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A STUDY OF THE ELECTROCARDIOGRAM AS AN INDEX OF ANXIETY

A THESIS

PRESENTED TO

THE UNIVERSITY OF MANITOBA

IN PARTIAL FULFILLMENT

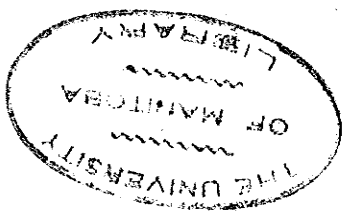
OF THE REQUIREMENTS FOR THE DEGREE

MASTER OF SCIENCE

BY

WILLIAM GORDON LAMBERD

MAY 1957



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ABSTRACT

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The literature regarding the effects of emotional stress on cardiovascular function is reviewed and special attention is paid to a review of the mechanisms of production of EKG changes in psychiatric syndromes. The effects of autonomic imbalance, respiratory changes, anoxia, tachycardia, pain and other factors are considered.

A study of the electrocardiogram as an index of anxiety is presented in three parts:

a) The incidence and type of EKG abnormalities in a group of anxious patients.

b) The effect on the EKG of anxiety induced during discussion of stressful life situations.

c) A consideration of a group of anxious patients with primary T wave changes in the EKG.

In part (a) 41 anxious patients were studied electrocardiographically and two patients with primary T wave changes were discovered. These two patients both had a clinical diagnosis of conversion hysteria and both fell into the lower end of a scale of anxiety. One of these patients was studied further in part (b) of the investigation.

Part (b) consisted of an investigation of the effect on the EKG of increasing anxiety by discussion of stressful life

situations. Six patients were studied. It was concluded that anxiety of the type described in the investigation is accompanied by EKG changes, but that the probable causes of these changes are increases in heart rate and changes in respiratory pattern. As the changes are small and subject to alteration by many factors, it is evident that the EKG could not be used as an index of anxiety.

Part (c) of the investigation was a consideration of four anxious patients, discovered to have abnormal EKG's with primary T wave changes, on routine examination. All of these patients were later found to have physical disease which accounted for the EKG abnormalities.

The importance of concomitant physical disease in producing EKG abnormalities in anxious patients is emphasized.

Finally, it is suggested that the great variations in the reported incidence of EKG abnormalities in psychiatric patients is due to differing criteria of abnormality and if strict criteria are applied, few abnormalities will be found.

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INTRODUCTION

The relationship between life stress and heart function has long been recognized and has been perpetuated in language and legend. Cardiologists have frequently pointed out the effect of anxiety on cardiac function: Harvey and Levine, for example, describe a possible mechanism of death from fright (16) and many others (4, 10, 40), have described cardiac abnormalities following emotional stress. Wolff (49) in particular points out that the subject reacts as a whole to any adequate stimulus whether it be physical or emotional stress. Part of this reaction involves alterations in rate, rhythm, force and magnitude of contraction of the heart's action. Since these changes may be reflected in the electrocardiogram (EKG) the present study has been attempted to investigate the relationship of one aspect of emotional stress - anxiety - to EKG changes.

CHAPTER I

GENERAL REVIEW OF THE LITERATURE REGARDING THE EFFECTS OF EMOTIONAL STRESS ON CARDIOVASCULAR FUNCTION

There is considerable agreement in the literature as to the general relationship between emotional stress and cardiovascular function but just as considerable disagreement as to the more specific manner in which these cardiovascular changes are manifest.

With regard to EKG changes associated with emotional stress there are wide differences of opinion regarding, firstly, the occurrence, and secondly, the nature of these changes and it would appear that in many instances these differences of opinion depend on the criteria of abnormality used in interpreting the EKG.

With regard to the nature of the changes described by some authors, there is considerable doubt whether there is any direct relationship to emotional stress and it may be that all the changes described are due to indirect expression of anxiety such as tachycardia, or change in respiratory pattern.

Stevenson (39) studying 35 patients, the majority of whom had organic heart disease, showed that during discussion of

personal problems of great significance the EKG showed changes which would have been interpreted as abnormal if they had occurred during standard exercise tests. These changes consisted of depressed T waves and S-T depressions and were seen in 18 of the 35 patients. Stevenson comments that some of the T wave changes may have been due to changes in heart rate but the wide diversity of changes in patients with comparable rates indicated that the greater changes were not solely due to increase in rate.

Bruenn (7) found that several patients with impaired A-V conduction time showed distinct reduction in P-R duration during what was interpreted as acute emotional stress. This occurred despite little or no acceleration of ventricular rate. Hickam et al (19) using both healthy students, anxious because of imminent examinations, and clinic patients anxious about their hearts, commented on the impressive extent of the extra work imposed by anxiety and suggested that this could be a factor in the precipitation of anginal attacks and pulmonary oedema in certain patients. They remark that in the majority of persons, anxiety has an effect on the circulation similar to small doses of Adrenalin. Cardiac output is abnormally high in proportion to the rate of oxygen consumption.

Under these circumstances EKG changes would be expected to occur with acute anxiety especially in subjects with

already impaired cardiac function.

Wolf and Wolff (50) in a day to day study of two subjects over a period of about one year and short term observation of patients with heart disease, conclude that:-

1. Dyspnea may occur in response to stressful life situations in association with anxiety, anger, guilt, rage, frustration and tension.
2. Palpitation associated with increased stroke volume may occur under similar circumstances.
3. Heart pain in the presence of anatomical narrowing of coronary arteries may result from increased work of the heart attendant on increased blood pressure and cardiac output in association with rage, resentment, anxiety, fear and tension.
4. Heart pain in the presence of anatomical narrowing of coronary arteries may result from a fall in cardiac output and coronary blood flow in association with desperation and defeat.
5. Giddiness and faintness from cerebral anoxia may result from diminished venous return from the heart or from hyper-ventilation. Both may occur in association with feelings of exhaustion, anxiety and fear.

These results indicate that in a setting of adverse life circumstances and associated emotional reactions, performance

in terms of respiration and work of the heart is costly. This high cost may manifest itself in cardiovascular symptoms which are not dependent upon gross structural heart disorder.

More specifically, a number of studies have reported EKG changes associated with emotional disturbance. These seem to be evenly divided between those postulating specific EKG changes with emotional stress and those studies either rejecting the idea of any changes whatever and those describing non specific changes.

An early study of this nature was published by Mainzer and Krause in 1940 (26) who studied patients before, during and after surgical operations and reported EKG changes in 28 of 51 patients. These changes consisted essentially of S-T depression and flattened or inverted T waves and were attributed to the effects of fear of the operation. However, their results have been criticized by Benedict (3) on the grounds of failure to define criteria for S-T and T wave changes, the considerable tachycardia in some subjects, the preponderance of women in the group and the inclusion of patients with pre-existing coronary artery disease.

Loftus et al (23) described EKG changes in two patients without evidence of heart disease in the presence of strong emotion. These findings were observed primarily in a setting of intense anxiety, tension, resentment and sexual excitement, but it could not be stated

that specific emotions produce specific changes in cardiac functioning. These authors studied 41 patients in all, suffering from personality disorders with intense emotional reactions and found only the above two patients to have abnormal EKG records. In one case the EKG was abnormal on two occasions out of 27 total tracings over a period of five months. The abnormality consisted of marked lowering of T waves in leads 1 and 2. Both abnormal records were obtained during a period of intense anxiety. In the second case, 11 out of 26 tracings were abnormal, showing inverted P waves in one or all leads. A statistically valid correlation was found between the P wave inversion and states of sexual excitement accompanied by anxiety and resentment. The change was independent of heart rate and blood pressure.

Winton and Wallace (48) compared the EKG in 76 neurotic patients with a large group of normal subjects. They concluded that:-

1. There is no combination of abnormalities which fits a distinct pattern characterizing this group electrocardiographically.
2. There is a tendency for about 12% of cases to present a right heart strain pattern as suggested by tall P waves and right axis shift and S-T depression in the limb leads.
3. Flat or inverted T waves in leads 1 and 2 occurred 15 times as frequently in the neurotic group as in a large group of

healthy young aviators.

4. S-T depression of at least 0.5 mm. in leads 1 and 2 occurred about five times more frequently than in normal individuals.

Only four of the records could be classified as "definitely abnormal", two were "probably abnormal", eight "borderline", and the rest "probably normal" or "within normal limits".

Wendkos (43) reported an 80% incidence of abnormalities in T waves in the precordial leads and 20% in the limb leads in patients with "neurocirculatory asthenia". In a later paper (44) he discussed "autonomic imbalance" as a factor in the production of these abnormalities and suggested that heightened sympathetic activity was chiefly responsible for the T wave changes in the limb leads and demonstrated that ergotamine tartrate eliminated these abnormalities or prevented them from occurring.

Heyer et al (18) studying 200 psychotic patients reported a 21.5% incidence of abnormalities in the EKG as compared with a 3% incidence in 200 normal subjects. These abnormalities included lengthened P-R intervals, small R waves and lowered, diphasic and inverted T waves. This study included patients of ages from 18 to 64 years and no attempt was made to exclude patients with organic heart disease. Six of the abnormal records

were from patients with obvious heart disease and it is difficult to assess the importance of the remainder. There were presumably no cases of inverted T waves in the limb leads.

Magendanz and Shortsleeve (25) studied 22 patients without organic heart disease but with S-T segment deviations and low or diphasic T waves in various leads. Most of these deviations disappeared after rest and reassurance of the patient without change in heart rate. As 17 of these patients had psychiatric diagnoses of various types, these authors suggested that anxiety was a factor in the production of the changes.

Littman (22) reported nine cases of gross EKG abnormality without demonstrable heart disease. Deviations were greatest in the chest leads. Essentially normal records were eventually obtained in most subjects by various means. Of this group of patients, two had definite organic disease other than heart disease and a third had frequent extrasystoles. Two patients had a persistence of a juvenile pattern of the T waves and one had an abnormal EKG only after meals when he swallowed quantities of air. The remaining three patients were probably suffering from cardiac neurosis. The fact that most of the deviations were seen in the chest leads throws some doubt on the validity of this study as it is well known that the chest leads are subject to deviation due to

many extra-cardiac causes.

Blom (6) studying acutely psychotic patients found 42% of abnormal records in 193 patients of average age of 20 years. He described changes in S-T segments and T waves of the "sympathetic type". Most of these patients were acute schizophrenics but no consideration was paid to the possibility of dehydration and changes in electrolyte balance in these disturbed subjects and no attempt was made to correlate the changes with heart rates or disturbed respiratory patterns.

Bennett and Scott (5) in a study of five patients under hypnosis were able to produce lowering of the T wave in lead 1 and flattening or disappearance of T2 and T3 in the EKG of one subject when anxiety and anger were produced by suggestion. These changes occurred during a period of tachycardia with a heart rate of 120/minute. Exercise later produced a heart rate of 115/minute in this subject without similar T wave changes, suggesting that tachycardia was not responsible for the original T wave changes under hypnosis. The administration later of 1 mgm. of adrenalin subcutaneously produced lowering of T1 and T2 in this subject and the authors suggest that the release of endogenous adrenalin during anxiety is responsible for the T wave changes observed.

Thompson (41) described T wave abnormalities in all

leads in the EKG's of subjects with anxiety neuroses manifested by tachycardia, precordial pain and hyperventilation. He expressed uncertainty as to whether such individuals had perfectly normal hearts and considered the possibility that alkalosis resulting from hyperventilation caused further constriction of coronary vessels already altered to a sub-clinical degree. Scherf and Schlachman (33) found lowering of R and T waves in hyperventilation but could demonstrate no parallelism between the degree of alkalosis found and the EKG changes. The changes found in hyperventilation were the same as those produced by a maximal deep inspiration and these authors explain the effect by positional changes of the heart due to alteration of the height of the diaphragm. Master et al (28) state that severe neurotics may exhibit EKG changes following the two-step exercise test, which are indistinguishable from those of organic disease. Using five neurotic patients with EKG changes following exercise but without demonstrable heart disease, they demonstrated that intravenous ergotamine tartrate administered 30 minutes before the test eliminated the abnormalities. In five other patients with organic heart disease and EKG changes, the tracings were not altered by ergotamine tartrate. These authors suggest that the mechanism of EKG abnormalities in psychoneurotic subjects may be related to altered coronary blood flow or to a

direct effect of the autonomic system on the electrical potentials of the heart or on cardiac metabolism. However it has been shown (29) that the administration of nitroglycerin or amyl nitrite plus 100% oxygen does not alter the T wave changes in this type of subject.

Logue, Hanson and Knight (24) studying 150 patients with "neurocirculatory asthenia" described T wave changes in the limb leads which they considered to be similar to those observed in coronary artery disease. They concluded that 49% of their patients had abnormal cardiograms. These abnormalities consisted of low T waves in leads 1, 2 and 3 (less than 1 mm.). However, the number of inverted T waves in the significant leads 1 and 2 was much smaller. They reported two cases of inversion of lead 1 and nine cases of inverted or diphasic lead 2. No attempt was made to correlate the T wave changes with tachycardia or changes in respiratory pattern. The authors state that there appears to be no characteristic EKG pattern in "neurocirculatory asthenia".

White, Cohen and Chapman (46) studied 144 cases of "neurocirculatory asthenia" at rest and after exercise but found no EKG abnormalities in this group. Friedman (11) in another study of this condition found few and non-characteristic changes in

the EKG. Cohen, White and Johnson (8) in a controlled study of neurocirculatory asthenia, concluded that there are no EKG changes in this condition.

Oltman and Friedman (31) in an EKG study of 812 psychiatric patients failed to find a significantly higher incidence of abnormalities than in a control group of healthy young aviators. In 100 of these patients, retested following frontal lobotomy, again no significant EKG changes were found.

Benedict (3) studied the effect of conscious anxiety on the EKG in 50 medical students about to take an examination. Sixty percent of these students were said to be "mildly to moderately anxious" and 20% were "very apprehensive". Many exhibited physical signs and symptoms of anxiety, such as flushing, sweating and tremor. The pre-examination records were compared with control records. The double Master exercise test was administered as part of the investigation. This author concluded that conscious anxiety of the intensity described, produces few EKG changes in healthy young subjects when the tracing is taken 30 to 60 minutes before the anxiety producing event.

CHAPTER II

REVIEW OF THE LITERATURE REGARDING MECHANISMS OF PRODUCTION OF EKG CHANGES IN PSYCHIATRIC SYNDROMES

(a) Autonomic Imbalance.

Wendkos (43, 44) and Master et al (28) have attributed the EKG abnormalities found in functional heart disease and neuro-circulatory asthenia to disruption of normal vago-sympathetic relationship and suggest that the changes may be due to heightened sympathetic tone. They were able to eliminate these changes by the administration of ergotamine tartrate or similar drugs. Marcos (27) in a study of EKG changes during migraine attacks demonstrated low T waves and marked decrease of total potentials in precordial leads, reversible quickly after giving ergotamine tartrate intramuscularly. He concluded that the EKG changes were related to the development of an "adrenosympatheticotonic" condition during the migraine attack. Solomon (37) however, found that ergotamine removed not only many of the "false normalities" but also not infrequently abolished organically determined EKG changes.

Bennett and Scott (5), Hickham et al (19) and Steven-son et al (39) have shown that anxiety produced EKG changes

similar to those produced by small doses of adrenalin. Many studies (9, 17, 29) have shown that small amounts of adrenalin will depress T waves in the EKG and the magnitude of the depression is not significantly different among normal subjects, anxious patients and patients with angina pectoris. Hartwell et al (17) investigating the effects of adrenalin, ergotamine, atropine and mecholyl on the EKG, with particular reference to the effect on T waves, conclude that adrenergic factors lower T waves and cholinergic factors raise T waves. They also demonstrated that bradycardia produced by carotid sinus pressure produces increased T waves, presumably via a vagal effect, whereas the tachycardia of exercise results in lowered T waves.

Mitchell and Shapiro (29) studying a single case of T wave inversion in an emotionally unstable patient without organic disease, showed that intravenous adrenaline produced similar changes to those produced by anxiety and fear in this subject. They concluded that the original T wave changes resulted from the endogenous production of adrenalin during anxiety and also suggested that there was an increased sensitivity of the myocardium to adrenalin in this subject. Crede and Chivers (9) in a similar study on a patient with S-T sag and T wave inversion associated with anxiety, concluded that the changes were not due to alkalosis,

anoxemia or positional changes of the heart. By giving 400 mgms. of tetraethylammonium chloride, an autonomic blocking agent, to this patient and demonstrating the persistence of the EKG changes, they further concluded that the changes were not originally due to autonomic imbalance. The EKG changes associated with insulin and electric-shock treatment have been discussed by a number of authors (2, 14) and are of interest in view of the autonomic changes which take place during shock treatment.

Although it seems to be agreed that sympathetico-mimetic factors produce lowering of T waves in most subjects and occasionally S-T depression and greater P wave amplitude, it has yet to be demonstrated conclusively that anxious subjects either produce an excess of endogenous adrenalin or have a state of "increased sympathetic tone" due to "autonomic imbalance", whatever the latter term may mean. Furthermore, it has been shown (17) that the amount of adrenalin required to invert the T waves in a normal individual is relatively large and probably unphysiological. The effects of adrenalin administration on plasma potassium levels is usually to reduce the general level with perhaps consequent T wave changes due to hypopotassemia. The effect of the sympathetic and parasympathetic nerves on coronary vessels and the effects of the autonomic nervous system on cardiac

action potentials is unknown in man, although stimulation of the cardiac sympathetic nerves in dogs is reported to produce lowering of T waves (18). Experiments in autonomic blockade, such as that of Crede and Chivers (9) are unsatisfactory with most agents at present in clinical use as the blockading dose is too close to the toxic dose and lower doses, such as used by the above authors, are ineffective in producing complete autonomic blockade (30).

(b) The Influence of Respiratory Changes and Alkalosis.

Hyperventilation is a common symptom in anxiety neurosis and neurocirculatory asthenia, and it has been suggested that changes in respiratory pattern may produce EKG changes by production of alkalosis or by alteration of the position of the diaphragm with consequent changes in the position of the heart. Wolff (49) showed that in anxiety the diaphragm tends to be flattened due to increased muscular tone and shortening. He suggests that this accounts for the inability to draw a full breath, the substernal tightness and sensation of breathing from the top of the chest experienced in severe anxiety. Scherf and Weisberg (34) discussed the effects of diaphragmatic movement on the EKG and Stevenson et al (39) showed that the EKG in maximal inspiration showed similar changes to those produced by emotion in seven of 15 patients, although only in one case were the changes comp-

letely reproduced. Scherf and Schlachman (33) demonstrated lowering of R and R waves in lead 1 in hyperventilation and showed that this was similar to the effect of maximal deep inspiration and was probably due to diaphragmatic changes.

The effect of change in posture has been discussed by Wendkos (43, 44) and by White and Chamberlain (45). The former author suggests that T wave changes produced by changes from the supine to the erect or semi-erect position are related to augmentation of sympathetic activity rather than to positional changes of the heart. The effect of asthenic build and the possibility of increased cardiac mobility in patients with "neurocirculatory asthenia" has been mentioned by both Wendkos and White and Chamberlain. Crede and Chivers (9) however, demonstrated that the T wave changes which occurred on changing from the supine to the sitting position decreased with maintenance of this position and then returned with resumption of the supine position. They consider that this renders unlikely the explanation that these T wave changes are due to positional changes of the heart and suggest that changes in heart rate and ventricular filling may be responsible.

Alkalosis as a factor in EKG changes in anxious patients has been investigated by Scherf and Schlachman (33),

Thompson (41) and by Barker et al (1) who produced T wave distortion in five out of seven subjects by feeding sodium bicarbonate. They were unable, however, to demonstrate any strict parallelism between pH changes and EKG changes. Stevenson et al (39) showed that in hyperventilation in anxious patients, the T wave inversion occurred at the onset of the hyperventilation and did not increase with further ventilation and was thus unlikely to be due to the production of alkalosis. Crede and Chivers (9) and Mitchell and Shapiro (29) showed that hyperventilation with 7% carbon dioxide in ambient air produced the same T wave inversions in their anxious patients as did ordinary hyperventilation and they suggested that this eliminated alkalosis as a factor in the production of the EKG changes in their cases.

The available evidence thus suggests that T wave changes may be produced by alkalosis but that this is probably not a common mechanism in the T wave changes seen during anxiety. Transient T wave changes and S-T segment depression associated with a maximal inspiration may be seen in the records of anxious patients, but these would not persist throughout the record but would wax and wane with respiration. Hyperventilation of the degree described by the above authors is seldom seen in anxious patients and clinical signs of alkalosis, such as tetany, are uncommon

in these patients.

It is unlikely that persistent T wave changes in anxious patients are related solely to changes in respiratory pattern or to alkalosis.

(c) Anoxia.

Increased myocardial demand for oxygen has been discussed as a possible explanation for EKG changes in anxious patients by a number of authors (9, 29, 43, 44) and the possibility has been suggested that endogenous adrenalin increase in anxiety is responsible for the increased myocardial demand.

However, Crede and Chivers (9) and Mitchell and Shapiro (29) demonstrated in two subjects that T wave inversion persisted during anxiety, despite the breathing of 100% oxygen and inhalation of amyl-nitrite or ingestion of nitroglycerin. In fact, if the T wave changes were not present in these patients these procedures precipitated them. Thompson (41) expressed uncertainty as to whether neurotic patients with abnormal cardiograms, but no other findings, had perfectly normal hearts and considered the possibility that a subclinical degree of coronary constriction existed and that further constriction might be caused by hyperventilation during anxiety attacks.