wave magnitude became relatively smaller after drug.

+ indicates wave magnitude became relatively larger after drug.

* All these waves are from the Drug Time of More Than Two Hours Series.

TABLE 46

SPATIAL ANGLES OF EACH WAVE TO THE QRS_m VECTOR CALCULATED
FROM TIME-BASED VECTORCARDIOGRAM OF PRE-TREATED
ANESTHETIZED DOG

Dog No.	P- QRS_m	QRS_i - QRS_m	QRS_t - QRS_m	ST_a - QRS_m	ST_b - QRS_m	ST_c - QRS_m	T- QRS_m
7	21°	9°	173°	46°	-	15°	173°
8	10°	12°	165°	10°	-	12°	11°
10	21°	3°	174°	0°	-	28°	175°
12	10°	1°	171°	-	170°	170°	179°
13	21°	6°	152°	50°	-	40°	152°
14	5°	17°	5°	4°	45°	27°	170°
19	7°	7°	7°	6°	6°	25°	158°

Angles in degrees.

TABLE 47

SPATIAL ANGLES OF EACH WAVE TO THE QRS_m VECTOR CALCULATED
FROM TIME-BASED VECTORCARDIOGRAM AFTER DRUG TREATMENT
OF ANESTHETIZED DOG

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS _i - QRS _m	QRS _t - QRS _m	ST _a - QRS _m	ST _b - QRS _m	ST _c - QRS _m	T - QRS _m
8	.25	1	12	11°	168°	48°	-	5°	19°
10	.25	1	20	6°	166°	3°	99°	55°	178°
12	.25	1.5	14	5°	173°	168°	170°	-	14°
13	1.0	2	16	9°	159°	98°	172°	163°	53°
14	.50	2	20	12°	130°	5°	1°	28°	9°

Angles in degrees.

Drug Times: 2 hours or less.

Drug - G Strophanthin, given i.v.

TABLE 48

SPATIAL ANGLES OF EACH WAVE TO THE QRS_m VECTOR CALCULATED
FROM TIME-BASED VECTORCARDIOGRAM AFTER DRUG TREATMENT
OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS _i - QRS _m	QRS _t - QRS _m	ST _a - QRS _m	ST _b - QRS _m	ST _c - QRS _m	T - QRS _m
7	.50*	24	12	3°	180°	-	9°	9°	2°
10	.25	4	20	5°	145°	4°	173°	128°	175°
14	.50	6.5	20	17°	147°	4°	-	23°	5°
14	.50	7.5		18°	145°	6°	-	6°	10°
19	.25	4.5	15	14°	12°	6°	174°	3°	2°

Angles in degrees.

Drug Times: More than 2 hours.

Drug - G Strophanthin, given i.v.

* Dose of drug given i.m. in this experiment.

TABLE 49

DIFFERENCES OF SPATIAL ANGLES TO QRS_m CALCULATED FROM
TIME-BASED VECTORCARDIOGRAM OF PRE-TREATED AND DRUG TREATED
ANESTHETIZED DOGS, WITH STATISTICAL ANALYSIS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	QRS ₁ - QRS _m	QRS _t - QRS _m	ST _a - QRS _m	ST _b - QRS _m	ST _c - QRS _m	T - QRS _m
8	.25	1	12	1°	-3°	-38°	0°	7°	-8°
10	.25	1	30	-3°	8°	-3°	99°	-30°	-3°
12	.25	1.5	14	-4°	-2°	-168°	0°	170°	165°
13	1.0	2	16	-3°	-7°	48°	172°	-123°	99°
14	.5	2	20	5°	-125°	1°	49°	-1°	161°
Mean Differences				.8	-25.8	-32°	63°	4°	83°
Standard Deviation				3.8	55.7	82°	73°	-	85°
Standard Error				1.70	24.9	37°		-	38°
"t" Test				< 1	1.04	< 1	1.91	< 1	2.18
Significance									

Differences in degrees.

Drug Times: 2 hours or less.

Drug - G Strophanthin, given i.v.

TABLE 50

DIFFERENCES OF SPATIAL ANGLES TO QRS_m CALCULATED FROM
TIME-BASED VECTORCARDIOGRAM OF PRE-TREATED AND DRUG-TREATED
ANESTHETIZED DOGS, WITH STATISTICAL ANALYSIS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	P-QRS _m	QRS ₁ -QRS _m	QRS _t -QRS _m	ST _a -QRS _m	ST _b -QRS _m	ST _c -QRS _m	T-QRS _m
7	.50*	24	12	12°	6°	-7°	46°	-9°	6°	-171°
10	.25	4	20	14°	-2°	29°	-4°	-173°	-100°	0°
14	.50	6.5	20	1°	0°	-142°	0°	45°	4°	165°
14	.50	7.5		-2°	-1°	-140°	-2°	45°	21°	160°
19	.25	4.5	15	1°	-7°	-5°	0°	-168°	22°	156°
Mean Differences				5.2	.8	-53	8°	-52°	-9.4°	62°
Standard Deviation				72.6	4.7	81.9	21.3	110	51.3	147
Standard Error				32.4	2.10	36.6	9.5	49.1	22.9	66
"t" Test				< 1	< 1	1.45	< 1	1.06	< 1	.94
Significance										

Differences in degrees.

Drug Times: More than 2 hours.

Drug - G Strophanthin, given i.v.

*Dose of drug given i.m. in this experiment.

TABLE 51

HEART RATES AND INTERVALS MEASURED FROM TIME-BASED
VECTORCARDIOGRAM ON PRE-TREATED
ANESTHETIZED DOGS

Dog No.	Heart Rate beats/ Minute	Intervals				
		P	P-R	QRS	Q-T	RR'
7	160	.03	.08	.030	.188	.356
8	155	.02	.08	.022	.168	.388
10	160	.05	.08	.026	.196	.376
12	176	.05	.08	.032	.204	.340
13	193	.03	.08	.028	.124	.312
14	183	.03	.08	.024	.156	.328
19	136	.04	.08	.040	.190	.412

Intervals in seconds.

TABLE 52

HEART RATES AND INTERVALS MEASURED FROM TIME-BASED
VECTORCARDIOGRAM AFTER DRUG TREATMENT
OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate Beats/ minute	Intervals				
					P	P-R	QRS	QT	HR'
8	.25	1	12	165	.03	.08	.022	.18	.368
10	.25	1	20	188	.03	.07	.024	.18	.320
12	.25	1.5	14	185	.04	.09	.034	.16	.304
13	1.0	2	16	155	.03	.10	.026	.15	.388
14	.50	2	20	200	.03	.08	.026	.15	.300

Intervals in seconds.

Drug Times: 2 hours or less.

Drug - G Strophanthin, given i.v.

TABLE 53

HEART RATES AND INTERVALS MEASURED FROM TIME-BASED
VECTORCARDIOGRAM AFTER DRUG TREATMENT
OF ANESTHETIZED DOGS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate Beats/ minute	Intervals				RR'
					P	P-R	QRS	QT	
7	.50*	24	12	150	.04	.13	.030	.270	.504
10	.25	4	20	200	.03	.09	.024	.168	.300
14	.50	6.5	20	200	.04	.09	.024	.150	.300
14	.50	7.5		200	.04	.08	.026	.180	.276
19	.25	4.5	15	15	.03	.08	.025	.150	.280

Intervals in seconds.

Drug Times: More than 2 hours.

Drug - G Strophanthin, given i.v.

*Dose of drug given i.m. in this experiment.

TABLE 54

**DIFFERENCES OF HEART RATE AND INTERVALS MEASURED FROM
VECTORCARDIOGRAM OF PRE-TREATED AND DRUG-TREATED
ANESTHETIZED DOGS WITH STATISTICAL ANALYSIS**

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate Beats/ minute	Intervals			
					P	P-R	QRS	QT
8	.25	1	12	-10	0	0	.006	.028
10	.25	1	20	-28	.02	.01	.002	.016
12	.25	1.5	14	-9	.01	-.01	-.002	.044
13	1.0	2	16	38	0	-.02	.002	.026
14	.50	2	20	-17	0	0	-.002	.006
Mean Differences					.006	-.004	.0012	.024
Standard Deviation					-	-	.003	.014
Standard Error					-	-	.001	.006
"t" Test					< 1	< 1	< 1	4.00
Significance								+

Drug Times: 2 hours or less.

Drug - G Strophanthin, given i.v.

TABLE 55

DIFFERENCES OF HEART RATES AND INTERVALS MEASURED FROM
TIME-BASED VECTORCARDIOGRAM OF PRE-TREATED AND DRUG TREATED
ANESTHETIZED DOGS WITH STATISTICAL ANALYSIS

Dog No.	Dose in Mg.	Time in Hours	Wt. in Lbs.	Heart Rate Beats/ minute	Intervals			
					P	P-R	QRS	QT
7	.50*	24	12	0		-.01	-.05	0
10	.25	4	20	-40	.02	-.01	.002	.018
14	.50	6.5	20	17	-.01	.01	0	.006
14	.50	7.5		17	-.01	0	-.002	.076
19	.25	4.5	15	-72	.01	0	.015	.04
Mean Differences				-15.6	.01	-.006	.007	.028
Standard Deviation				39.2	.013	.008	.020	.031
Standard Error				17.5	.006	.004	.009	.014
"t" Test				.89	1.66	1.50	.77	2.00
Significance								

Drug Time: More than 2 hours.

Drug - G Strophanthin, given i.v.

*Dose of drug given i.m. in this experiment.

TABLE 56

SUMMARY OF SIGNIFICANT DIFFERENCES OF INTERVALS

	Changes in Mean	"t" Test	Signifi- cance
QT Interval	.024	4.00	+

Drug Time: 2 hours or less.

DRUG STUDIES - SERIES II - UNANESTHETIZED DOGS.

For this study, four dogs were trained to lie on their right sides. Digitoxin was given orally at a dose of 0.1 mg. per day for the low-dose condition and 1.0 mg. per day for the high dose condition. The recording and dose schedule is given in Table 1 (page 37).

All the data obtained with the three methods were evaluated using analysis of variance. For the purpose of this analysis, the major sources of variation separated were: 1) between dogs, 2) between conditions (non-drug, low-dose drug and high-dose drug conditions), and 3) between waves (the voltage, magnitude or angles of the waves measured in each method). Minor sources of variance, separated, were the interactions: 1) dogs x conditions, 2) dogs x waves, 3) conditions x waves and 4) dogs x conditions x waves.

Standard Clinical Method: An analysis of variance was performed for each lead. Tables 57 to 62 contain the analysis of variance for each of the limb leads and Tables 63 to 69 contain the analysis of variance for each of the chest leads.

Since this study was designed to study the effects of the selected drugs on the electrocardiogram, it is noted that these effects are contained in the variances between conditions. A summary of the significant comparisons is given in Table 57. Summarizing, differences are noted between non-drug and drug, and were significant in leads AVF, V_1 , V_2 , V_3 and V_4 . Table 57 also lists the wave analysis for these significant leads. The differences between waves was significant in the following: 1) R wave is decreased in voltage, comparing non-drug versus low-dose drug condition, in leads V_1 , V_2 , V_3 and V_4 ; the R wave is increased in voltage, comparing non-drug versus high-dose conditions, in leads AVF, V_1 , V_2 , V_3 and V_4 ; 2) the S wave is increased in voltage, comparing non-drug versus high-dose drug conditions, in lead V_2 ; and 3) the T wave is increased in voltage, comparing non-drug versus high-dose conditions, in lead V_2 .

The source of variance, between dogs, was highly significant in all the leads. This suggests that there is a large variation from dog to dog. The source of variation, between waves, was also highly significant in all leads. This is an expected result because the waves are all different by definition. It may be noted that a number of the interactions were also significant. In this study these are of no special interest, except for calculation purposes, and, hence, no further analysis or mention will be made of them.

TABLE 57

SUMMARY OF SIGNIFICANT FINDINGS FROM THE ANALYSIS
OF VARIANCE FOR CONDITIONS

Lead	F Ratio	Signifi- cance	Wave	Conditions Means*			"t" Test Comparisons		Differences in Means	
				Non-Drug (N-D)	Low Dose (L-D)	High Dose (H-D)	ND vs. LD	Signifi- cance	ND vs. HD	Signifi- cance
AVF	6.54	++	R	1.074	1.080	1.233	.006		.153	+++
V ₁	7.40	+	R	1.015	.924	1.283	-.091	+	.359	+++
V ₂	17.32	+++	R	1.148	.978	4.373	-.170	+++	3.395	+++
			S	.126	.108	.441	-.018		.333	+++
			T	.119	.089	.423	-.030		.334	+++
V ₃	16.39	+++	R	1.247	.923	1.433	-.324	+++	.510	+++
V ₄	9.16	+++	R	1.039	.850	1.161	-.189	+++	.291	+++

* Means of conditions in millivolts.

TABLE 58

ANALYSIS OF VARIANCE FOR LEAD I, SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D.F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	.1112	.0371	5.22	+++
Conditions (C)	2	.0188	.0094	< 1	
Waves (W)	5	11.3539	2.2708	32.96	++++
D x C	6	.2619	.0436	6.14	+++
D x W	15	1.0328	.0689	9.70	+++
C x W	10	.1823	.0182	2.56	
D x C x W	30	.5649	.0188	2.65	+++
Error	294	2.0863	.0071		
Total	365	15.6121			

TABLE 59
ANALYSIS OF VARIANCE FOR LEAD II, SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D.F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	2.5281	.8427	82.62	++++
Conditions (C)	2	.2127	.1063	3.10	
Waves (W)	5	67.2370	13.4474	26.94	++++
D x C	6	.2058	.0343	3.36	+++
D x W	15	7.4878	.4992	48.94	+++
C x W	10	.3803	.0380	3.73	
D x C x W	30	2.7436	.915	8.97	+++
Error	294	2.9836	.0102		
Total	365	81.5089			

TABLE 60
ANALYSIS OF VARIANCE FOR LEAD III, SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D.F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	1.2264	.4088	31.20	++++
Conditions (C)	2	.0022	.0011	< 1	
Waves (W)	5	31.0795	6.2159	21.01	++++
D x C	6	.5073	.0846	6.46	+++
D x W	15	4.4386	.2959	22.59	+++
C x W	10	.0341	.0034	< 1	
D x C x W	30	.1980	.0066	< 1	
Error	294	3.8531	.0131		
Total	365	41.3392			

TABLE 61
ANALYSIS OF VARIANCE FOR LEAD \overline{AVR} , SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D. F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	1.0094	.3365	46.10	++++
Conditions (C)	2	.0400	.0200	2.73	
Waves (W)	5	36.6094	7.3219	31.97	++++
D x C	6	.0461	.0077	1.05	
D x W	15	3.4348	.2290	31.37	+++
C x W	10	.1251	.0125	1.34	
D x C x W	30	.2790	.0093	1.27	
Error	294	2.1543	.0073		
Total	365	43.6981			

TABLE 62
ANALYSIS OF VARIANCE FOR LEAD AVL, SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D.F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	.3558	.1186	16.03	++++
Conditions (C)	2	.0515	.0257	1.31	
Waves (W)	5	7.6752	1.5350	10.51	++++
D x C	6	.1176	.0196	2.65	+
D x W	15	2.1913	.1461	19.74	+++
C x W	10	.1921	.0192	71	
D x C x W	30	2.6387	.0880	11.89	+++
Error	294	2.1740	.0074		
Total	365	13.2222			

TABLE 63a
ANALYSIS OF VARIANCE FOR LEAD AVF, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio	Significance
Dogs (D)	3	1,7117	.5706	52.35	++++
Conditions (C)	2	.1426	.0713	6.54	++
Waves (W)	5	55.0174	11.0035	28.54	++++
D x C	6	.0876	.0146	1.34	
D x W	15	5.7822	.3855	35.37	+++
C x W	10	.2134	.0213	1.95	+
D x C x W	30	.2305	.0077	< 1	
Error	294	3.1908	.0109		
Total	365	66.4362			

TABLE 63b
ANALYSIS OF WAVES IN LEAD AVF

Waves	Conditions - Means*			Comparisons ND vs. LD	Differences in Means ND vs. HD
	Non-Drug (N-D)	Low Dose (L-D)	High Dose (H-D)		
P	.096	.092	.094	.004	.002
Q	.164	.147	.208	.017	.061
R	1.074	1.080	1.233	.006	.153 +++ **
S	.078	.095	.129	.017	.034
T	.054	.069	.086	.015	.017
ST	.003	.001	.002	.002	.001

*Means in millivolts.

**Significance.

TABLE 64a
ANALYSIS OF VARIANCE OF LEAD V₁, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio	Significance
Dogs (D)	3	.1479	.0493	5.30	++
Conditions (C)	2	.3227	.1613	7.40	+
Waves (W)	5	50.0588	10.0117	197.47	++++
D x C	6	.1309	.0218	2.35	+
D x W	15	.7610	.0507	5.45	+++
C x W	10	1.0828	.1083	3.23	++
D x C x W	30	1.0050	.0335	3.60	+++
Error	294	2.7268	.0093		
Total	365	56.2359			

TABLE 64b
ANALYSIS OF WAVES IN LEAD V₁

Waves	Conditions - Means*			Comparisons ND vs. LD	Differences in Means ND vs. HD
	Non-Drug (N-D)	Low Dose (L-D)	High Dose (H-D)		
P	.034	.034	.024	0	.010
Q	.004	.017	0	.013	.017
R	1.015	.924	1.283	-.091 + **	.359 +++ **
S	.124	.108	.167	.016	.059
T	.145	.107	.143	.038	.036
ST	.008	-.003	.003	.011	.006

*Means in millivolts.

**Significance.

TABLE 65a
ANALYSIS OF VARIANCE OF LEAD V₂, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio	Significance
Dogs (D)	3	.3067	.1022	7.15	+++
Conditions (C)	2	.4955	.2477	17.32	+++
Waves (W)	5	61.4668	12.2933	97.49	++++
D x C	6	.1498	.0250	1.75	
D x W	15	1.8909	.1261	8.82	+++
C x W	10	1.8812	.1881	6.99	+++
D x C x W	30	.8076	.0269	1.88	++
Error	294	4.2006	.0143		
Total	365	71.1991			

TABLE 65b
ANALYSIS OF WAVES IN LEAD V₂

Waves	Conditions - Means*			Comparisons ND vs. LD	Differences in Means ND vs. HD
	Non-Drug (N-D)	Low Dose (L-D)	High Dose (H-D)		
P	.032	.034	.029	.002	-.005
Q	.013	.011	.039	.002	.028
R	1.148	.978	4.373	.170 +++ **	3.395 +++
S	.126	.108	.441	.018	.333 +++
T	.119	.089	.423	.030	.334 +++
ST	.006	-.003	.003	.009	.006

*Means in millivolts.

**Significance.

TABLE 66a

ANALYSIS OF VARIANCE OF LEAD V₃, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio	Significance
Dogs (D)	3	.7223	.2407	13.37	++++
Conditions (C)	2	.5901	.2951	16.39	++++
Waves (W)	5	61.3438	12.2687	53.30	++++
D x C	6	.2012	.0335	1.86	
D x W	15	3.4531	.2302	12.79	+++
C x W	10	2.3781	.2378	10.38	+++
D x C x W	30	.6855	.0229	1.27	
Error	294	5.2970	.0180		
Total	365	74.6711			

TABLE 66b

ANALYSIS OF WAVES IN LEAD V₃

Waves	Conditions - Means*			Comparisons ND vs. LD	Differences in Means ND vs. HD
	Non-Drug (N-D)	Low Dose (L-D)	High Dose (H-D)		
P	.035	.032	.027	.003	.005
Q	.013	.021	.011	.008	.010
R	1.247	.923	1.433	.324+++**	.510+++**
S	.101	.077	.114	.024	.037
T	.119	.078	.104	.041	.026
ST	.004	.002	-.008	.002	.010

*Means in millivolts.

**Significance.

TABLE 67a

ANALYSIS OF VARIANCE OF LEAD V_4 , SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio	Significance
Dogs (D)	3	.6929	.2310	12.91	++++
Conditions (C)	2	.3279	.1639	9.16	+++
Waves (W)	5	45.2314	9.0462	35.43	++++
D x C	6	.0068	.0011	<1	
D x W	15	3.8303	.2553	14.26	+++
C x W	10	.7800	.0780	3.32	++
D x C x W	30	.7059	.0235	1.31	
Error	294	5.2650	.0179		
Total	365	56.8402			

TABLE 67b

ANALYSIS OF WAVES IN LEAD V_4

Waves	Conditions - Means*			Comparisons ND vs. LD	Differences in Means ND vs. HD
	Non-Drug (N-D)	Low Dose (L-D)	High Dose (H-D)		
P	.031	.037	.028	.006	.009
Q	.016	.035	.033	.019	.002
R	1.039	.850	1.161	.189+++**	.291+++**
S	.084	.062	.081	.022	.019
T	.096	.050	.058	.046	.008
ST	-.002	.002	-.004	.004	.006

*Means in millivolts.

**Significance.

TABLE 68
ANALYSIS OF VARIANCE OF LEAD V₅, SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D.F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	.4884	.1628	11.07	+++
Conditions (O)	2	.0391	.0196	1.33	
Waves (W)	5	35.2227	7.0445	37.59	++++
D x C	6	.0914	.0152	1.03	
D x W	15	2.8110	.1874	12.75	+++
C x W	10	.2353	.0235	1.10	
D x C x W	30	.6424	.0214	1.46	
Error	294	4.3278	.0147		
Total	365	43.8581			

TABLE 69
ANALYSIS OF VARIANCE OF LEAD V₆, SERIES II

Source of Variation (V.S.)	Degrees of Freedom (D.F.)	Sums of Squares (S.S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	.4811	.1603	12.43	+++
Conditions (C)	2	.0373	.0186	< 1	
Waves (W)	5	30.2710	6.0542	32.92	+++
D x C	6	.2946	.0491	3.81	+++
D x W	15	2.7590	.1839	14.25	+++
C x W	10	.1702	.0170	71	
D x C x W	30	1.6777	.0559	4.33	+++
Error	294	3.7818	.0129		
Total	365	39.4727			

The analysis of variance for the wave intervals is given in Table 70, for the frontal axes in Table 71, and for the QRS-ST-T angles in Table 72. The degree of variation, between conditions, is not significant in any of these analyses. The variation between dogs is significant in the analyses of intervals and angles, again indicating a large variation from dog to dog.

TABLE 70

ANALYSIS OF VARIANCE OF INTERVALS, STANDARD
ELECTROCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio (F)	Significance
Dogs (D)	3	.0030	.0010	3.30	+
Conditions (C)	2	.0048	.0024	3.00	-
Waves (W)	1	.1992	.1992	16.6	+
D x C	6	.0042	.0008	2.66	+
D x W	3	.0035	.0012	4.00	++
C x W	2	.0002	.0001	< 1	
D x C x W	6	.0015	.0002	< 1	
Error	98	.0325	.0003		
	121				

TABLE 71

ANALYSIS OF VARIANCE OF FRONTAL AXIS, STANDARD ELECTROCARDIOGRAM

Source of Variation (V. S.)	Degrees of Freedom (D. F.)	Sums of Squares (S. S.)	Mean Square (M.S.)	Variance Ratio (F)	Significance
Dogs (D)	3	3,184	1,061	<1	
Conditions (C)	2	10,802	5,401	1.81	
Waves (W)	2	192,459	96,229	4.94	
D x C	6	29,673	4,946	1.65	+++
D x W	6	116,843	19,474	6.53	
C x W	4	19,762	4,941	1.66	
D x C x W	12	46,531	3,878	1.30	
Error	147	438,528	2,983		
Total	182	857,782			

Axis in degrees.

TABLE 72

ANALYSIS OF VARIANCE OF QRS-ST-T ANGLES, STANDARD ELECTROCARDIOGRAM

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio	Significance
Dogs (D)	3	50,783	16,927	9.41	+++
Conditions (C)	2	3,894	1,947	<1	
D x C	6	27,292	4,548	2.53	+
Error	49	88,054	1,797		
Total	60				

Angles in degrees.

TABLE 73

SUMMARY OF ANALYSIS OF VARIANCE OF SIGNIFICANT CONDITIONS AND
ASSOCIATED WAVES, VECTORCARDIOGRAM LEADS

Lead	F Ratio	Signifi- cance	Axis Wave	Conditions - Means (Degrees)			Comparisons		Differences in Means	
				Non-Drug (ND)	Low Dose (LD)	High Dose (HD)	ND vs. LD	Signifi- cance	ND vs. HD	Signifi- cance
Sagittal	16.89	+++	QRS _t	-127.9	-127.9	-140.7	0		12.8	+++

Vectorcardiograms of Series II:

An analysis of variance for the sagittal and frontal leads of this method was studied. Only the measurements of the angles of the QRS_m , QRS_i and QRS_t (instantaneous vector) were included in the analysis of variance because measurements of the P and ST-T $s\hat{E}$ loop are difficult, since these waves are superimposed upon $QRS\ s\hat{E}$ loop. This information can be easily obtained from the Time-Based vectorcardiographic method which is reported in the next section.

Analysis of variance of wave angles for the frontal lead are given in Table 74 and for the sagittal lead in Table 75a. The variation between conditions is significant in the sagittal lead. Analysis of the magnitude of the waves, between conditions, for this lead is given in Table 75b.

A summary of the analysis of variance of conditions and associated wave angles is given in Table 73. There is significance between conditions in the sagittal lead. Further analysis shows that the QRS_t wave angle is larger, comparing the non-drug versus the high-dose drug conditions.

The source of variation, between dogs, is significant in both of these leads, indicating a large variation occurring from dog to dog. Source of variation, between waves, was significant only in the sagittal lead, indicating that smaller differences in the shape of the $QRS\ s\hat{E}$ -loop occur as compared to the changes in its orientation.

TABLE 74

ANALYSIS OF VARIANCE OF WAVE ANGLES IN FRONTAL LEAD
OF VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Ratios	Significance
Dogs (D)	3	114,303	38,101	4,233.44	++++
Conditions (C)	2	451	226	4.03	
Waves (W) (QRS, QRS _i and QRS _t)	2	756,342	378,171	<1	
D x C	6	-336	56	6.22	+++
D x W	6	231,286	38,548	4,283.11	++++
C x W	4	518	129	3.14	
D x C x W	12	-496	41	4.56	+++
Error	144	1,300	9		
Total	179	1,103,368			

TABLE 75a

ANALYSIS OF VARIANCE OF WAVE ANGLES IN SAGITTAL LEAD
OF VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Ratios	Significance
Dogs (D)	3	133,021	44,340	1,198.37	++++
Conditions (C)	2	1,249	625	16.89	++++
Waves (W) (QRS, QRS _i and QRS _t)	2	768,579	384,289	10.08	+
D x C	6	-249	-42	1.13	
D x W	6	234,585	39,098	1,056.70	++++
W x C	4	26,459	6,614	3.01	
D x W x C	12	-26,298	-2,192	59.24	++++
Total	144	5,265	37		

TABLE 75b

ANALYSIS OF WAVES IN SAGITTAL LEAD OF
VECTORCARDIOGRAM, SERIES II

Wave	Conditions - Means (Degrees)			Comparisons		Differences in Means	
	Non-Drug (ND)	Low Dose (LD)	High Dose (HD)	ND vs. LD	Signifi- cance	ND vs. HD	Signifi- cance
QRS _m	7.8	7.0	4.8	-0.8		-2.2	
QRS _i	10.2	8.4	6.3	-1.8		-2.1	
QRS _t	-127.9	-127.9	-140.7	0		12.8	+++

Time-Based Vectorcardiograms, Series II:

The spatial magnitudes of the P, QRS_m , QRS_1 , QRS_t , ST_a , ST_b , ST_c and T deflections were calculated using formula (1) (see page 28). As mentioned earlier, these magnitudes were transformed into ratios, using the QRS_m vector as 100. The analysis of variance studied used as the major sources of variation: 1) between dogs, 2) between conditions (drug and non-drug) and 3) between waves. Minor sources of variation, interactions of these sources, were used in the calculations.

Tables 76 to 79 give analyses of variance for the ratios of the spatial magnitudes. Tables 80 to 83 give the analyses of variance for the spatial angles. Table 84 summarizes the significant findings which are obtained between conditions.

Summarizing the significant findings shows that the analysis of variance of the QRS_1 - QRS_m and QRS_t - QRS_m spatial angles, between conditions, was highly significant. The analysis of these waves shows that QRS_t angle increased, comparing the non-drug versus high-dose drug conditions.

The only other significant findings were between dogs, indicating that a large variability occurs between dogs. Some of the interactions were noted to be significant.

TABLE 76

ANALYSIS OF VARIANCE OF QRS_i/QRS_m AND QRS_t/QRS_m MAGNITUDE
CALCULATED FROM THE TIME-BASED VECTORCARDIOGRAM,
SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratios (F)	Significance
Dogs (D)	3	.167752	.055917	6.59	+++
Waves (W)	1	1.076146	1.076146	7.73	
Conditions (C)	1	.005342	.005432	<1	
D x W	3	.417599	.139199	16.42	+++
D x C	3	.014143	.004714	<1	
W x C	1	.021453	.026453	2.53	
D x W x C	3	.014986	.004995	<1	
Error	40	.339032	.008476		
Total	55	2.056453			

Conditions: Non-Drug and low-dose drug.

TABLE 77

ANALYSIS OF VARIANCE OF RATIOS OF P, ST_a, ST_b, ST_c AND T
 SPATIAL MAGNITUDES TO THE QRS_m CALCULATED FROM
 TIME-BASED VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratios (F)	Significance
Dogs (D)	3	.015394	.005131	2.71	+
Waves (W)	4	.344395	.086099	53.38	+++
Conditions (C)	1	.000059	.000059	<1	
D x W	12	.019351	.001613	<1	
D x C	3	.013610	.004537	2.40	
W x C	4	.000868	.000217	<1	
D x W x C	12	.023057	.001921	1.01	
Error	100	.188778	.001888		
Total	139	.605512			

Conditions: Non-drug and low-dose drug.

TABLE 78

ANALYSIS OF VARIANCE OF RATIOS OF QRS_i AND QRS_t TO
THE QRS_m VECTOR CALCULATED FROM TIME-BASED
VECTOCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratios (F)	Significance
Dogs (D)	3	.140944	.046781	2.81	+
Waves (W)	1	2.018172	2.018172	11.61	+++
Conditions (C)	1	.016127	.016127	<1	
D x W	3	.521289	.173763	10.42	+++
D x C	3	.065364	.021788	1.31	
W x C	1	.031504	.031504	1.89	
D x W x C	3	.012314	.004105	<1	
Error	46	.766667	.016667		
Total	61	3.572381			

Conditions: Non-drug and high-dose drug.

TABLE 79

ANALYSIS OF VARIANCE OF RATIOS OF P, ST_a, ST_b, ST_c AND T WAVES
TO THE QRS_m VECTOR CALCULATED FROM TIME-BASED
VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratios (F)	Significance
Dogs (D)	3	.082382	.027461	16.02	++++
Waves (W)	4	.527631	.131908	20.16	++++
Conditions (C)	1	.000422	.000422	<1	
D x W	12	.078523	.006543	3.81	+++
D x C	3	.000348	.000116	<1	
W x C	4	.007582	.001896	1.10	
D x W x C	12	.007232	.000602	<1	
Error	115	.197129	.001714		
Total	154	.901249			

Conditions: Non-drug and high-dose drug.

TABLE 80

ANALYSIS OF VARIANCE OF SPATIAL ANGLES OF THE QRS_i AND
 QRS_t WITH THE QRS_m SPATIAL VECTOR CALCULATED FROM
 THE TIME-BASED VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratios (F)	Significance
Dogs (D)	3	96,504	32,168	1,398.60	++++
Conditions (C)	1	10	10	<1	
Waves (W)	1	301,187	301,187	9.11	
D x C	3	258	86	3.73	+
D x W	3	99,108	33,036	1,436.34	++++
C x W	1	45	45	1.95	
D x C x W	3	38	13	<1	
Error	58	1,329			
Total	73	498,479			

Conditions: Non-drug and low-dose drug.

TABLE 81

ANALYSIS OF VARIANCE OF SPATIAL ANGLES OF P, ST_a, ST_b, ST_c AND
T SPATIAL VECTORS WITH THE QRS_m SPATIAL VECTOR CALCULATED
FROM TIME-BASED VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratios (F)	Significance
Dogs (D)	3	35,280	11,760	8.30	+++
Conditions (C)	1	1,119	1,119	< 1	
Waves (W)	3	11,844	3,948	2.79	+
D x C	3	1,408	469	< 1	
D x W	9	17,559	1,951	1.37	
C x W	3	3,769	1,256	< 1	
D x C x W	9	4,029	447	< 1	
Error	116	164,284	1,416		
Total	147	239,292			

Conditions: Non-drug and low-dose drug.

TABLE 82a

ANALYSIS OF VARIANCE OF SPATIAL ANGLES OF QRS_1 AND QRS_t
WITH THE QRS_m SPATIAL VECTOR CALCULATED FROM THE
TIME-BASED VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Ratio	Significance
Dogs (D)	3	77,556	25,852	1,124.00	++++
Conditions (C)	1	263	263	11.43	+++
Waves (W)	1	264,818	264,818	10.35	+
D x C	3	-89	-30	1.30	
D x W	3	76,724	25,575	1,111.95	++++
C x W	1	592	592	3.21	
D x C x W	3	-552	-184	8.00	+++
Error	46	1,052	23		
Total	61	420,364			

Conditions: Non-drug and high-dose drug.

TABLE 82b

ANALYSIS OF WAVES OF SIGNIFICANT CONDITIONS FOR THE CALCULATED
SPATIAL ANGLES FROM THE TIME-BASED VECTORCARDIOGRAM

Wave Angles	Conditions - Mean Angles		Comparisons	
	Non-Drug (ND)	High Dose (HD)	ND vs. HD	Significance
$QRS_1 - QRS_m$	4.6°	4.1°	.5°	
$QRS_t - QRS_m$	130.9°	139.6°	8.7°	+++

Angles in degrees.

TABLE 83

ANALYSIS OF VARIANCE OF SPATIAL ANGLES OF P, ST_a, ST_b, ST_c, AND T
 SPATIAL VECTORS WITH THE QRS_m SPATIAL VECTOR CALCULATED
 FROM TIME-BASED VECTORCARDIOGRAM, SERIES II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Ratios	Significance
Dogs (D)	3	1,699	566	1.77	
Conditions (C)	1	18	18	< 1	
Waves (W)	3	428	143	< 1	
D x C	3	411	137	< 1	
D x W	9	1,636	182	< 1	
C x W	3	799	266	< 1	
D x C x W	9	2,146	238	< 1	
Error	92	29,277	318		
Total	123	36,444			

Conditions: Non-drug and high-dose drug.

TABLE 84

**SUMMARY OF ANALYSES OF VARIANCE OF BETWEEN CONDITIONS AND ASSOCIATED
WAVES OF TIME-BASED VECTORCARDIOGRAM METHOD, SERIES II**

Measurement	F Ratios	Signifi- cance	Wave	Conditions-Means (Degrees)		Differences in Means	
				Non-Drug (ND)	High Dose (HD)	ND vs. HD	Signifi- cance
Angles (between conditions)	11.43	+++	QRS _t - QRS _m	130.9	136.6	8.7	+++

DRUG STUDIES - SERIES THREE - CONTROLLED ANESTHESIA

The anesthetized dogs of Series I revealed that no characteristic "digitalis pattern" was obtained in the "normal" dog after administration of G strophanthin. This series was designed to control, as much as possible, the effects of anesthesia so that any such effects could be separated from the drug effects.

Six conditions are studied: (I) non-drug and early anesthesia, (II) non-drug and 3 hour anesthesia, (III) low-dose drug, 1 hour drug time and 4 hours anesthesia, (IV) low-dose drug, 24 hours drug time and early anesthesia, (V) low-dose drug, 25 hours drug time and 3 hours anesthesia, (VI) low-dose drug, 28 hours drug time and 4 hours anesthesia. Analysis of variance was performed using the factorial methods of Batson (1951 and 1953) with the following independent comparisons: I versus II, I versus IV, II versus V, II versus III plus VI, and III versus VI.

Standard Clinical Method: The means of these voltages are given in Tables 85 to 88 for these 12 standard clinical leads. The factorial analysis of variance was performed only for those waves, which showed some differences in the means, by inspection. Table 89 gives the means of each wave analyzed and the F ratio for each of the independent comparisons of the limb leads. Similar data is analyzed and presented in Table 90 for the chest leads.

Table 91 lists the means of the voltage of waves and leads for each condition with the comparisons that are significant.

A summary of the comparisons, condition I (early anesthesia) versus condition II (3 hour anesthesia) shows: 1) there is a Q wave decreased voltage in lead I and increased voltage in lead II and 2) the ST wave decreases voltage in leads V_2 and V_3 .

A summary of the comparisons, condition I (early anesthesia) versus condition IV (24 hour drug, early anesthesia) shows: 1) the P wave decreased voltage in lead V_4 and 2) the T wave increased voltage in lead V_1 .

A summary of the comparisons, condition II (3 hour anesthesia) versus condition V (24 hour drug, 3 hour anesthesia) shows: 1) the P wave decreased voltage in lead V_4 and 2) the R wave decreased voltage in lead V_2 .

A summary of the comparison, condition II (3 hour anesthesia) versus conditions III (4 hour anesthesia, 1 hour drug) plus VI (4 hour anesthesia, 25 hour drug plus 1 hour drug) shows: 1) the P wave decreases voltage in leads AVL and V_4 , and 2) the Q wave decreases voltage in lead II, and 3) the R wave decreased voltage in leads V_2 , V_3 and V_5 .

A summary of the comparison, condition III (4 hour anesthesia, 1 hour drug) versus condition VI (4 hour anesthesia, 25 hour drug plus one hour drug) shows: 1) the P wave decreases voltage in leads AVL, AVF, V_2 , V_3 and V_4 , and 2) the T wave increases voltage in lead V_5 .

TABLE 85

MEAN VOLTAGES IN MILLIVOLTS OF THE WAVES FROM ELECTROCARDIOGRAM OF
STANDARD CLINICAL LIMB LEADS FOR THE SIX CONDITIONS

Condition	Anesthesia Duration	Drug Duration	Day	Lead I					
				P	Q	R	S	T	S-T
I	Early	0	1	.03	.18	.52	0	-.014	.02
II	3 hrs.	0	1	.024	.13	.56	0	-.014	.01
III	4 hrs.	1 hr.	1	.02	.13	.57	0	-.04	-
IV	Early	24 hrs.	2	.03	.22	.49	0	-.026	.014
V	3 hrs.	25 hrs.	2	.02	.25	.57	0	-.026	.016
VI	4 hrs.	28 hrs.	2	.02	.24	.54	0	-.03	.02

Condition	Anesthesia Duration	Drug Duration	Day	Lead II					
				P	Q	R	S	T	S-T
I	Early	0	1	.20	.24	2.19	.086	.094	.03
II	3 hrs.	0	1	.27	.57	1.74	.06	.06	.05
III	4 hrs.	1 hr.	1	.22	.21	1.95	.15	.036	-.046
IV	Early	24 hrs.	2	.17	.19	1.82	.17	-.01	.008
V	3 hrs.	25 hrs.	2	.20	.29	1.89	.12	.036	-.036
VI	4 hrs.	28 hrs.	2	.10	.24	1.85	.15	.07	-.02

Condition	Anesthesia Duration	Drug Duration	Day	Lead III					
				P	Q	R	S	T	S-T
I	Early	0	1	.14	.13	1.72	.10	.13	.02
II	3 hrs.	0	1	.18	.12	1.63	.14	-.04	-.04
III	4 hrs.	1 hr.	1	.14	.12	1.22	.13	-.01	-.06
IV	Early	24 hrs.	2	.12	.11	1.25	.12	.04	0
V	3 hrs.	25 hrs.	2	.116	.13	1.28	.086	.086	-.03
VI	4 hrs.	28 hrs.	2	.05	.09	1.19	.19	.17	-.036

TABLE 86

MEAN VOLTAGES IN MILLIVOLTS OF THE WAVES FROM ELECTROCARDIOGRAM OF
STANDARD CLINICAL LIMB LEADS FOR THE SIX CONDITIONS

Condition	Anesthesia Duration	Drug Duration	Day	Lead \overline{AVR}					
				P	Q	R	S	T	S-T
I	Early	0	1	.11	.18	1.48	.05	.07	.03
II	3 hrs.	0	1	.16	.15	1.43	.06	-.05	-.018
III	4 hrs.	1 hr.	1	.13	.15	1.32	.066	-.05	.004
IV	Early	24 hrs.	2	.12	.23	1.29	.07	-.05	-.002
V	3 hrs.	25 hrs.	2	.116	.25	1.29	.09	.03	-.03
VI	4 hrs.	28 hrs.	2	.06	.22	1.29	.08	-.01	-.03

Condition	Anesthesia Duration	Drug Duration	Day	Lead \overline{AVL}					
				P	Q	R	S	T	S-T
I	Early	0	1	.06	.05	.76	.07	.012	.004
II	3 hrs.	0	1	.07	.03	.68	.07	-.016	-.02
III	4 hrs.	1 hr.	1	.04	.03	.41	.12	.05	-.03
IV	Early	24 hrs.	2	.04	.02	.58	.13	.03	0
V	3 hrs.	25 hrs.	2	.04	.01	.51	.11	.04	.01
VI	4 hrs.	28 hrs.	2	.004	.01	.49	.11	.12	-.03

Condition	Anesthesia Duration	Drug Duration	Day	Lead \overline{AVF}					
				P	Q	R	S	T	S-T
I	Early	0	1	.20	.22	2.18	.13	-.09	.02
II	3 hrs.	0	1	.25	.26	2.01	.14	-.07	-.016
III	4 hrs.	1 hr.	1	.22	.20	1.87	.17	-.05	-.06
IV	Early	24 hrs.	2	.16	.32	1.84	.13	.03	.05
V	3 hrs.	25 hrs.	2	.19	.22	1.86	.20	.09	-.03
VI	4 hrs.	28 hrs.	2	.09	.16	1.76	.24	.14	-.07

TABLE 87

MEAN VOLTAGES IN MILLIVOLTS OF THE WAVES FROM ELECTROCARDIOGRAM OF
STANDARD CLINICAL LIMB LEADS FOR THE SIX CONDITIONS

Condition	Anesthesia Duration	Drug Duration	Day	Lead V ₁					
				P	Q	R	S	T	S-T
I	Early	0	1	.07	-	2.06	.43	.06	.04
II	3 hrs.	0	1	.09	-	1.49	.44	.25	-.01
III	4 hrs.	1 hr.	1	.07	-	1.35	.55	.20	-.016
IV	Early	24 hrs.	2	.06	-	1.88	.56	.30	.06
V	3 hrs.	25 hrs.	2	.06	-	1.31	.63	.32	-.01
VI	4 hrs.	28 hrs.	2	.04	-	1.30	.63	.36	-.04

Condition	Anesthesia Duration	Drug Duration	Day	Lead V ₂					
				P	Q	R	S	T	S-T
I	Early	0	1	.09	-	2.63	.21	.05	.15
II	3 hrs.	0	1	.15	-	2.52	.31	.25	.02
III	4 hrs.	1 hr.	1	.13	-	1.94	.32	.21	.01
IV	Early	24 hrs.	2	.05	-	2.27	.43	.23	.10
V	3 hrs.	25 hrs.	2	.09	-	1.93	.40	.30	.01
VI	4 hrs.	28 hrs.	2	.06	-	1.78	.36	.28	-.03

Condition	Anesthesia Duration	Drug Duration	Day	Lead V ₃					
				P	Q	R	S	T	S-T
I	Early	0	1	.124	.01	3.09	.15	.200	.14
II	3 hrs.	0	1	.152	0	2.62	.33	.192	.022
III	4 hrs.	1 hr.	1	.14	0	2.15	.298	.12	-.008
IV	Early	24 hrs.	2	.098	.004	2.69	.298	.082	.134
V	3 hrs.	25 hrs.	2	.088	0	2.23	.302	.18	-.006
VI	4 hrs.	28 hrs.	2	.06	0	1.88	.29	.304	-.008

TABLE 88

MEAN VOLTAGES IN MILLIVOLTS OF THE WAVES FROM ELECTROCARDIOGRAM OF
STANDARD CLINICAL LIMB LEADS FOR THE SIX CONDITIONS

Condition	Anesthesia Duration	Drug Duration	Day	Lead V ₄					
				P	Q	R	S	T	S-T
I	Early	0	1	.162	.044	2.24	.066	.008	.10
II	3 hrs.	0	1	.208	.088	1.92	.096	-.01	-.028
III	4 hrs.	1 hr.	1	.166	.132	1.59	.096	.058	.014
IV	Early	24 hrs.	2	.142	.092	1.85	.108	-.024	.062
V	3 hrs.	25 hrs.	2	.126	.052	1.89	.208	.066	-.002
VI	4 hrs.	28 hrs.	2	.104	.072	1.61	.166	.174	-.028

Condition	Anesthesia Duration	Drug Duration	Day	Lead V ₅					
				P	Q	R	S	T	S-T
I	Early	0	1	.16	.182	1.98	.074	-.016	.05
II	3 hrs.	0	1	.174	.094	1.96	.132	.018	-.008
III	4 hrs.	1 hr.	1	.158	.148	1.47	.114	.078	-.02
IV	Early	24 hrs.	2	.112	.228	1.62	.12	.056	.014
V	3 hrs.	25 hrs.	2	.11	.178	1.65	.156	.042	.026
VI	4 hrs.	28 hrs.	2	.096	.11	1.43	.148	.176	-.026

Condition	Anesthesia Duration	Drug Duration	Day	Lead V ₆					
				P	Q	R	S	T	S-T
I	Early	0	1	.13	.26	1.66	.08	.06	.043
II	3 hrs.	0	1	.174	.32	1.39	.034	.032	-.006
III	4 hrs.	1 hr.	1	.146	.20	1.39	.104	-.06	.008
IV	Early	24 hrs.	2	.118	.37	1.25	.06	.064	.032
V	3 hrs.	25 hrs.	2	.10	.258	1.43	.138	.03	-.028
VI	4 hrs.	28 hrs.	2	.088	.20	1.31	.17	.174	.004

TABLE 89a

FACTORIAL ANALYSIS OF VOLTAGE OF THE WAVES FROM STANDARD CLINICAL LIMB LEADS

Lead	Wave	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2							
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
I	Q	.184	.126	.132	.2221	.246	.200	3.57 ++ **	<1	1.53	<1	1.24
II	Q	.238	.574	.210	.192	.286	.242	2.29 + **	<1	1.68	3.45 ++ **	<1
II	S	.086	.064	.152	.168	.122	.150	<1	<1	<1	1.08	<1
II	T	.092	.060	.036	-.008	.036	.074	<1	<1	<1	<1	<1
II	ST	.028	.032	-.046	.008	-.056	-.018	<1	<1	<1	<1	<1

*Means in millivolts.

**Significance

TABLE 89b

FACTORIAL ANALYSIS OF VOLTAGE OF THE WAVES FROM STANDARD CLINICAL LIMB LEADS

Lead	Wave	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2			I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug					
III	R	1.72	1.63	1.42	1.25	1.28	1.19	< 1	1.68	< 1	1.07	< 1
III	S	.100	.136	.132	.122	.182	.190	< 1	< 1	< 1	< 1.	< 1
AVR	Q	.180	.150	.156	.228	.246	.222	< 1	< 1	< 1	< 1	< 1
AVR	R	1.48	1.43	1.32	1.29	1.29	1.29	< 1	< 1	< 1	< 1	< 1
AVL	P	.058	.088	.044	.038	.036	.004	< 1	< 1	1.58	3.79 ++**	2.35 + **

*Means in millivolts.

**Significance

TABLE 89c

FACTORIAL ANALYSIS OF VOLTAGE OF THE WAVES FROM STANDARD CLINICAL LIMB LEADS

Lead	Wave	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2			I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug					
AVL	Q	.050	.028	.032	.024	.010	.010	<1	1.21	<1	<1	<1
AVF	P	.202	.246	.222	.156	.186	.088	<1	<1	<1	<1	4.16 +++ **
AVF	R	2.18	2.01	1.87	1.84	1.86	1.76	<1	<1	<1	<1	<1
AVF	S	.130	.140	.168	.134	.196	.240	<1	<1	<1	<1	<1
AVF	T	-.086	-.072	-.048	.030	.086	.138	<1	<1	<1	<1	<1

*Means in millivolts.

**Significance

TABLE 90a

FACTORIAL ANALYSIS OF VOLTAGE OF THE WAVES FROM STANDARD CLINICAL CHEST LEADS

Lead	Wave	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2			I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug					
V ₁	T	.064	.252	.196	.300	.318	.364	1.51	2.39 + **	1.87	< 1	1.21
V ₂	P	.092	.152	.132	.048	.092	.056	< 1	< 1	< 1	2.20	2.82 + **
V ₂	R	2.63	2.52	1.94	2.27	1.93	1.78	< 1	1.16	3.12 ++ **	5.25 +++ **	< 1
V ₂	S-T	.154	.022	.012	.098	.014	-.034	2.90 + **	< 1	< 1	< 1	< 1
V ₃	P	.124	.152	.140	.098	.088	.060	< 1	< 1	1.96	1.73	3.08 ++ **
V ₃	R	3.09	2.62	2.13	2.69	2.23	1.88	1.61	1.07	1.18	3.75 ++ **	< 1

*Means in millivolts.

**Significance

TABLE 90b

FACTORIAL ANALYSIS OF VOLTAGE OF THE WAVES FROM STANDARD CLINICAL CHEST LEADS

Lead	Wave	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2			I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug					
V ₃	S-T	.14	.002	-.008	.134	-.006	-.008	2.94 + **	<1	<1	<1	<1
V ₄	P	.162	.208	.166	.142	.126	.104	1.60	3.03 ++ **	5.09 +++	16.1 +++ **	2.91 + **
V ₄	S	.066	.096	.096	.108	.208	.166	<1	<1	1.04	<1	<1
V ₅	R	1.98	1.96	1.47	1.62	1.65	1.43	<1	1.19	<1	3.31 ++ **	<1
V ₅	T	-.016	.018	-.072	.056	.042	.176	<1	<1	<1	<1	2.22 + **
V ₆	S	.080	.034	.104	.060	.138	.174	<1	<1	1.25	1.70	<1
V ₆	T	.060	.032	-.060	.064	.030	.174	<1	<1	<1	<1	2.05

*Means in millivolts.

**Significance

TABLE 91a

SUMMARY OF SIGNIFICANT FINDINGS FROM FACTORIAL ANALYSIS
OF STANDARD ELECTROCARDIOGRAPHIC LEADS

Wave	Lead	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2							
		I	II	III	IV	V	VI					
		Early Anes- thesia	3 hr. Anes- thesia	4 hr. Anes- thesia 1 hr. Drug	Early Anes- thesia	3 hr. Anes- thesia	4 hr. Anes- thesia 1 hr. Drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
P	AVL	.058	.088	.044	.038	.036	.004				(-)3.79 ++	(-)2.35 +
	AVF	.204	.246	.222	.156	.186	.088					(-)4.16 +++
	V ₂	.092	.152	.132	.048	.092	.056					(-)2.82 +
	V ₃	.124	.152	.140	.098	.088	.060					(-)3.08 ++
	V ₄	.162	.208	.166	.142	.126	.104		(-)3.03 ++	(-)5.09 +++	(-)16.1 +++	(-)2.91 +

*Means in millivolts.

(-) Second condition voltage is decreased.

TABLE 91b

SUMMARY OF SIGNIFICANT FINDINGS FROM FACTORIAL ANALYSIS
OF STANDARD ELECTROCARDIOGRAPHIC LEADS

Wave	Lead	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2							
		I	II	III	IV	V	VI					
		Early Anes- thesia	3 hr. Anes- thesia	4 hr. Anes- thesia 1 hr. Drug	Early Anes- thesia	3 hr. Anes- thesia	4 hr. Anes- thesia 1 hr. Drug					
Q	I	.184	.126	.132	.222	.246	.200	(-)3.57 ++				
	II	.238	.574	.210	.192	.286	.242	2.29 +			(-)3.45 ++	
R	V ₂	2.63	2.52	1.94	2.27	1.93	1.78			(-)3.12 ++	(-)5.25 +++	
	V ₃	3.09	2.62	2.13	2.69	2.23	1.88				(-)3.75 ++	
	V ₅	1.98	1.96	1.47	1.62	1.65	1.43				(-)3.31 ++	

*Means in millivolts.

(-) Second condition voltage is decreased.

TABLE 91c

SUMMARY OF SIGNIFICANT FINDINGS FROM FACTORIAL ANALYSIS
OF STANDARD ELECTROCARDIOGRAPHIC LEADS

Wave	Lead	Conditions*						Comparisons - F Ratios				
		Day 1			Day 2							
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
T	V ₁	.064	.252	.196	.300	.318	.364		2.39 +			
	V ₅	-.016	.018	-.072	.056	.042	.176					2.22 +
S-T	V ₂	.154	.022	.012	.098	.014	-.034	(-)2.90 +				
	V ₃	.140	.002	-.008	.134	-.006	-.008	(-)2.94 +				

*Means in millivolts.

(-) Second condition voltage is decreased.

The heart rate and interval measurement of the P-R, RR', QRS, and QT are given and analyzed in Tables 92 to 95. Estimation of the QRS, ST and T axes in the frontal plane are given and analyzed in Tables 96 to 99. The estimation of the spatial angles of the QRS-T and ST-T are given and analyzed in Tables 100 and 101.

Table 102 lists the means of each of these interval measurements and estimation of the angles that show some significant comparisons.

A summary of the comparison, condition II (3 hour anesthesia) versus conditions III (4 hour anesthesia, 1 hour drug) + VI (4 hour anesthesia, 25 hour drug + 1 hour drug) shows: the P-R interval increases in duration. All the other interval and angles do not show any significant differences with the various condition comparisons.

TABLE 92

**FACTORIAL ANALYSIS OF HEART RATE FROM
STANDARD ELECTROCARDIOGRAM, SERIES III**

Heart Rate (beats per minute)	Conditions					
	Day 1			Day 2		
	I	II	III 4 hour Anes- thesia 1 hour drug	IV	V	VI 4 hour Anes- thesia 1 hour drug
	Early Anes- thesia	3 hour Anes- thesia		Early Anes- thesia	3 hour Anes- thesia	
Dog #20	173	210	167	120	182	165
Dog #21	140	150	160	137	158	165
Dog #22	155	165	167	158	150	185
Dog #23	106	208	214	140	175	130
Dog #24	100	152	116	136	160	172
Sums	674	885	824	691	825	817
Means	135	177	165	138	165	163

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	44521	4452	5.75	+++
I vs IV	10	289	28.9	<1	
II vs V	10	3600	360	<1	
II vs III + VI	30	16641	544.7	<1	
III vs VI	10	49	4.9	<1	
Error	29	774			

TABLE 93

FACTORIAL ANALYSIS OF P-R INTERVAL FROM
STANDARD ELECTROCARDIOGRAM, SERIES III

P-R Interval	Conditions					
	Day 1			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	.09	.08	.09	.14	.11	.14
Dog #21	.09	.10	.09	.10	.09	.08
Dog #22	.11	.08	.08	.09	.08	.09
Dog #23	.11	.08	.09	AV Block	.14	.18
Dog #24	.10	.09	.11	.10	.09	AV Block
Sums	.50	.43	.46	.59	.51	.67
Means	.10	.086	.088	.118	.102	.136

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.0049	.00049	<1	
I vs IV	10	.0081	.00081	<1	
II vs V	10	.0064	.00064	<1	
II vs III + VI	30	.2209	.0736	8.85	+++
III vs VI	10	.0441	.00441	5.82	+++
Error	29	.000831			

TABLE 94

FACTORIAL ANALYSIS OF RR' INTERVAL FROM
STANDARD ELECTROCARDIOGRAM, SERIES III

RR' Interval	Conditions					
	Day 1			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	.348	.288	.360	.600	.332	.364
Dog #21	.428	.400	.376	.448	.380	.364
Dog #22	.388	.364	.360	.380	.400	.324
Dog #23	.560	.288	.280	.580	.344	.460
Dog #24	.600	.392	.516	.440	.376	.348
Sums	2.324	1.732	1.892	2.448	1.832	1.860
Means	.465	.346	.378	.489	.366	.372

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.350464	.0350	4.48	+++
I vs IV	10	.01537	.00154	<1	
II vs V	10	.01000	.0010	<1	
II vs III + VI	30	.082944	.0027648	<1	
III vs VI	10	.001024	.000102	<1	
Error	29	.0078			

TABLE 95

FACTORIAL ANALYSIS OF THE QRS INTERVAL FROM
STANDARD ELECTROCARDIOGRAM, SERIES III

QRS Interval	Conditions					
	Day 1			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	.04	.04	.03	.03	.03	.03
Dog #21	.04	.03	.03	.03	.03	.03
Dog #22	.03	.03	.03	.03	.03	.03
Dog #23	.03	.03	.03	.03	.03	.03
Dog #24	.03	.03	.03	.03	.03	.03
Sums	.17	.16	.15	.15	.15	.15
Means	.032	.032	.030	.030	.030	.030

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.0001	.00001	< 1	
I vs IV	10	.0004	.00004	< 1	
II vs V	10	.0001	.00001	< 1	
II vs III + VI	30	.0004	.00004	< 1	
III vs VI	10	0	0	< 1	
Error	29	.0281			

TABLE 96

**FACTORIAL ANALYSIS OF Q-T INTERVAL FROM
STANDARD ELECTROCARDIOGRAM, SERIES III**

Q-T Interval	Conditions					
	Day			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	.190	.160	.160	.248	.180	.180
Dog #21	.240	.210	.200	.240	.190	.180
Dog #22	.210	.190	.180	.220	.190	.160
Dog #23	.230	.160	.170	.410	.190	.200
Dog #24	.240	.190	.190	.220	.190	.190
Sums	1.110	.910	.900	1.338	.940	.910
Means	.222	.182	.180	.268	.188	.182

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.0400	.004	1.85	+
I vs IV	10	.05198	.00519	2.40	
II vs V	10	.000900	.00009	<1	
II vs III + VI	30	.000100	.000003	<1	
III vs VI	10	.000100	.00001	<1	
Error	29	.002156			

TABLE 97

**FACTORIAL ANALYSIS OF QRS AXIS IN THE FRONTAL PLANE
FROM STANDARD ELECTROCARDIOGRAM, SERIES III**

QRS Axis	Conditions					
	Day 1			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	65°	63°	65°	80°	65°	65°
Dog #21	85°	65°	70°	85°	80°	75°
Dog #22	65°	80°	85°	80°	85°	85°
Dog #23	85°	80°	70°	76°	80°	75°
Dog #24	85°	85°	85°	70°	65°	70°
Sums	385°	373°	375°	391°	375°	370°
Means	77°	75°	75°	78°	75°	74°

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	144	14.4	>1	
I vs IV	10	36	3.6	>1	
II vs V	10	4	0.4	>1	
II vs III + VI	30	1	.03	>1	
III vs VI	10	25	2.5	>1	
Error	29		68		

TABLE 98

FACTORIAL ANALYSIS OF ST AXIS IN THE FRONTAL PLANE
FROM STANDARD ELECTROCARDIOGRAM, SERIES III

ST Axis	Conditions					
	Day 1			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	30°		-90°		-80°	-70°
Dog #21		-75°	-90°	-65°	-100°	-95°
Dog #22		-95°	-90°	110°	-90°	-90°
Dog #23	90°	30°	90°	90°	90°	90°
Dog #24			90°	90°	20°	50°
Sums	120°	-140°	-90°	225°	-160°	-115°
Means	64°	-28°	-18°	45°	-32°	-23°

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10	67600	6760	1.20	
I vs IV	10	11025	1102	< 1	
II vs V	10	400	40	< 1	
II vs III + VI	30	5625	187.5	< 1	
III vs VI	10	625	62	< 1	
Error	29		5598		

TABLE 99

FACTORIAL ANALYSIS OF T AXIS IN FRONTAL PLANE
FROM STANDARD ELECTROCARDIOGRAM, SERIES III

T Axis*	Conditions					
	Day 1			Day 2		
	I Early Anes- thesia	II 3 hour Anes- thesia	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	-95°	-95°	-95°	-95°	-110°	-120°
Dog #21	90°	+88°	85°	90°	90°	90°
Dog #22	-100°	-90°	-100°	-100°	-100°	-100°
Dog #23	100°	-105°	90°	-105°	75°	75°
Dog #24	90°	89°	85°	89°	85°	85°
Sums	85°	-113°	265°	-121°	40°	30°
Means	17°	- 23°	53°	-24°	8°	6°

* Axis in degrees.

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	39,204	3,920.4	<1	
I vs IV	10	42,436	4,244	<1	
II vs V	10	23,409	2,341	<1	
II vs III + VI	30	18,225	2,002	<1	
III vs VI	10	55,225	5,523	<1	
Error	29		9,101		

TABLE 100

FACTORIAL ANALYSIS OF SPATIAL QRS-T ANGLE
FROM STANDARD ELECTROCARDIOGRAM, SERIES III

QRS-T Angle*	Conditions					
	Day 1			Day 2		
	I	II	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	35°	85°	185°	175°	175°	170°
Dog #21	5°	20°	10°	5°	10°	15°
Dog #22	170°	170°	175°	170°	175°	175°
Dog #23	15°	175°	20°	180°	5°	0°
Dog #24	5°	5°	0°	20°	25°	20°
Sums	230°	455°	390°	550°	390°	380°
Means	46°	91°	78°	110°	78°	76°

* Angles in degrees.

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	50,625	5,063	<1	
I vs IV	10	102,400	10,240	1.59	
II vs V	10	4,225	423	<1	
II vs III + VI	30	19,600	653	<1	
III vs VI	10	100	10	<1	
Error	29		6,421		

TABLE 101

FACTORIAL ANALYSIS OF SPATIAL ST-T ANGLE
FROM STANDARD ELECTROCARDIOGRAM, SERIES III

ST-T Angle*	Conditions					
	Day 1			Day 2		
	I	II	III 4 hour Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hour Anes- thesia	VI 4 hour Anes- thesia 1 hour drug
Dog #20	100°	--	10°	--	20°	60°
Dog #21	--	20°	170°	170°	170°	175°
Dog #22	--	5°	10°	180°	5°	10°
Dog #23	10°	120°	0°	165°	15°	15°
Dog #24	--	--	5°	2°	50°	40°
Sums	110°	145°	195°	517°	260°	300°
Means	22°	29°	39°	103°	52°	60°

* Angles in degrees.

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	1,225	123	< 1	++
I vs IV	10	165,649	16,565	3.61	
II vs V	10	13,225	1,323	< 1	
II vs III + VI	30	42,025	1,401	< 1	
III vs VI	10	11,025	1,103	< 1	
Error	29		4,588		

TABLE 102a

SUMMARY OF SIGNIFICANT COMPARISONS OF INTERVALS
OF STANDARD ELECTROCARDIOGRAM

Intervals	Conditions*						Comparisons - F Ratios				
	Day 1			Day 2			I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
	I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. drug					
Heart** Rate	135	177	165	138	165	163	5.75 +++				
P-R	.10	.086	.088	.118	.102	.136				8.85 +++	5.82 +++
RR'	.465	.346	.378	.489	.336	.372	4.48 +++				
QT	.222	.182	.180	.268	.188	.182		2.40 +			

* Means in millivolts

** Beats per minute

TABLE 102b

SUMMARY OF SIGNIFICANT SPATIAL ANGLES
OF STANDARD ELECTROCARDIOGRAM

Angles	Conditions*						Comparisons - F Ratios				
	Day 1			Day 2							
	I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
ST-T	22°	29°	39°	103°	52°	60°		3.61 ++			

* Angles in degrees

Vectorcardiograms:

The factorial statistical analyses of the QRS_m , QRS_i and QRS_t angles in the frontal and sagittal leads only are given for this method. The other information can be more easily obtained from the Time-Based Vectorcardiogram method and is given in that section.

The measurements of the angles in the frontal and sagittal leads of the QRS_m vector are given in Tables 103 and 104, for the QRS_i vector in Tables 105 and 106, and for the QRS_t vector in Tables 107 and 108.

Table 109 lists the means of the angle and the wave for each condition which comparisons are significant.

A summary of these comparisons shows that, condition I (early anesthesia) versus condition II (3 hour anesthesia), and condition I (early anesthesia) versus condition IV (early anesthesia, 24 hours drug) belong to the same populations.

A summary of the comparison, condition II (3 hours anesthesia) versus condition V (3 hours anesthesia, 27 hours drug), shows: that the QRS_i vector's angle is smaller in the sagittal lead.

A summary of the comparison, condition II (3 hours anesthesia) versus condition III (early anesthesia, 24 hours drug) + VI (4 hours anesthesia, 28 hours drug + 1 hour drug) shows that the QRS_t vector's angle is larger in the frontal lead.

A summary of the comparison, condition III (4 hours anesthesia, 1 hour drug) versus condition VI (4 hours anesthesia, 28 hours drug + 1 hour drug) shows that the QRS_m vector's angle is smaller in the sagittal lead.

TABLE 103

**FACTORIAL ANALYSIS OF QRS_m VECTOR'S ANGLE
IN FRONTAL LEAD FROM VECTORCARDIOGRAM**

QRS _m Angle Frontal Plane	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	84	84	87	83	85	85
Dog #21	88	64	55	79	80	82
Dog #22	87	89	88	86	87	88
Dog #23	89	87	89	88	88	87
Dog #24	89	90	89	88	90	89
Sums	437	414	408	424	430	431
Means	87	83	81	85	86	86

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10	529	53	<1	
I vs IV	10	169	17	<1	
II vs V	10	256	26	<1	
III vs III + VI	30	121	4	<1	
III vs VI	10	529	53	<1	
Error	29	564			

TABLE 104

**FACTORIAL ANALYSIS OF ANGLE OF QRS_m VECTOR
IN SAGITTAL LEAD FROM VECTORCARDIOGRAM**

QRS _m Angle Sagittal Plane	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	6	6	6	15	13	3
Dog #21	2	10	13	11	6	3
Dog #22	2	2	2	3	0	1
Dog #23	5	5	4	2	1	-2
Dog #24	5	3	8	2	0	3
Sums	20	26	33	33	20	8
Means	4	5.2	6.6	6.6	4	1.6
Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance	
I vs II	10	36	3.6	<1	++	
I vs IV	10	169	16.9	<1		
II vs V	10	169	16.9	<1		
II vs III + VI	30	225	7.5	<1		
III vs VI	10	625	62.5	3.60		
Error	29	17.4				

TABLE 105

**FACTORIAL ANALYSIS OF ANGLE OF QRS₁ VECTOR
IN THE FRONTAL LEAD FROM VECTORCARDIOGRAM**

QRS ₁ Angle Frontal Plane	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	84	84	87	83	85	85
Dog #21	88	78	80	77	90	90
Dog #22	87	90	90	89	88	89
Dog #23	90	90	90	89	90	89
Dog #24	89	90	90	88	90	90
Sums	438	432	437	426	443	443
Means	88	86	87	85	89	89

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10	36	3.6	<1	
I vs IV	10	144	14.4	<1	
II vs V	10	121	12.1	<1	
II vs III + VI	30	256	8.2	<1	
III vs VI	10	36	3.6	<1	
Error	29	13.8			

TABLE 106

**FACTORIAL ANALYSIS OF THE ANGLE OF THE QRS₁ VECTOR
IN THE SAGITTAL LEAD FROM VECTORCARDIOGRAM**

QRS ₁ Angle Sagittal Plane	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	16	16	13	8	7	10
Dog #21	14	10	12	18	6	3
Dog #22	6	4	4	7	0	1
Dog #23	3	7	8	3	1	0
Dog #24	11	9	10	2	0	3
Sums	50	46	47	38	14	17
Means	10	9.2	9.4	7.6	2.8	3.4

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10	16	1.6	<1	++
I vs IV	10	144	14.4	<1	
II vs V	10	1,024	102.4	3.85	
II vs III + VI	30	784	26.1	<1	
III vs VI	10	400	40.0	1.50	
Error	29	26.6			

TABLE 107

**FACTORIAL ANALYSIS OF THE ANGLE OF THE QRS_t VECTOR
IN FRONTAL LEAD FROM VECTORCARDIOGRAM**

QRS _t * Angle Frontal Plane	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	6	6	173	180	180	185
Dog #21	180	176	185	189	179	181
Dog #22	180	173	180	182	180	180
Dog #23	180	180	180	180	179	180
Dog #24	180	180	180	180	180	180
Sums	726	715	898	909	898	906
Means	145	143	180	182	180	181

* Data transformed so all angles are positive

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10	121	12	< 1	
I vs IV	10	33,489	3,349	1.71	
II vs V	10	33,489	3,349	1.71	
II vs III + VI	30	3,254,416	108,481	5.54	+++
III vs VI	10	64	6	< 1	
Error	29	1,959			

TABLE 108

**FACTORIAL ANALYSIS OF THE ANGLE OF THE QRS_t VECTOR
IN THE SAGITTAL LEAD FROM VECTORCARDIOGRAM**

QRS _t * Angle Sagittal Plane	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	0	0	0	178	193	160
Dog #21	167	172	165	172	177	178
Dog #22	180	180	174	9	180	180
Dog #23	180	169	170	175	180	177
Dog #24	175	175	176	178	177	180
Sums	702	696	685	694	907	875
Means	140	139	137	138	181	175

* Transformed so all angles will be positive

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10	36	4	<1	
I vs IV	10	64	6	<1	
II vs V	10	44,521	4,452	1.16	
II vs III + VI	30	28,224	941	<1	
III vs VI	10	36,100	3,610	<1	
Error	29	3,821			

TABLE 109

SUMMARY OF SIGNIFICANT COMPARISONS OF ANGLES FROM VECTORCARDIOGRAM

Wave Angle	Lead	Conditions						Comparisons - F Ratios				
		Day 1			Day 2							
		I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
QRS _m	Sag.	4	5.2	6.6	6.6	4	1.6					3.60 ++
QRS _i	Sag.	10	9.2	9.4	7.6	2.8	3.4			(-)3.85 ++		
QRS _t	Front.	145	143	180	182	180	181				5.54 +++	

(-) decreased in 2nd conditions

Time-Based Vectorcardiogram:

The magnitudes of the voltages of the P, QRS_m , QRS_1 , QRS_t , ST_a , ST_b , ST_c , and T waves were calculated using formula (1). Factorial analysis of the magnitudes of the QRS_m and T spatial vectors are given in Tables 110 and 111. The magnitudes of all the other waves were transformed into ratios using the QRS_m vector as unity. Factorial analysis of these transformed magnitudes are given in Tables 112 to 118. Table 119 gives a summary of the significant comparisons and the means of each condition.

A summary of the comparison, condition I (early anesthesia) versus condition II (anesthesia 3 hours), shows the QRS_m magnitude is smaller in condition II (anesthesia 3 hours).

A summary of the comparison, condition II (anesthesia 3 hours) versus condition V (anesthesia 3 hours, drug 27 hours), shows that the QRS_1/QRS_m voltage is decreased in condition V.

A summary of the comparison, condition III (anesthesia 4 hours, drug 1 hour) versus condition VI (anesthesia 4 hours, drug 28 hours + drug 1 hour), shows that the P/ QRS_m wave voltage ratio is significantly smaller in condition VI.

The spatial angles of the P- QRS_m , QRS_1 - QRS_m , QRS_t - QRS_m , ST_a - QRS_m , ST_b - QRS_m , ST_c - QRS_m and T- QRS_m were calculated using formulas (1), (2), and (3). Factorial analysis of the independent comparisons are given in Tables 120 to 125. A summary of the significant comparisons along with their means is given in Table 126.

A summary of the comparison, condition I (early anesthesia) versus condition II (anesthesia 3 hours), shows that the QRS_1 - QRS_m spatial angle is

larger in condition II.

A summary of the comparison, condition II (anesthesia 3 hours) versus condition V (anesthesia 3 hours, drug 27 hours), shows that the QRS_1 - QRS_m spatial angle is smaller in condition V.

A summary of the comparison, condition II (anesthesia 3 hours) versus condition III (anesthesia 4 hours, drug 1 hour) + VI (anesthesia 4 hours, drug 28 hours + drug 1 hour), shows: 1) that the QRS_1 - QRS spatial angle is smaller in conditions III + VI, and 2) that T - QRS_m spatial angle is smaller in condition III + VI.

A summary of the comparisons III (anesthesia 4 hours, drug 1 hour) versus condition VI (anesthesia 4 hours, drug 28 hours + drug 1 hour), shows: 1) that the QRS_1 - QRS_m spatial angle is smaller in condition VI, and 2) that the ST_a - QRS_m spatial angle is larger in condition VI.

The factorial analyses of the measured intervals are given in Tables 127 to 131 (P, P-R, QRS, QT, and RR' intervals). Table 132 summarizes the significant comparisons of these intervals.

Only the comparisons of condition I (early anesthesia) versus condition II (anesthesia 3 hours) yielded significant findings. These were: 1) that the QT interval was smaller in condition II, and 2) that the RR' interval was smaller in condition II.

TABLE 110

**FACTORIAL ANALYSIS OF SPATIAL MAGNITUDE OF QRS_m VECTOR
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM**

QRS Wave	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.60	.60	1.61	1.55	1.40	1.12
Dog #21	3.62	2.11	1.88	2.78	2.62	2.33
Dog #22	3.38	1.71	1.74	3.40	3.44	3.65
Dog #23	2.96	2.62	2.55	2.60	2.24	2.64
Dog #24	3.18	2.86	2.81	2.83	2.80	2.64
Sums	13.74	9.90	10.59	13.16	12.50	12.38
Means	2.75	1.98	2.12	2.63	2.50	2.48

Comparisons	Degress of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	14.7456	1.4746	2.15	+
I vs IV	10	.3364	.0336	< 1	
II vs V	10	6.7600	.6760	< 1	
II vs III + VI	30	10.0489	.3349	< 1	
III vs VI	10	3.2041	.3204	< 1	
Error	29	.6868			

TABLE 111

**FACTORIAL ANALYSIS OF SPATIAL MAGNITUDE OF T VECTOR
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM, SERIES III**

T Wave	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.13	.13	.03	.19	.11	.17
Dog #21	.24	.08	.05	.14	.12	.21
Dog #22	.44	.11	.10	.34	.24	.18
Dog #23	.15	.31	.22	.14	.22	.23
Dog #24	.65	.60	.58	.96	1.50	1.40
Sums	1.61	1.23	.98	1.77	2.19	2.19
Means	.32	.25	.20	.35	.44	.44
Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance	
I vs II	10	.1444	.0144	< 1		
I vs IV	10	.0256	.0026	< 1		
II vs V	10	.9216	.0922	< 1		
II vs III + VI	30	.5041	.0168	< 1		
III vs VI	10	1.4641	1.468	1.09		
Error	29	.1346				

TABLE 112

FACTORIAL ANALYSIS OF P/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM, SERIES III

P Wave P/QRS Ratio x 10 ³	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	166	167	199	148	136	249
Dog #21	130	123	154	126	141	094
Dog #22	053	053	575	059	067	094
Dog #23	152	206	196	100	201	151
Dog #24	113	150	149	148	061	144
Sums	614	699	1273	581	606	717
Means	123	140	255	116	121	143

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	7225	723	< 1	
I vs IV	10	1089	109	< 1	
II vs V	10	8649	865	< 1	
II vs III + VI	30	350,464	11,682	1.32	
II vs VI	10	309,136	30,914	3.49	++
Error	29	8869			

TABLE 113

FACTORIAL ANALYSIS OF QRS_1/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

QRS ₁ Wave QRS ₁ /QRS x 10 ³	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	750	750	609	658	800	857
Dog #21	630	663	654	701	511	571
Dog #22	639	672	770	606	639	727
Dog #23	649	771	580	250	442	519
Dog #24	597	766	740	555	625	678
Sums	3265	3622	3353	2770	3017	3352
Means	653	724	671	554	603	670

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	127,449	12,745	< 1	+
I vs IV	10	245,025	24,503	1.30	
II vs V	10	366,025	36,603	2.55	
II vs III + VI	30	290,521	9,684	< 1	
III vs VI	10	1	0.1	< 1	
Error	29	14,330			

TABLE 114

**FACTORIAL ANALYSIS OF QRS_t/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM**

QRS_t Wave QRS_t/QRS $\times 10^3$	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	733	733	609	77	107	241
Dog #21	226	331	394	349	427	524
Dog #22	92	158	17	168	203	227
Dog #23	91	179	217	92	121	178
Dog #24	248	227	242	307	275	292
Sums	1390	1628	1478	993	1133	1462
Means	278	326	296	199	227	292

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	56,644	5,664	< 1	
I vs IV	10	157,609	15,761	< 1	
II vs V	10	245,025	24,503	< 1	
III vs III + VI	30	99,856	3,329	< 1	
III vs VI	10	256	26	< 1	
Error	29	33,113			

TABLE 115

FACTORIAL ANALYSIS OF ST_a/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

ST_a Wave	Conditions					
	Day 1			Day 2		
	I	II	III	IV	V	VI
ST_a/QRS $\times 10^3$	Early Anesthesia	3 hour Anesthesia	4 hour Anesthesia 1 hour Drug	Early Anesthesia	3 hour Anesthesia	4 hour Anesthesia 1 hour Drug
Dog #20	117	117	0	65	14	18
Dog #21	52	19	0	22	57	77
Dog #22	112	76	57	121	64	31
Dog #23	142	46	55	138	107	64
Dog #24	110	98	96	32	79	95
Sums	533	356	208	378	321	285
Means	106	71	42	76	64	57

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	31,329	3,133	1.86	
I vs IV	10	24,025	2,403	1.43	
II vs V	10	961	96	< 1	
II vs III + VI	30	6,561	219	< 1	
III vs VI	10	5,929	593	< 1	
Error	29	1,685			

TABLE 116

FACTORIAL ANALYSIS OF ST_b/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

ST_b Wave	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	50	50	81	26	79	89
Dog #21	17	9	21	0	57	77
Dog #22	9	47	63	24	41	70
Dog #23	44	0	0	23	22	19
Dog #24	47	45	53	78	68	57
Sums	192	151	218	151	267	312
Means	38	30	44	30	53	62

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	1,681	168	< 1	
I vs IV	10	1,681	168	< 1	
II vs V	10	13,456	1,346	1.88	
II vs III + VI	30	51,984	1,733	2.41	
III vs VI	10	8,836	884	1.23	
Error	29	718			

TABLE 117

FACTORIAL ANALYSIS OF ST_c/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

ST _c Wave ST _c /QRS x 10 ³	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	50	50	68	6	0	0
Dog #21	99	90	101	101	53	56
Dog #22	12	35	46	12	17	42
Dog #23	81	0	59	35	40	0
Dog #24	176	196	164	297	325	44
Sums	418	371	438	451	435	142
Means	84	74	88	90	87	28
Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance	
I vs II	10	2,209	221	< 1		
I vs IV	10	1,089	109	< 1		
II vs V	10	4,096	110	< 1		
II vs III + VI	30	26,244	875	< 1		
III vs VI	10	87,616	8,762	1.30		
Error	29	6,724				

TABLE 118

**FACTORIAL ANALYSIS OF T/QRS_m RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM**

T Wave T/QRS x 10 ³	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	217	217	19	123	79	152
Dog #21	66	38	27	50	46	90
Dog #22	130	64	57	100	70	51
Dog #23	51	118	86	54	98	87
Dog #24	204	210	206	339	536	53
Sums	668	647	395	666	829	433
Means	134	129	79	133	166	87

Comparisons	Degrees of Freedom (DF)	Sums of Squares (ss)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	441	44	< 1	
I vs IV	10	4	0.4	< 1	
II vs V	10	324	32	< 1	
II vs III + VI	30	217,156	7,239	< 1	
III vs VI	10	1,444	144	< 1	
Error	29	11,587			

TABLE 119

SUMMARY OF SIGNIFICANT COMPARISONS OF MAGNITUDES AND RATIOS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

Wave	Conditions*						Comparisons - F Ratios				
	Day 1			Day 2							
	I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
QRS _m MV	2.75	1.98	2.12	2.63	2.50	2.48	(-)2.15 +				
P/QRS _m	12.3	14.0	25.5	11.6	12.1	14.3					(-)3.49 ++
QRS ₁ /QRS _m									(-)2.55 +		

* Means in millivolts

(-) - Second condition voltage
is decreased

TABLE 120

FACTORIAL ANALYSIS OF QRS₁-QRS_m SPATIAL ANGLE
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

QRS ₁ -QRS _m Angle	Conditions*					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	11	11	9	7	8	3
Dog #21	2	10	10	8	7	3
Dog #22	5	17	2	4	2	1
Dog #23	6	6	5	8	6	4
Dog #24	6	10	8	2	4	1
Sums	30	54	34	29	27	12
Means	6	11	7	6	5	2

* Angles in degrees

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	576	58	4.43	+++
I vs IV	10	1	0.1	< 1	
II vs V	10	729	73	5.61	+++
II vs III + VI	30	3844	128	9.85	+++
III vs VI	10	484	48	3.72	++
Error	29	13			

TABLE 121

FACTORIAL ANALYSIS OF QRS_t-QRS_m SPATIAL ANGLE
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

QRS _t -QRS _m Angle	Conditions *					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	11	11	5	161	156	162
Dog #21	168	156	160	174	170	163
Dog #22	173	170	177	177	178	177
Dog #23	176	170	170	166	170	171
Dog #24	178	175	174	174	178	179
Sums	706	682	686	852	852	852
Means	141	136	137	170	170	170

* Angles in degrees

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	5,776	578	< 1	
I vs IV	10	21,316	2,132	< 1	
II vs V	10	4,900	490	< 1	
II vs III + VI	30	30,276	1,009	< 1	
III vs VI	10	27,556	2,756	1.11	
Error	29	2,472			

TABLE 122

FACTORIAL ANALYSIS OF ST_a -QRS_m SPATIAL ANGLE
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

ST _a -QRS _m Angle	Conditions *					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	5	5	--	5	7	95
Dog #21	6	35	--	9	175	171
Dog #22	7	3	6	4	2	3
Dog #23	3	6	4	3	2	1
Dog #24	7	5	3	17	2	1
Sums	28	54	13	38	188	271
Means	5.6	10.8	2.6	7.6	37	54

* Angles in degrees

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	676	68	< 1	
I vs IV	10	100	10	< 1	
II vs V	10	17,956	1,796	< 1	
II vs III + VI	30	30,976	1,032	< 1	
III vs VI	10	66,564	6,656	3.26	++
Error	29	2,043			

TABLE 123

FACTORIAL ANALYSIS OF ST_b -QRS_m SPATIAL ANGLE
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

ST_b -QRS _m Angle	Conditions *					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	169	169	173	171	173	172
Dog #21	6	21	33	--	175	171
Dog #22	176	177	174	167	178	177
Dog #23	3	0	0	3	2	0
Dog #24	6	4	3	3	2	1
Sums	360	371	383	344	530	521
Means	72	74	77	69	106	104

* Angles in degrees

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	121	12	<1	
I vs IV	10	256	26	<1	
II vs V	10	1,681	168	<1	
II vs III + VI	30	26,244	875	<1	
III vs VI	10	19,044	1,904	<1	
Error	29	7,275			

TABLE 124

FACTORIAL ANALYSIS OF ST_c-QRS_m SPATIAL ANGLE
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

ST _c -QRS _m Angle	Conditions *					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	125	125	173	25	--	--
Dog #21	25	13	19	9	18	14
Dog #22	50	43	161	112	159	177
Dog #23	3	--	4	13	2	--
Dog #24	5	3	5	2	2	1
Sums	208	187	362	161	181	192
Means	41	37	72	32	36	38

* Angle in degrees

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	441	44	< 1	
I vs IV	10	2,209	221	< 1	
II vs V	10	36	4	< 1	
II vs III + VI	30	32,400	1,080	< 1	
III vs VI	10	28,900	2,890	< 1	
Error	29	3,602			

TABLE 125

FACTORIAL ANALYSIS OF T-QRS_m SPATIAL ANGLE
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

T-QRS _m Angle	Conditions *					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	174	174	7	172	24	13
Dog #21	44	14	23	0	10	11
Dog #22	178	156	18	176	172	9
Dog #23	13	168	11	3	6	1
Dog #24	6	5	3	2	1	1
Sums	715	517	62	353	213	35
Means	143	103	12	71	43	7

* Angle in degrees

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	39,204	3,920	<1	+++
I vs IV	10	131,044	104	<1	
II vs V	10	92,416	9,242	1.73	
II vs III + VI	30	877,969	292,656	5.49	
III vs VI	10	729	73	<1	
Error	29	5,332			

TABLE 126

**SUMMARY OF SIGNIFICANT COMPARISONS OF SPATIAL ANGLES
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM**

Spatial Angle	Conditions*						Comparisons - F Ratios				
	Day 1			Day 2			I vs. II	II vs. IV	II vs. V	II vs. III + VI	III vs. VI
	I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug					
QRS ₁ -QRS _m	6	11	7	6	5	2	4.43 +++		(-)5.61 +++	(-)9.85 +++	(-)3.72 ++
ST _a -QRS _m	5.6	10.8	2.6	7.6	37	54					3.26 ++
T-QRS _m	148	103	12	71	43	7				(-)5.49 +++	

* Means in millivolts

(-) - Second condition
voltage is decreased

TABLE 127

FACTORIAL ANALYSIS OF P INTERVAL
MEASURED FROM TIME-BASED VECTORCARDIOGRAM

P Interval	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.03	.03	.03	.04	.04	.04
Dog #21	.04	.04	.04	.04	.04	.04
Dog #22	.04	.04	.04	.03	.03	.03
Dog #23	.04	.04	.03	.04	.04	.04
Dog #24	.03	.03	.03	.04	.04	.03
Sums	.18	.18	.17	.19	.19	.18
Means	.036	.036	.034	.038	.038	.036

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	0	0	$\triangle 1$	
I vs IV	10	.0001	.00001	$\triangle 1$	
II vs V	10	.0001	.00001	$\triangle 1$	
II vs III + VI	30	.0001	.000003	$\triangle 1$	
III vs VI	10	.0001	.00001	$\triangle 1$	
Error		.000024			

TABLE 128

**FACTORIAL ANALYSIS OF P-R INTERVAL
MEASURED FROM TIME-BASED VECTORCARDIOGRAM**

P-R Interval	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.08	.08	.09	.11	.11	.11
Dog #21	.08	.08	.07	.10	.07	.07
Dog #22	.08	.08	.08	.08	.08	.07
Dog #23	.08	.08	.07	AV Block	.12	.15
Dog #24	.11	.09	.10	.10	.10	AV Block
Sums	.43	.41	.41	.53	.48	.56
Means	.086	.082	.082	.106	.096	.112

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.0004	.00004	$\triangle 1$	
I vs IV	10	.01	.001	$\triangle 1$	
II vs V	10	.0049	.00049	$\triangle 1$	
II vs III + VI	30	.0225	.0075	$\triangle 1$	
III vs VI	10	.0225	.0023	$\triangle 1$	
Error	29	.06			

TABLE 129

**FACTORIAL ANALYSIS OF QRS INTERVAL
MEASURED FROM TIME-BASED VECTORCARDIOGRAM**

QRS Interval	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.024	.024	.024	.028	.024	.022
Dog #21	.022	.028	.028	.030	.030	.030
Dog #22	.030	.026	.026	.034	.028	.030
Dog #23	.030	.030	.030	.032	.032	.030
Dog #24	.022	.022	.022	.028	.028	.024
Sums	.128	.130	.130	.152	.142	.136
Means	.026	.026	.026	.030	.028	.027

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significance
I vs II	10			< 1	
I vs IV	10	.0000576	.000006	< 1	
II vs V	10	.0000144	.00000144	< 1	
II vs III + VI	30	.00000036	.000000011	< 1	
III vs VI	10	.00000036	.000003	< 1	
Error	29		.000008		

TABLE 130

**FACTORIAL ANALYSIS OF QT INTERVAL
MEASURED FROM TIME-BASED VECTORCARDIOGRAM**

QT Interval	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.18	.16	.16	.23	.19	.20
Dog #21	.23	.20	.20	.22	.18	.18
Dog #22	.20	.19	.19	.22	.18	.18
Dog #23	.20	.16	.17	.20	.18	.20
Dog #24	.23	.18	.21	.21	.19	.18
Sums	1.04	.89	.93	1.08	.92	.94
Means	.21	.18	.19	.22	.18	.19

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.0225	.0023	5.75	+++
I vs IV	10	.0016	.00016	< 1	
II vs V	10	.0009	.00009	< 1	
II vs III + VI	30	.0081	.00027	< 1	
III vs VI	10	.0001	.00001	< 1	
Error	29		.0004		

TABLE 131

**FACTORIAL ANALYSIS OF RR' INTERVAL
MEASURED FROM TIME-BASED VECTORCARDIOGRAM**

RR' Interval	Conditions					
	Day 1			Day 2		
	I Early Anesthesia	II 3 hour Anesthesia	III 4 hour Anesthesia 1 hour Drug	IV Early Anesthesia	V 3 hour Anesthesia	VI 4 hour Anesthesia 1 hour Drug
Dog #20	.380	.300	.380	.448	.384	.396
Dog #21	.412	.372	.368	.440	.328	.368
Dog #22	.372	.340	.340	.352	.396	.300
Dog #23	.480	.268	.292	.380	.276	.312
Dog #24	.692	.400	.480	.432	.420	.376
Sums	2.336	1.680	1.860	2.052	1.804	1.752
Means	.467	.336	.372	.410	.361	.350

Comparisons	Degrees of Freedom (DF)	Sums of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Signifi- cance
I vs II	10	.430336	.043034	6.66	+++
I vs IV	10	.080656	.008066	1.25	
II vs V	10	.015376	.001538	< 1	
II vs III + VI	30	.063504	.00211	< 1	
III vs VI	10	.011664	.001166	< 1	
Error	29		.006456		

TABLE 132

SUMMARY OF SIGNIFICANT COMPARISONS OF INTERVALS
CALCULATED FROM TIME-BASED VECTORCARDIOGRAM

Interval	Conditions*						Comparisons - F Ratios				
	Day 1			Day 2							
	I Early Anes- thesia	II 3 hr. Anes- thesia	III 4 hr. Anes- thesia 1 hr. Drug	IV Early Anes- thesia	V 3 hr. Anes- thesia	VI 4 hr. Anes- thesia 1 hr. Drug	I vs. II	I vs. IV	II vs. V	II vs. III + VI	III vs. VI
QT	.21	.18	.19	.22	.18	.19	(-)5.75 +++				
RR'	.467	.336	.372	.410	.361	.350	(-)6.66 +++				

* Means in millivolts

(-) - Second condition voltage is decreased

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this study was to analyze the spatial cardiac electromotive force before and after the administration of digitoxin and G-strophanthin in the dog. This was accomplished by the development of a new method and the building of a new instrument (Time-Based Vectorcardiogram) for the linear time vectorial recording of the electrical activity of a complete cardiac cycle. Such recordings were analyzed by a calculation of the spatial voltage magnitudes and spatial angles of selected instantaneous spatial vectors, chosen along the cardiac cycle. This method is easy to use and similar enough to the conventional methods to facilitate easy correlation. Recordings, using the conventional standard and vector methods, were also taken and correlated with the new Time-Based vectorcardiographic method.

The genesis and form of the electrocardiogram recorded from the surface of the body is dependent on three factors. The first being the shape of the action potential from the cardiac cells (Weidmann, 1956b); the second, the sequence of activation of these cells (Scher & Young, 1957); and the third, the electrical inhomogeneity of the tissues and their influence upon the electrocardiographic lead performance (Schwan & Kay, 1957). The wave of the electrocardiogram represents not only the relative activities of the various anatomical portions of the heart but also relative electrical processes (the action potential) that occur in the same portions of the heart. The P and QRS-T deflections are examples of electrical activity of different portions of the heart musculature, while the P and Ta or the QRS and T deflections,

the different electrical processes that occur in the same portions of the heart musculature.

The shape of the action potential can be correlated and is thought to be dependent on rapid movements of ions across the cell membranes (Hodgkin, 1951; Hodgkin, 1957) and/or changes in the relative permeability of these ions (Hodgkin and Huxley, 1952b; Hoffman & Cranefield, 1960).

If a micro-electrode (Ling & Gerard, 1949) is inserted into a cardiac cell (Woodbury, Woodbury, & Hecht, 1950), a resting potential is measured and it is a negative voltage of approximately 90 mv with respect to the outside of the cell. Under suitable conditions an uneven distribution of ions in an aqueous solution, for example, the unequal concentrations of K ions or Na ions separated by a membrane selectively permeable to one of the ions, will act as a battery or concentration cell (Höber, 1945; Davson, 1951; Bayliss, 1924). The potential developed by such an unequal distribution of ions can be described by applying the relationship of Nernst (Robertson & Dunihue, 1954). The calculated potential differences across the cellular membrane attributed to the K ions and the Na ions are -92.6 mv and a +84 mv respectively (the inside potential as compared to the outside potential of the cell). The resting membrane potential measurements give a voltage of -80 to -90 mv (Woodbury, Woodbury, & Hecht, 1950; Draper & Weidmann, 1951; Hodgkin, 1951; Cranefield & Hoffman, 1958a). Since the transmembrane potential is negative it is obvious that the K ion contributes the greatest influence in the determination of the membrane potential. This also suggests that the relative permeabilities of the two ions are markedly different,

with the greater membrane permeability to the K ion (Hodgkin & Huxley, 1952; Hodgkin, 1957). If the transmembrane potential is made up primarily of the emf resulting from the K ion gradient, changes in concentration gradient of this ion should change the resting membrane potential to a predictable degree as indicated by the Nernst equation. This has been shown to be the case for many types of fibers (Hodgkin, 1951). Increasing the external concentration of the K ion will decrease the membrane potential (depolarize the membrane) and lead to inexcitability. Increasing the K ion concentration of the perfusion fluid in the isolated heart will also lead to a diastolic cessation of activity.

A reduction of the K ion to 25% of normal will cause a marked increase in the resting potential of the frog (Brady & Woodbury, 1957) and of the turtle (Weidmann, 1956a); however, reduction of the K ion concentration of mammalian fibers usually leads to deteriorative changes with the resting potential changes not what would be predicted by the Nernst equation (Carmeliet and Lacquet, 1958; Hoffman & Suckling, 1956; Hoffman & Crane-field, 1960). Changes in the Na ion on the other hand seem to have little effect on the resting membrane potential (Délèze, 1959).

Excitation of the heart is associated with a striking change in the resting potential, the action potential (Woodbury, et.al., 1950). This action potential is thought to be the result of changes in the relative permeability and/or movements of the K and Na ions (Hoffman & Crane-field, 1960). The first phase of the action potential (Phase I) is a rapid reversal of the transmembrane potential to about +20 mv (over shoot). This portion

of the action potential is influenced by the external Na ion concentration, a decrease in the Na ion concentration results in a decrease in the rising velocity of the action potential (Hoffman & Craneffeld, 1960). Also the overshoot of the rising velocity of the action potential is decreased by reducing the external Na ion concentration (Brady & Woodbury, 1957) and has been shown to accompany an increase in permeability of the membrane to this ion (Nastuk & Hodgkin, 1950). This depolarization phase of the action potential seems to be regenerative in nature (Woodbury & Patton, 1960). Following the increase in the permeability of the Na ion there is an increase in the permeability of the K ion, resulting in an efflux of this ion subsequent to an influx of Na ions. The increase in the permeability of the K ion probably accounts for the descent of the overshoot voltage to zero (Hodgkin & Huxley, 1952).

Repolarization (Phase II, a slow phase, and Phase III, a more rapid phase) is markedly prolonged in heart muscle as compared to skeletal muscle and nerve. This portion of the action may be either degenerative in nature, the greater the degree of repolarization the more slowly it proceeds (Woodbury & Patton, 1960) or may be regenerative in nature, suggested by the highly non-linear response of the transmembrane potential to anodal stimuli applied during Phase II of the action potential (Craneffeld & Hoffman, 1958b). However, all phases of repolarization seem to be based on enzymatic processes (Coraboeuf & Weidmann, 1954) and this sustained depolarization may be important in maintaining the contraction characteristic of heart muscle. There is considerable disagreement as to the ionic shifts that occur during

this portion of the action potential. The return of the resting membrane potential seems to require a more complicated interplay of ions. There is general agreement that K ion leaves the cardiac cell during activity and this efflux probably occurs at the end of Phase II of the action potential, reaching a maximum during Phase III. The accumulation of K ions on the external surface of the cell at the end of Phase II may be directly concerned with the returning of the membrane potential to the resting level. Since it is assumed that the permeability of the K ions increases in Phase III of the action potential, a development of the membrane potential would require a decrease permeability to Na ions and the activity of a Na pump. Such an active transport would consume energy and must be metabolically driven (Hodgkin, 1957).

The genesis of the electrocardiographic waves, although dependent on the action potential of the cardiac cells, correlates with the sequence of activation of these cells (Scher & Young, 1957). An understanding of the electrocardiographic complexes can only be achieved with a knowledge of the pathways of depolarization and repolarization.

The spread of the wave of depolarization over the atria results in the production of a surface potential on the surface of the chest (P wave of the electrocardiogram). The impulse originates from the S-A node in the right atria and spreads radially like a wave pattern produced when a pebble is dropped in water. No specialized atrial conduction system has been discovered as of yet, although there may be such a system (Cranefield & Hoffman, 1959). Because of the shape, orientation and absence of an endocardial-epicardial gradient (Liebow & Hellerstein, 1951), the depolari-

zation, P wave, may be viewed as three divergent waves moving inferior, to the right, and slightly anteriorly from the S-A node toward the inferior borders. This results in electrical vectors pointing inferiorly and a positive P wave in Leads I, II, III, AVF, and the V leads.

The topical spread of repolarization in the atria occurs in a similar order as that of depolarization (Katz, 1947) and results in a auricular T wave (Ta) normally in the opposite direction of that of the P wave. However, it is usually buried in the QRS complex.

The potentials generated by the A-V node and the Purkinje fibers are probably too small to be recorded at the body surface. This results in an interval between the P and QRS complexes where no voltage can be recorded. (P-R interval). The impulse from the atria reaches the A-V node when the atrial depolarization is about 2/3 complete (Cranefield & Hoffman, 1959). No potentials can be recorded in the node for about 5 to 15 ms after depolarization of the atrial cells near the node, in the dog (Scher, Rodriguez, Liikane, & Young, 1959).

From the A-V node, the impulse passes to the Purkinje fibers of the common bundle and on to the right and left bundles. While the conduction velocity is 0.1 m/sec in the A-V node, the conduction velocity of the Purkinje fibers is up to 2 m/sec. As a result of the distribution of Purkinje fibers, the spread of activity is first endocardial at a velocity of about 1 m/sec (Scher & Young, 1955). In general the movement of the excitation wave is from within outward (Lewis & Rothschild, 1915). The septum is excited almost entirely from the left, giving an early left-to-

right preponderance to the vectors of the QRS (Medrano, Bisteni, Brancato, Pileggi, & Sodi-Pallares, 1957).

Through both walls of the ventricles and the septum, incomplete cones of depolarization occur. These cones grow by the movement of the advancing wave outward in the ventricular walls and towards the center septum. As a consequence of this, a double invasion of the septum occurs, canceling some of the electrical forces. The activity in both walls of the ventricles leads to numerous vectors whose over all orientation is toward the apex. Since the right ventricle is thinner than the left, epicardial breakthrough becomes more prominent on this side leaving predominant activity to the left with posterior orientation. This will shift the vectors to the left and posteriorly. This usually occurs approximately half way through the QRS. The breakthrough in the left ventricle occurs more extensively apically, which swings the vectors finally towards the base of the heart. These terminal, apically orientated vectors undoubtedly reflect activity in the basal wall and more important activity pointing toward the auricles in the central septum (Scher & Young, 1957).

Since the dog's heart is most often placed quite vertically in the chest, the orientation of the vectors reflected on the surface of the chest will be quite similar in orientation to those described in relation for the heart itself. This is not the case for the human, because the human heart's base-to-apex orientation is more often parallel to the diaphragm.

Repolarization of the ventricles is responsible for the genesis of the T wave. However, the understanding of this process and its relation to the shape or form of the T wave is meager as compared to the QRS complex

(Schaefer, 1957). In general, if repolarization were to follow the same pathway as depolarization, the polarity of the T wave's vectors would be in the opposite direction as the QRS vectors. Also, the sum of the areas under the curves or the sum of the vectors for both QRS and T complexes should add up to zero, resulting in no gradient (Wilson, Macleod, Barker, & Johnston, 1934). However in the human and to some extent in the dog, the T wave is usually or very often of the same polarity as the QRS deflection giving a large gradient. Repolarization therefore probably tends to follow a pathway opposite to that of depolarization. Other indications of this are the negative potentials recorded within the right and left ventricles during repolarization (Sodi-Pallares, et.al., 1957). Further interpretation of these negative potentials suggest that an up-right T wave is the result of a spread of repolarization from the outside to the inside and that the electrical forces from the right ventricle and septum normally are cancelled and remain relatively electrically silent.

Whether or not repolarization is propagated or not is not known. The reproducibility of the T waves would tend to indicate that repolarization is propagated. The application of an appropriate stimuli (a stimuli causing the inside of a fiber to become negative) can cause repolarization which is propagated (Cranefield & Hoffman, 1959; Weidmann, 1956). In addition, the description of the radial spread of relaxation from an anode electrode (Biedermann, 1884) and also the motion pictures of Cranefield (1957), suggest propagation.

Although the available data does not allow the acceptance of any one theory concerning ventricular repolarization, it is generally accepted that repolarization is apparently independent and generally opposite to that of depolarization, at least for the human.

The relationship between the three methods for recording electrocardiograms, used in this study, may not be obvious. It should be noted that the standard electrocardiograph uses a two dimensional type recording, which is supposedly scalar in nature (non-directional). Each lead has an amplitude dimension and a time dimension (linear time scale or moving strip). These two dimensional standard recordings are taken using either of two types of leads. The bipolar type measures the voltage difference between two poles or electrodes and the unipolar lead type measures the voltage difference between the single pole or electrode and a general indifferent source (central terminal). Several of these scalar leads "tap" the field, which reflects the total cardiac electromotive force from different vantage points at its periphery, the chest. The combination of the data from these leads, usually accomplished mentally or in one's mind's eye (Grant, 1950) gives the "scalar" information some degree of spatial direction. This changes the "scalar" information to mental vectorial information.

The vector electrocardiographic analysis attempts to describe the cardiac electromotive force in terms of magnitude, sense (polarity), and direction (spatial). However, it should be pointed out that the cardiac electromotive force is not a single vector quantity which occurs at any

particular instant of time, but is a changing electromotive force which occurs over a period of time (the cardiac cycle). Thus a linear time scale is essential for adequate description and understanding of the electromotive force in space, of a complete cardiac cycle, and as reflected at the surface of the body.

The vectorcardiogram adds vector information. However, in developing this method a second dimension of amplitude on the horizontal axis was substituted for the time dimension (the moving strip). Even though these recordings are vectorial in nature, they do not give a progressive (timed) recording of the changes of the cardiac electromotive force in a complete cardiac cycle. In the portions of the cycle which show large rapid changes, like the QRS \hat{sE} -loop, the timed spatial relationship may be given. However, during other periods many of the important relationships are lost.

The new Time-Based vectorcardiogram keeps the time scale of the standard clinical method and, in addition, provides the vector information obtainable in the vectorcardiograms. In order to accomplish a type of recording which would give linear time and vector information (two dimensions), it was necessary to construct an instrument capable of recording two dimensions of amplitude on a time scale. In addition, the orientation of the time dimension, in each of three leads, should be such that a perpendicular measurement of any particular wave would give one of the components necessary for the separate calculation of its magnitude and spatial angle. Each of three leads then should give one orthogonally perpendicular component (X, Y or Z) of each vector for each wave on a time scale.

An analogy illustrating this type of recording or graphing of data is difficult to find although three dimensional graphs are common. The reason for this may not be readily apparent. The usual type of graphing of electrical data which are dealt with in electric circuits are: 1) sinusoidal in the steady state, 2) sinusoidal with variable frequency, or 3) sinusoidal regarding frequency as a complex variable, i.e., by considering not only sinusoidal excitation of constant amplitude, but also exponentially damped or growing excitations. Time rate parameters of a sinusoidal nature are studied and the "shape" of the source current or voltage has a fixed functional dependence on time. In other words, sinusoidal quantities are graphed where the relative direction of this voltage or current is changing continuously at a constant rate holding this variable constant so that the problem reverts to a pseudo two-dimensional one. These vector directions or orientations are usually expressed in degrees, a single angular quantity, which is a measure of an instant in time within a cycle. The graph of this single quantity is an expression of the "relative phase," and its character at that instant is considered with respect to its zero-degree reference point as an angle. Usually this angle is the expression of the instantaneous magnitude or orientation of an instant within a wave function with respect to its maximum voltage. This angle then is an indirect measure of time differences because the sinusoidal nature of waves is a function of time (Fano, Chu, & Adler, 1960).

A vastly different situation exists for the heart. Whereas in electronics, a single sinusoidal wave function is studied, the heart gives

several different waves (P, QRS, T, etc.) in a single electrical cycle. Further, these wave "shapes" do not have a functional dependence in time (not sinusoidal in nature), but have waves which are a function of the pathways or order of depolarization and repolarization of the heart muscle (Scher & Young, 1957). A graph of the electrical activities of the heart should then give serial, instant to instant vectorial presentation of the electrical field, produced on the surface of the chest by the heart, so that a correlation with the pathways of the electrical activities can be made.

A further complicating factor in making analogies with electronic data, is that in electronics the vector itself is usually measured or graphed. It is then studied by breaking it down into its component parts, a resolution of the vector is made. In the vectorial registration of the electrical activity from the heart, only the component parts of the spatial electrical vectors can be measured and methods are needed to synthesize these components into instantaneous spatial vectors. A method such as the new Time-Based vectorcardiographic method should and does give the synthesis of two components (leads) into a graph so that a study of the serial instant to instant electrical vectorial changes can be made as they are generated on the surface of the chest by the heart.

The records obtained with the Time-Based vectorcardiographic method are a graph of three separate voltages or pieces of information. The three voltages are from: 1) a horizontal orthogonal lead, giving a horizontal component, 2) a vertical orthogonal lead, giving a vertical component, and 3) a blanking saw-tooth wave generator, giving the time component.

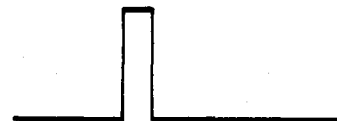
For illustration purposes, suppose two rectangular pulses are substituted for the horizontal and vertical leads respectively, but keep the saw-tooth wave. Oscilloscope displays of the three separate signals are given in A, B, and C of Figure XX. A graph of the three voltages as obtained with the Time-Based vectorcardiographic method is given in D of the same figure.

To illustrate further, suppose two sine waves of one cycle each, 45° out of phase are substituted for the two orthogonal leads, instead of the rectangular pulses. Oscillographic displays of each of the three signals is given in A, B, and C of figure XXI. A graph of the three voltages as obtained with the Time-Based vectorcardiographic method is given in D of the same figure.

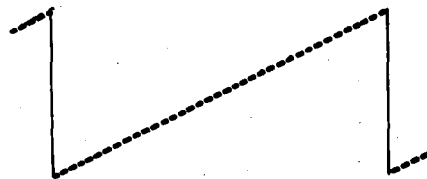
It can be readily seen that a serial vectorial sampling of a large interval of time (one sweep) can be accomplished by this method. The graph obtained is a vectorial presentation of the electrical field from the surface of the chest produced by the heart expressed as a curve. It is blanked in such a way as to give several serial instantaneous vectorial samplings within each of several cardiac electrical cycles.



A. HORIZONTAL COMPONENT



B. VERTICAL COMPONENT

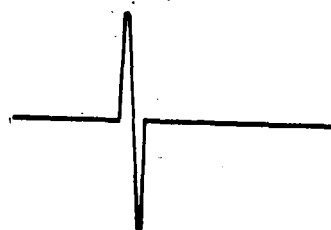


C. SAW-TOOTH COMPONENT

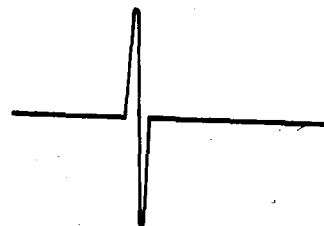


D. TIME-BASED VECTOR GRAPH

Fig. XX. A and B are oscilloscope tracings of two 1 mv rectangular pulses. C is an oscilloscope tracing of a 4 sec saw-tooth wave from the sweep generator. D is the graph of the three voltages.



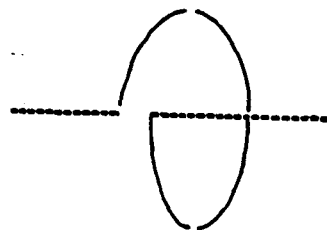
A. HORIZONTAL COMPONENT



B. VERTICAL COMPONENT



C. SAW-TOOTH COMPONENT



D. TIME-BASED VECTOR GRAPH

Fig. XXI. A and B are oscilloscope tracings of two 1 mv sine wave pulses. C is an oscilloscope tracing of a 4 sec saw-tooth wave from the sweep generator. D is the graph of the three voltages.

A graph of pulsatile blood flow through an elastic artery is somewhat analogous to the recordings obtained with the Time-Based Vectorcardiographic method. Both blood and electricity may be considered as non-compressible fluids and can be compared.

Volume (three dimensional) flow is obtained by multiplying the rate of flow (length) times the cross sectional area (width X height). Most flow measurements are made with the variables of the cross sectional area fixed, thus simplifying the recording technique. The flow rate times a constant (fixed cross sectional area) then equals the volume flow. However, the blood flow through an artery like the aorta would require the simultaneous measurement of the cross sectional area with the flow rate because of the distensibility of this artery with pressure. Assuming the cross sectional area of the aorta is circular (this makes one of the variable dimensions of cross sectional area, a constant) then the cross sectional area becomes a function of the radius or diameter only. The simultaneous measurement of the diameter, giving the function of the cross sectional area, and the flow rate can be plotted to give volume flow. In essence, the plot of the three dimensional system has reverted to a two dimensional graph. If the serial instant to instant plot of these two parameters is made on a time scale, giving the volumetric flow-time relationship (pulsatile flow), then one obtains a graph containing three dimensions similar to that obtained with the Time-Based Vectorcardiographic method. The main differences in the two methods is that blood flow measurements are usually scalar while electrocardiographic field measurements are vectorial (a quantity with direction).

This Time-Based vectorcardiographic method may be directly correlated with the standard clinical method, if the standard method is analysed vectorially. The Time-Based vectorcardiographic method does on actual recordings what one does mentally when one analyses vectorially standard clinical recordings from a group of leads. In other words, this method integrates into one three-dimensional lead the six two-dimensional limb leads. Into a second three-dimensional lead, the six two-dimensional precordial chest leads are similarly integrated. A third lead integrates the fifteen esophageal leads. Visualization and calculation of the electromotive changes in space on a time scale are very much simplified. Each lead of the Time-Based vectorcardiogram gives information which is vectorial and on a time scale. The three leads, when analysed together, give a three dimensional view of the spatial cardiac electromotive changes on a time scale.

The recording apparatus for the Time-Based vectorcardiograph was designed and built for this study. This recorder has more than adequate characteristics of frequency response, phase shift and differential input rejection (Gelford, 1949).

Several lead systems for vectorcardiographic examination of the human are available (Frank, 1956; Grishman, 1951; Simonson, 1959 and Wilson, 1947). No standard reference system has been studied or established which could be utilized with the Time-Based vectorcardiograph. Such a lead system should measure the projection of the cardiac electromotive force from side to side (X component), up and down (Y component) and forward and backward (Z component). The lead systems which have been utilized for the human can be

divided into two groups, those using bipolar combination of electrodes and those using unipolar combination of electrodes. For the unipolar combination of electrodes no central terminal has been established in the dog. On the other hand, the cube system of Grishman (1951) is a system of bipolar electrode combinations which does not depend on a central terminal. This lead system assumes that the heart is a sphere with the dipole at its center, and the electrodes are placed on the chest in a cube arrangement so that they are approximately equidistant from the heart.

The modification of the positioning of the chest leads for the standard clinical electrocardiograph, of Lombard and Witham (1955), was followed in this study in order to make comparisons with previous data. However, with this modification few transitional patterns are obtained in the chest leads.

In a comparison of the results obtained, with the standard clinical method and the vector methods using the cube lead system of Grishman, the cube lead system gives an angle for the QRS_m which is approximately 15 degrees larger than the vector analysis of the standard clinical leads for the frontal plane. In general, however, the results from both of these lead systems can be compared.

The low intravenous dose of G-strophanthin (0.25 mg.) in the dog represents approximately one third the single digitalizing dose recommended for the human (0.7 mg. to 1.0 mg., i.v.). Twice this dose was used for a high dose. The low daily oral dose of digitoxin was 0.1 mg., and the high daily dose was 1.0 mg. This high dose for the dog is approximately ten times the

daily recommended human dose of digitoxin. The average dog's weight was around 10 kilograms, or approximately one-seventh the human weight. Even though these doses appear extremely high, as compared to the human, they were below the dose needed to produce arrhythmias.

In a search for vector type data in the dog which might serve as a background for the present study, only one paper (Horan, et al., 1957) and an unpublished thesis (Dobbie, 1955) was found.

The Time-Based vectorcardiographic method provides general vector information and, in addition, allows the independent description, by calculation, of the spatial magnitudes and the spatial angles of any selected instantaneous vector in each cardiac cycle. It should be pointed out that the T wave of the dog is considerably different from that described for the human. This difference is especially paramount in the Time-Based vectorcardiographic method. Because of this difference, the ST-T segment for the dog was described by measurement of four separate instantaneous vectors.

A comparison of the description of the pre-treated unanesthetized and the pre-treated anesthetized dog was done in order to see if the pentobarbital anesthesia had any effect. The most striking effect produced by the anesthesia was a two-fold increase in the heart rate. The effect on conduction, noted in both the standard ECG and Time-Based VCG methods, was a decrease in the P-R interval and shortening of the QT interval.

The voltages of the P and R waves in the standard ECG were larger in some leads in the anesthetized series of dogs. These effects could be produced either by a difference in spatial orientation of these waves or an

increase in the spatial voltage of these waves. The Time-Based VCG clarified this problem. It showed that the P/QRS_m magnitude was increased two fold and that the $P-QRS_m$ spatial angle did not change significantly. This indicates that the change in P and R voltages in standard ECG leads were those of altered magnitude and not spatial orientation.

A small increase in the QRS_m spatial voltage was noted but was not significant. This would correlate somewhat with the increases of voltage of the R wave in the standard ECG. Although none of the spatial angles were changed, the axes of the QRS_m and QRS_i angles in the frontal lead were slightly smaller after anesthesia, indicating a slightly more left axis deviation.

Summarizing these comparisons of the unanesthetized and anesthetized dogs, the change of heart rate is the most significant. Secondly, the two fold increase in the spatial voltages of the P wave was prominent. This effect may be the result of the anesthesia on the myocardium or may be secondary, resulting from the increase in heart rate.

The results of Series I, which were observations on anesthetized dogs studied after the administration of G-strophanthin, show no characteristic "digitalis pattern." Only minor changes were obtained. The only conduction change was a lengthening of the QT interval as measured both on the standard ECG and the Time-Based ECG. The R wave (standard ECG) shows a decrease in voltage in most of the chest leads and in lead AVF. This is correlated with a slight shift in the electrical axis of the QRS_m vector in the sagittal lead of the Time-Based VCG. The voltage of the P waves was increased in the

standard ECG. The Time-Based VCG also showed an increase in the magnitude of the P wave with no axis shift or change in the P-QRS_m angle, thus again indicating a true magnitude (voltage) change and not a shift in spatial axis. This information cannot be ascertained with a standard clinical lead.

In the recordings taken more than two hours after administration of the drug, the T wave, in the standard ECG, showed an increase in magnitude in most of the chest leads and in lead II. On the other hand, the Time-Based VCG showed a decrease in voltage of the T wave from recordings taken at the same time. It should be pointed out that the standard ECG measures T wave voltages that are either positive or negative. A decrease in the voltage of a negative T wave would be reported as an increase in positive voltage. This could be a misleading result. The Time-Based VCG reports the spatial magnitudes of a wave independent of its orientation, hence these results cannot be misleading. In this series of dogs, some of the T waves were negative in the control pattern and the spatial magnitude of the T wave became smaller after drug. The standard ECG, in this situation, would report an increase in voltage of the T waves because they became less negative.

In summary, only minor effects were found in this series. The T wave spatial magnitude became smaller and a depression of voltage of the R wave, in some of the leads, was correlated and explained as a slight shift in the electrical axis as measured in the sagittal lead of the Time-Based VCG.

The results of Series II, unanesthetized dogs given daily oral doses of digitoxin, again showed only very minor and scattered changes. The standard ECG showed small but significant changes in the R wave in most of

the chest leads. The Time-Based VCG method did not show any significant shifts in the axis of the QRS_m in the sagittal lead. Two reasons may be given for this failure of correlation. The first is that very small changes in the axis of the $QRS \hat{sE}$ -loop in the sagittal plane causes large changes in the R waves in the standard method because of the close proximity of these leads to the heart. These leads in the dog may reflect some local effects mixed with field effects, thus magnifying very small spatial changes in orientation of the QRS_m wave. Secondly, such changes may be the result of changes in resistances of the skin, electrodes, etc., which are cancelled out in the Time-Based VCG method by the transformation of the spatial magnitudes to ratios.

The axis of the QRS_t and QRS_t-QRS_m spatial angles were larger after administration of the drug. This indicates a thinning of the terminal portion of the $QRS \hat{sE}$ -loop.

Series III evaluated the combined effects of controlled periods of anesthesia plus the effects of G-strophanthin on the spatial electrocardiogram of dogs. The three hour anesthesia period resulted in an increase in the heart rate, and a corresponding decrease in the RR' interval measured in both the standard ECG and the Time-Based VCG. A QT shortening was obtained only with the Time-Based VCG method during this same period.

An isolated and unexplained lengthening of the P-R interval in the standard ECG was obtained after the second dose of the drug. A significant decrease in voltage of the P wave was obtained in several leads of the standard ECG. Analysis of the Time-Based VCG shows that a true decrease in

spatial voltage caused this change in the standard VCG leads and not a change in the P-QRS_m angle.

Other isolated changes were found which were significant, but they were very small and not particularly definitive. They did not delineate a type of "digitalis pattern."

The effects of G-strophanthin and digitoxin, analysed using the standard ECG and the new, more definitive Time-Based VCG method, demonstrate that these drugs do not produce any characteristic "digitalis pattern" in "normal" unanesthetized and anesthetized mongrel dogs.

A review of the literature tended to suggest that an increase in the voltage of the T wave would be expected after digitalis type drugs (Selenin, 1921, Bickel and Pawlow, 1913). Other authors suggest that no change in the electrocardiogram occurred (Rothberger and Winterberg, 1913), or that if a change occurred, it was unpredictable (Cohn and Stewart, 1929). Another author (Levine, 1951) suggests an "electrocardiographic pattern of digitalis" which was characterized by the following description: 1) depression of ST interval and flattening of the T wave in the precordial leads, and in VF, 2) absence of QT shortening, 3) abolition of the pattern by acceleration of apical repolarization (increase the dog's temperature to 42 degrees C by radiant heat).

Grant (1951) in a vectorial description using the standard ECG from the human suggested that digitalis type drugs cause certain of the repolarization forces to be generated earlier during the T interval and in an altered direction, so that they are opposite in direction to the mean spatial

QRS vector. Descriptively, he describes the spatial vector effects, as follows: 1) QRS spatial vector remaining unchanged, 2) QT interval is shortened, 3) T vector is reduced in magnitude, but changes little in spatial direction, and 4) the appearance of an S-T spatial vector, which is oriented in the opposite direction to the spatial QRS vector. He further suggests that the "hammock" shape of the ST interval (often considered a diagnostic effect of digitalis effects in the human) results from the fact that the junction (corresponding to the ST_a in the Time-Based VCG method) between the QRS and S-T interval is little or not at all displaced, even though the S-T interval grows in magnitude from instant to instant and is part of the repolarization process. It has been suggested by Beers, et al. (1951) that relatively small doses of digitalis drugs may change the S-T and T segments of abnormal heart, but not of normal heart, in the human. It may seem rather surprising that in this study only very minor changes in the spatial ECG was found in the dogs after the administration of relatively large doses of the digitalis drugs; however, very recent studies with uses of micro electrodes (Hoffman & Cranefield, 1960) suggest that ouabain in "therapeutic" concentrations does not alter the transmembrane potentials significantly in the dog's papillary muscle. This would tend to support the idea that digitalis compounds have relatively little effect on normal hearts.

The results of this study, the effect of digitalis on the spatial electrocardiogram, indicates that digitalis does not cause a "digitalis pattern" in the so called "normal" dog. This is in agreement with the

findings of Beers, et al. (1951) for the human, and Rothberger and Winterberg, (1913) for the dog. These findings suggest that a fruitful extension of this work should be a study of the factors or agents which would modify the "normal" dog heart in such a way as to produce the "digitalis pattern." This knowledge should contribute to a better understanding of the nature of this lesion and may give some clue as to the mechanism by which digitalis corrects the defect in cardiac failure.

The new Time-Based Vectorcardiographic method described in this dissertation can be applied to any condition which causes a modification of the electrical activity of the heart or where spatial electrical information is desired. Figures 1a and 1b in the appendix gives an example of the changes that are obtained with the Time-Based VCG method before and after the i.v. administration of 500 mg of quinidine to an anesthetized dog. Figures 2a and 2b in the appendix give records of a later experiment where a "digitalis pattern" was obtained. Only three such "digitalis patterns" were obtained in 40 experiments and this was the only experiment where a complete set of tracings was obtained.

In addition to the application of the Time-Based method to animal experimentation, this method will have utility in recording the spatial electrical activity of the heart in the human. An example of records obtained from the human is given in Figure 3 of the appendix. These records are from a 23 year old male graduate student, with no apparent or known cardiovascular or other illness.

This new Time-Based Vectorcardiographic method greatly simplifies the description of the spatial electric field produced by the heart on the

surface of the chest. It allows, for the first time, the presentation of electrocardiographic information of a complete electrical cycle in easily understandable and quantitative form which can be analysed and evaluated statistically. Much of this new information can be obtained directly by measurement from the graphs without calculation. These three dimensional graphs obtained with the new Time-Based Vectorcardiographic method correlate well with the other electrocardiographic methods and in addition extend these. For example, the combination of several of the standard ECG leads are equivalent to a single Time-Based Vectorcardiographic lead. This single lead shows phase differences which are not measureable in the several leads obtained with Standard ECG method. This new method also further extends Vectorcardiographic methods by presenting quantitative information of not only the large QRS deflection, but also of the smaller deflections (P and T) and more important, the more isoelectric portions of the electrical cycle (P-R, ST-T, T-P, and U) which are not measureable by other vector methods.

CHAPTER VI

SUMMARY

- I. A new method for studying the spatial vector electrocardiograms was devised. This method is unique in that the spatial magnitude and the spatial orientation of any instantaneous vector in a cardiac cycle can be directly measured and analyzed statistically.
- II. An instrument was designed and built for use by this method, the Time-Based Vectorcardiograph.
- III. Recordings were obtained with this new method from normal unanesthetized and anesthetized dogs. These spatial electrocardiograms were described and statistical evaluations of magnitudes and orientations of selected instantaneous vectors in the cardiac cycle made.
- IV. A new description of the T wave in the dog was made, since this is shown to be different from the general description of the T wave given for the human.
- V. Statistical evaluations of the electrocardiograms using the standard ECG, VCG, and the new Time-Based VCG before and after the administration of G-strophanthin and digitoxin were made on dogs, both unanesthetized and anesthetized, with the following findings:

- A. Anesthesia caused a twofold increase in heart rate, a decrease in the P-R and QT intervals, and a twofold increase in the relative spatial magnitude (voltage) of the P wave.
- B. Increasing the period of anesthesia caused an increase in the heart rate and a corresponding decrease in RR' interval.
- C. G-strophanthin administration intravenously to anesthetized dogs caused a small decrease in the spatial magnitude of the T wave with no change in its spatial orientation. This could only be measured with the new Time-Based VCG method.
- D. No significant effects were obtained after prolonged oral administration of digitoxin to unanesthetized trained dogs.
- E. Two doses of G-strophanthin to dogs anesthetized for 4 hours caused a decrease in the P spatial magnitude (voltage).

VI. The change in the spatial electrocardiogram following the administration of G-strophanthin and digitoxin to unanesthetized and anesthetized dogs are essentially minor in nature. No support for the appearance of a "digitalis pattern" was found in the "normal" mongrel dog.

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TABLE I

MEASUREMENTS OF WAVES FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDE
AND ANGLES OF THE PRE-TREATED ANESTHETIZED
DOGS IN SERIES I

Dog No.	Component	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
7	x	0	.42	.49	-.23	.04	0	.04	-.11
	y	.35	1.44	1.29	-.64	.04	0	.14	-.27
	z	.02	.57	.64	-.30	.09	0	.09	-.12
8	x	0	.03	-.04	.04	0	0	0	.02
	y	.23	1.83	1.08	-.68	.04	0	.05	.15
	z	0	.31	.41	-.31	0	0	0	-.05
10	x	0	.17	.12	0	0	0	.02	-.02
	y	.21	2.48	1.81	-.56	.23	0	.13	-.29
	z	-.04	.44	.40	-.15	0	0	.02	-.02
12	x	0	-.02	-.02	.01	0	0	0	0
	y	.41	2.62	1.85	-.44	0	-.13	-.05	-.33
	z	0	.46	.37	-.15	0	0	0	-.05
13	x	.08	.06	-.11	-.11	0	0	0	.08
	y	.18	1.01	1.13	-.36	.03	0	.02	-.19
	z	.02	.09	.45	-.18	-.03	0	.02	-.08
14	x	.02	0	-.02	.03	0	0	.04	0
	y	.88	3.17	1.89	1.19	.40	.10	.21	-.31
	z	0	.25	.79	0	0	0	.12	-.08
19	x	0	.01	.01	0	0	0	0	0
	y	.47	3.56	2.14	2.03	.61	.08	.26	-.32
	z	0	.41	.38	0	0	0	.16	0

x component-the perpendicular measurement from the Horizontal Lead

y component-the perpendicular measurement from the Frontal Lead

z component-the perpendicular measurement from the Sagittal Lead

Measurements-in millivolts

TABLE II

MEASUREMENTS OF WAVES FROM TIME BASED VECTORCARDIOGRAPHIC LEADS
USED IN THE CALCULATIONS OF THE SPATIAL MAGNITUDES AND
ANGLES AFTER DRUG TREATMENT OF ANESTHETIZED DOGS
IN SERIES I

Dog No.	Dose in Mg	Time in Hours	Wt. in lb.	Component	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
8	.25	1	12	x	0	.08	0	0	0	0	0	0
				y	.15	.87	.67	+.31	.07	0	.08	.14
				z	.07	.39	.45	-.30	-.03	0	.04	.13
10	.25	1	20	x	0	.2	.12	0	0	0	0	-.03
				y	.25	2.36	1.79	-.37	.23	0	.02	-.52
				z	0	.36	.44	-.15	.04	-.02	.04	-.10
12	.25	1.5	14	x	0	-.08	-.09	.04	0	0	0	0
				y	.50	1.61	1.14	-.55	-.33	-.36	0	.28
				z	0	.28	.29	-.17	-.13	-.13	0	.12
13	1.0	2	16	x	.03	.05	0	.02	0	0	0	0
				y	.22	1.14	1.16	-.41	0	0	-.18	.06
				z	0	.15	0	-.22	-.04	-.08	.03	-.06
14	.5	2	20	x	0	0	0	.22	0	0	0	0
				y	.82	2.58	1.53	-.18	.35	.16	.25	.27
				z	0	.37	.57	-.01	.02	.02	.18	0

x component-the perpendicular measurement from the Horizontal Lead

y component-the perpendicular measurement from the Frontal Lead

z component-the perpendicular measurement from the Sagittal Lead

Measurement-in millivolts

Drug Times-2 hours or less

TABLE III

MEASUREMENTS OF WAVES FROM TIME-BASED VECTORCARDIOGRAPHIC LEADS
 USED IN THE CALCULATIONS OF THE SPATIAL MAGNITUDES AND
 ANGLES AFTER DRUG TREATMENT OF ANESTHETIZED DOGS
 IN SERIES I

Dog No.	Dose in Mg	Time in Hours	Wt. in lb.	Component	P	QRS _m	QRS _i	QRS _t	ST _a	ST _b	ST _c	T
7	.5	24	12	x	0	0	0	0	0	0	0	0
				y	.23	1.20	.87	-.56	0	.04	0	.26
				z	0	.19	.10	-.07	0	0	.22	.05
10	.25	4	20	x	0	.07	.07	0	0	0	0	0
				y	.28	2.44	1.68	-.47	.16	-.16	-.05	-.35
				z	0	.30	.35	-.12	.03	0	.05	-.07
14	.5	6.5	20	x	0	0	-.16	.14	0	0	0	0
				y	.72	1.79	.91	-.22	.03	0	.04	.25
				z	0	.12	.29	0	0	0	.02	.04
14	.5	7.5		x	0	-.02	-.25	.12	0	0	0	-.04
				y	.69	1.84	.99	-.17	.10	0	.11	.25
				z	0	-.10	.16	0	0	0	0	.02
19	.25	4.5	15	x	0	0	0	0	0	0	0	0
				y	.53	2.39	1.64	1.42	.22	-.05	.30	.36
				z	0	.25	.61	-.16	-.05	0	.05	.05

x component-the perpendicular measurement from the Horizontal Lead

y component-the perpendicular measurement from the Frontal Lead

z component-the perpendicular measurement from the Sagittal Lead

Measurements-in millivolts

Drug Times-more than 2 hours

TABLE IV

MEASUREMENTS OF P WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

P Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I	II	III 4 hours Anes- thesia 1 hour drug	IV	V	VI 4 hours Anes- thesia 1 hour drug
		Early Anes- thesia	3 hours Anes- thesia		Early Anes thesia	3 hours Anes thesia	
20 181b.	x	0	0	0	0	0	.02
	y	.10	.35	.32	.23	.19	.28
	z	0	0	0	0	0	0
21 241b.	x	0	.16	.18	-.01	.11	.08
	y	.47	.20	.22	.35	.35	.20
	z	.05	.02	.04	0	0	0
22 291b.	x	.02	0	.02	.03	.05	0
	y	.18	.09	.10	.20	.22	.28
	z	0	0	0	0	0	0
23 261b.	x	0	0	.03	0	0	0
	y	.45	.54	.50	.26	.45	.40
	z	0	0	0	0	0	0
24 201b.	x	0	0	0	.03	0	0
	y	.36	.43	.42	.42	.17	.38
	z	0	0	0	0	0	0

x components-the perpendicular measurement from the Horizontal Lead
y components-the perpendicular measurement from the Frontal Lead
z components-the perpendicular measurement from the Sagittal Lead
Measurements-in millivolts

MEASUREMENTS OF QRS_m WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

QRS _m Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I	II	III 4 hours Anes- thesia 1 hour drug	IV	V	VI 4 hours Anes- thesia 1 hour drug
		Early Anes- thesia	3 hours Anes- thesia		Early Anes- thesia	3 hours Anes- thesia	
20	x	.04	.17	.13	.14	.11	.12
	y	.59	2.08	1.60	1.53	1.39	1.11
	z	.11	.19	.13	.18	.11	.10
21	x	.15	1.00	.98	.47	.81	.54
	y	3.60	1.84	1.56	2.68	2.48	2.26
	z	.31	.24	.36	.56	.22	.20
22	x	.14	.07	.07	.20	.13	.16
	y	3.37	1.71	1.73	3.39	3.44	3.64
	z	.18	.05	.15	.13	.08	.11
23	x	-.04	.14	.04	.04	.04	0
	y	2.95	2.60	2.54	2.60	2.24	2.64
	z	.15	.19	.16	.14	.07	-.06
24	x	.10	.10	.06	.07	.05	.07
	y	3.17	2.85	2.81	2.83	2.80	2.64
	z	.28	.19	.15	.13	.07	0

x component-the perpendicular measurement from the Horizontal Lead
y component-the perpendicular measurement from the Frontal Lead
z component-the perpendicular measurement from the Sagittal Lead
Measurements-in millivolts

MEASUREMENTS OF QRS₁ WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

QRS ₁ Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I	II	III 4 hours Anes- thesia	IV	V	VI 4 hours Anes- thesia
		Early Anes- thesia	3 hours Anes- thesia	1 hour drug	Early Anes- thesia	3 hours Anes thesia	1 hour drug
20	x	.08	.17	.10	.08	.12	.12
	y	.42	1.64	.95	.99	1.09	.95
	z	.15	.17	.23	.24	.25	.21
21	x	.15	.44	.44	.27	.27	.23
	y	2.25	1.32	1.12	1.82	1.30	1.31
	z	.32	.15	.23	.65	.16	.11
22	x	0	.07	.07	.18	.13	.16
	y	2.14	1.09	1.33	2.04	2.19	2.58
	z	.26	.12	.17	.25	.08	.11
23	x	.12	0	.10	.11	.11	.09
	y	1.91	2.00	1.46	.64	.98	1.37
	z	.19	.27	.21	.20	.09	0
24	x	.03	.10	.06	.06	.03	.07
	y	1.87	2.12	2.04	1.56	1.74	1.79
	z	.36	.53	.39	.11	.17	.04

x component-the perpendicular measurement from the Horizontal Lead
y component-the perpendicular measurement from the Frontal Lead
z component-the perpendicular measurement from the Sagittal Lead
Measurements-in millivolts

MEASUREMENT OF QRS_t WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
OF SERIES III

QRS _t Wave		Conditions					
		Day I			Day 2		
Dog No.	Com- po- nent	I Early Anes- thesia	II 3 hours Anes- thesia	III 4 hours Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hours Anes- thesia	VI 4 hours Anes- thesia 1 hour drug
20	x	.03	0	.11	0	0	0
	y	.44	1.47	.97	-.11	-.13	-.25
	z	0	.10	0	-.05	-.07	-.10
21	x	.05	.18	-.18	-.19	-.15	-.05
	y	-.78	-.68	-.72	-.91	-1.11	-1.21
	z	-.22	-.04	-.04	-.28	-.08	.15
22	x	0	0	0	-.02	-.04	0
	y	-.31	-.27	-.29	-.57	-.70	-.81
	z	-.05	-.04	-.04	-.05	0	0
23	x	0	.05	0	0	0	0
	y	-.27	-.46	-.54	-.24	-.27	-.47
	z	-.03	-.05	-.08	0	.04	-.06
24	x	0	0	0	0	0	0
	y	-.79	-.64	-.67	-.87	-.77	-.77
	z	-.06	-.09	-.11	.05	0	0

x component-the perpendicular measurement from the Horizontal Lead
y component-the perpendicular measurement from the Frontal Lead
z component-the perpendicular measurement from the Sagittal Lead
Measurements-in millivolts

MEASUREMENTS OF ST_a WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

ST _a Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I Early Anes- thesia	II 3 hours Anes- thesia	III 4 hours Anes- thesia 1 hour drug	IV Early Anes- thesia	V 3 hours Anes- thesia	VI 4 hours Anes- thesia 1 hour drug
20	x	0	0	0	0	0	0
	y	.07	.04	0	.10	.02	0
	z	.01	0	0	.01	0	-.02
21	x	0	0	0	0	-.05	-.02
	y	.19	.03	0	.07	-.14	-.18
	z	0	.02	0	0	0	0
22	x	0	0	0	0	0	0
	y	.38	.13	.10	.41	.22	.11
	z	-.02	0	0	0	0	0
23	x	0	0	0	0	0	0
	y	.42	.12	.14	.36	.24	.17
	z	0	0	0	0	0	0
24	x	0	0	0	-.03	0	0
	y	.34	.28	.27	.09	.22	.25
	z	.07	.04	0	0	0	0

x components-the perpendicular measurements from the Horizontal Lead
y components-the perpendicular measurements from the Frontal Lead
z components-the perpendicular measurements from the Sagittal Lead
Measurements-in millivolts

TABLE IX

MEASUREMENTS OF ST_T WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

ST _T Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I	II	III 4 hours Anes- thesia 1 hour drug	IV	V	VI 4 hours Anes- thesia 1 hour drug
		Early Anes- thesia	3 hours Anes- thesia		Early Anes- thesia	3 hours Anes- thesia	
20	x	0	0	0	0	0	0
	y	-.03	-.14	-.13	-.04	-.11	-.10
	z	0	-.03	0	-.01	0	0
21	x	0	0	0	0	-.04	-.02
	y	.06	.02	.04	0	-.14	-.18
	z	0	0	0	0	0	0
22	x	0	0	0	0	0	0
	y	-.03	-.08	-.11	-.08	-.14	-.25
	z	0	0	0	.02	0	0
23	x	0	0	0	0	0	0
	y	.13	0	0	.06	.05	-.05
	z	0	0	0	0	0	0
24	x	0	0	0	0	0	0
	y	.15	.13	.15	.22	.19	.15
	z	0	0	0	0	0	0

x components-the perpendicular measurements from the Horizontal Lead
y components-the perpendicular measurements from the Frontal Lead
z components-the perpendicular measurements from the Sagittal Lead
Measurements-in millivolts

TABLE X

MEASUREMENTS OF ST_c WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

ST _c Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I	II	III 4 hours Anes- thesia 1 hour drug	IV	V	VI 4 hours Anes- thesia 1 hour drug
		Early Anes- thesia	3 hours Anes- thesia		Early Anes- thesia	3 hours Anes- thesia	
20	x	0	.02	0	-.01	0	0
	y	-.02	0	-.11	0	0	0
	z	.02	.02	0	0	0	0
21	x	0	.05	.04	.05	0	0
	y	.31	.18	.18	.26	.14	.13
	z	.18	.04	.04	.10	.02	0
22	x	0	0	0	0	.02	0
	y	.03	.04	-.08	0	-.06	-.15
	z	.04	.04	.02	-.04	0	0
23	x	0	0	0	0	0	0
	y	.24	0	.15	.09	.09	0
	z	.02	0	0	0	0	0
24	x	0	.03	0	-.02	.04	0
	y	.55	.55	.46	.84	.91	1.17
	z	.09	.07	.06	.07	.04	0

x components-the perpendicular measurement from the Horizontal Lead
y components-the perpendicular measurement from the Frontal Lead
z components-the perpendicular measurement from the Sagittal Lead
Measurements-in millivolts

TABLE XI

MEASUREMENTS OF T WAVE FROM TIME-BASED VECTORCARDIOGRAPHIC
LEADS USED IN CALCULATION OF THE SPATIAL MAGNITUDES
AND ANGLES OF THE ANESTHETIZED DOGS
IN SERIES III

T Wave		Conditions					
		Day 1			Day 2		
Dog No.	Com- po- nent	I	II	III 4 hours Anes- thesia 1 hour drug	IV	V	VI 4 hours Anes- thesia 1 hour drug
		Early Anes- thesia	3 hours Anes- thesia		Early Anes- thesia	3 hours Anes- thesia	
20	x	-.01	-.02	0	.01	0	.03
	y	-.13	-.10	.03	-.19	.11	.16
	z	-.01	0	0	-.03	0	.03
21	x	.02	.02	.01	-.03	.02	.08
	y	.19	.08	.04	.10	.12	.19
	z	-.15	.02	.02	-.10	0	.08
22	x	-.03	-.02	-.01	-.04	-.04	-.02
	y	-.44	.10	.10	-.34	-.24	.18
	z	-.02	.04	-.02	0	0	0
23	x	-.02	-.04	-.03	0	0	0
	y	.15	-.31	.21	-.13	.22	.23
	z	-.02	.04	-.03	-.04	.03	0
24	x	-.03	0	0	.03	.04	0
	y	.64	.60	.57	.96	1.50	1.40
	z	-.03	.07	.09	.08	.06	0

x components-the perpendicular measurements from the Horizontal Lead
y components-the perpendicular measurements from the Frontal Lead
z components-the perpendicular measurements from the Sagittal Lead
Measurements-in millivolts

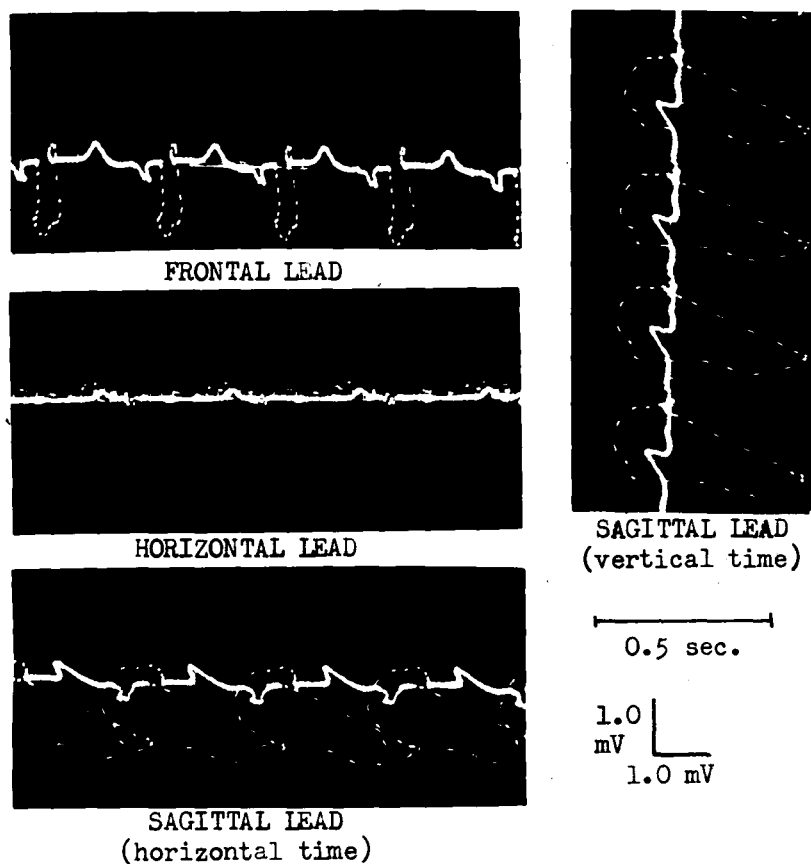


Figure 1a

Time-Based Vectrocardiogram: Pre-drug record of pento-barbital anesthetized 12.6 Kg dog. Milnor's lead system was used.

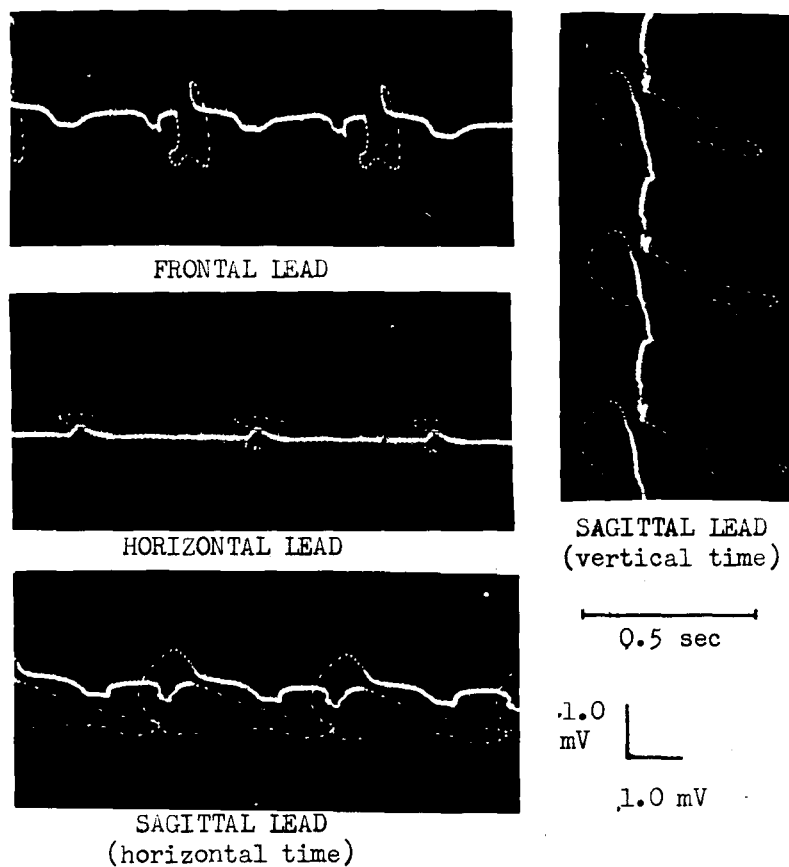


Figure 1b

Time-Based Vectorcardiogram: A record of the same anesthetized dog after 500 mg of quinidine. The quinidine was administered in 5 i.v. doses, at 15 minute intervals. Milnor's lead system was used.

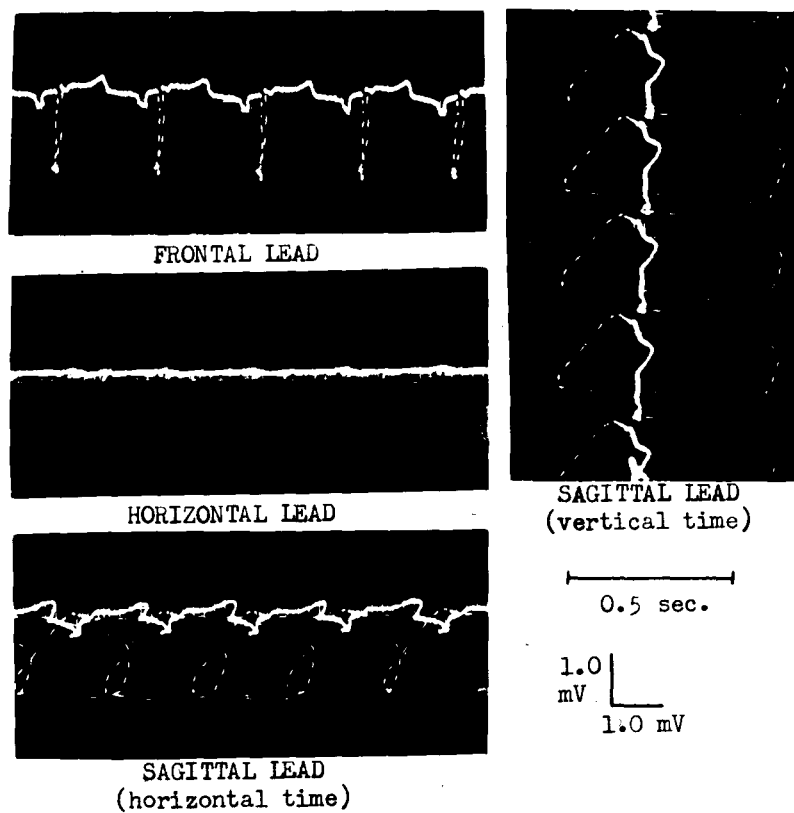


Figure 2a

Time-Based Vectrocardiogram: Pre-drug record of pento-barbital anesthetized 12.0 Kg dog. Milnor's lead system was used.

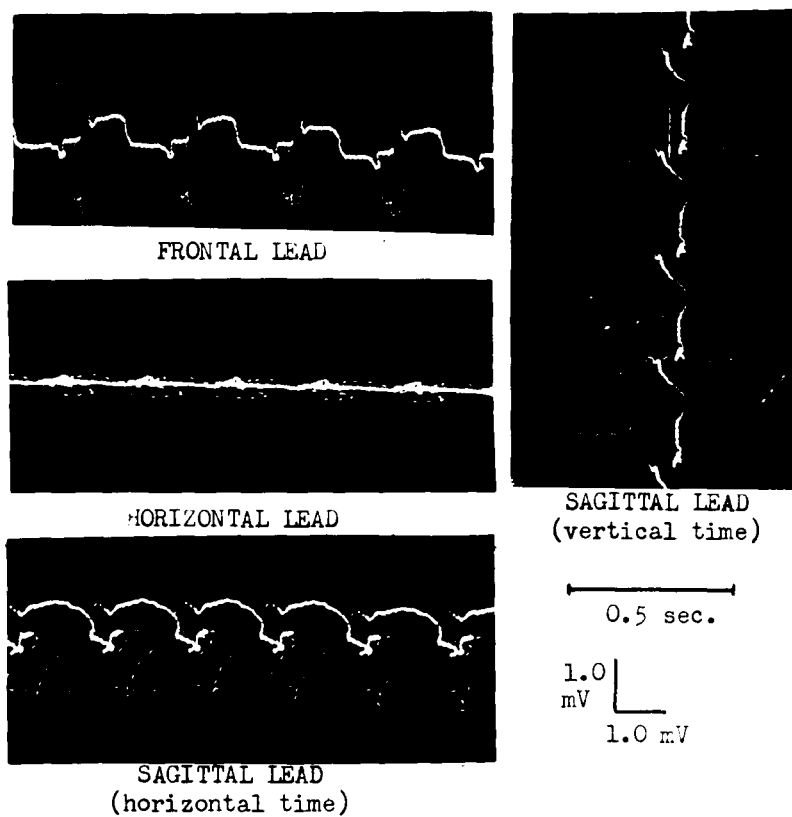


Figure 2b

Time-Based Vectorcardiogram: A record of the same anesthetized dog illustrating a rare "digitalis pattern" obtained after the i.v. administration of 0.65 mg ouabain.

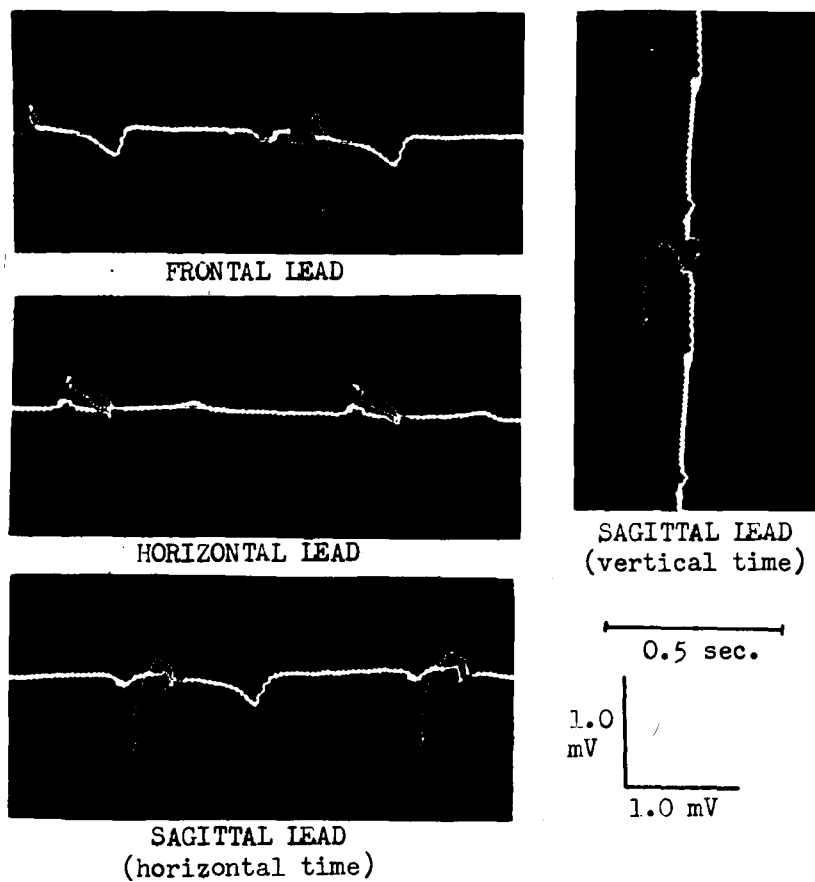


Figure 3

Time-Based Vectorcardiogram: A record obtained from a male human. He had no apparent or known cardiovascular disease or other illness.

APPROVAL SHEET

The dissertation submitted by Rene Richard Kempen has been read and approved by five members of the faculty of the Stritch School of Medicine, Loyola University.

The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the dissertation is now given final approval with reference to content, form, and mechanical accuracy.

The dissertation is therefore accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

23 Jan 1962

Date

J. T. Oster

Signature of Adviser