The Effect of Hyperventilation on the Normal Adult Electrocardiogram

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The effect of brief hyperventilation on the precordial T waves of 350 normal adults is described. Evidence is presented that brief hyperventilation initiates a vagal reflex which results in the T-wave inversion. Supportive data are also given to exclude respiratory alkalosis as a possible mechanism. Caution is advised in interpreting isolated T-wave inversions as indicative of organic heart disease. It is proposed that isolated T-wave inversion be deleted as a criterion for a "positive" exercise test.

TRANSIENT or persistent T-wave inversions in the left and midprecordial unipolar leads have been observed in approximately 10 per cent of apparently healthy, adult Negro males and less commonly in Caucasian adults. This pattern is known as the "juvenile pattern" because of its resemblance to the T-wave changes observed in infants and young children. The clinical importance of these electrocardiographic changes lies in the similarity to those of organic heart disease.

Previous reports showed that the T-wave inversions could be abolished by the oral administration of potassium salts or by propantheline bromide (Pro-Banthine, Searle) given intravenously. Hyperventilation, on the other hand, intensified the precordial T-wave inversions and, when the T-wave had transiently become upright, elicited the originally observed T-wave changes.

These observations with hyperventilation prompted a study of the electrocardiographic effects of hyperventilation on a number of adult patients who had normal resting electrocardiograms. In addition, the effects of breathing various concentrations of carbon dioxide and oxygen were investigated to determine whether the observed T-wave changes were due to respiratory alkalosis. The effects of the vagal blocking agent, Pro-Banthine, and the potassium ion in abolishing the hyperventilation effect were once again studied. The patients were also evaluated from the emotional standpoint, inasmuch as it has been established that the patients exhibiting the overt "juvenile electrocardiographic pattern" were tense, immature, and often neurotic.

MATERIALS AND METHODS

Electrocardiograms were taken of 901 patients in the Veterans Administration Hospital, Madison, Wis., between Jan. 1, 1954 and Sept. 30, 1955. Of this total, 350 patients were selected for inclusion in this study on the basis of the following criteria: (1) the presence of a normal resting electrocardiogram, (2) absence of debility, (3) an age range between 18 and 50 years and (4) no clinical evidence of coronary artery or significant cardiovascular disease. Of this group, there were 258 Caucasians and 92 Negroes; the mean age was 35 years.

All electrocardiograms were taken in recumbency, with a direct-writing machine. Hyperventilation consisted of 10 to 15 seconds of forced, rapid respiration that was repeated during the recording of each precordial unipolar lead. The patients exhibiting the most marked T-wave changes during hyperventilation (positive reactors) were subjected to the following additional studies:

1. Hyperventilation during Inhalation of Various Gaseous Mixtures

Six patients with the most striking T-wave inversion following hyperventilation were observed during the inhalation of various gaseous mixtures containing low, normal, and high concentrations of oxygen and carbon dioxide. Hyperventilation was
repeated during the inhalation of each of the 4 gaseous mixtures. The unipolar leads with the most marked T-wave changes during the control hyperventilation were recorded during the administration of the gaseous mixtures. Continuous monitoring with a Waters-Conley ear oximeter was carried out during the period of gas administration to detect changes in arterial saturation. Arterial blood pH, pCO₂ and venous blood potassium concentrations were not measured.

2. Vagal Blockade

The effect of a vagal blocking agent, Pro-Banthine, in abolishing the hyperventilation effect was studied in 11 instances. Pro-Banthine, (30 mg. diluted in 10 ml. of water) was administered intravenously in increments of 5 mg. over a 3 to 4 minute period. The endpoint of drug administration was tachycardia of 140 to 150 beats per minute. Hyperventilation was subsequently repeated during maximal Pro-Banthine activity, usually 45 to 90 minutes following the injection, when the drug-induced tachycardia had stabilized at 125 to 130 beats per minute.

3. Potassium Salts

The effect of 10 Gm. of orally administered potassium salts, (5 Gm. of potassium bicarbonate and 5 Gm. of potassium acetate, diluted in 30 ml. of water) in abolishing the electrocardiographic effect of hyperventilation was likewise studied in six instances. Hyperventilation was repeated 30 to 60 minutes after ingestion of potassium, the period of maximal drug effect.

4. Psychiatric Evaluation

Twelve patients had previously been referred for psychiatric consultation and 11 additional patients were available for psychiatric study when the evaluation of the emotional factors were undertaken. Twenty-five patients had completed the Madison Sentence Completion Form (a test method designed specifically to evaluate the attitudes and emotional reactions of patients with tuberculosis). Therefore, all patients in this study had either psychologic testing or psychiatric evaluation, and many had both. During the individual standardized psychiatric interviews, emphasis was placed on the patient's personality structure, maturity, and reactions to emotional stress.

Results

T-wave inversions were observed in 37 of the 350 patients tested by hyperventilation. The T-wave changes were observed in two or more of the mid and left precordial leads. Twenty-five were Caucasians and 12 were

FIG. 1. Lead V₁ electrocardiogram during complete hyperventilation study on L. M., 32 year old Negro. The percentages refer to oxygen saturation. The control tracing, with patient breathing room air, showed a very active hyperventilation reflex with marked T-wave inversion within 8 seconds. This effect persisted while the patient breathed low O₂, normal CO₂; high O₂, normal CO₂; low O₂, high CO₂; and high O₂, high CO₂. The T-wave inversion patterns during the inhalation of excessive CO₂ (11 per cent) were shorter than those seen on previous studies.
Negroes (9.5 and 13 per cent, respectively). The mean age of the positive reactors was 32 years and was similar in Caucasians and Negroes.

1. Hyperventilation during Inhalation of Various Gaseous Mixtures

Regardless of the inhaled gaseous concentration, persistent T-wave inversion was observed upon brief hyperventilation in the 6 patients studied. The T-wave inversion, however, that occurred during a period of inhalation of 89 per cent oxygen and 11 per cent carbon dioxide was of shorter duration. The effect of hyperventilation was not so great during this period, apparently because of the narcotizing effect of the high concentration of CO₂. Oxygen saturation increased uniformly during the period of hyperventilation in all gaseous atmospheres (fig. 1).

2. Vagal Blockade

Complete abolition of the hyperventilation effect by Pro-Banthine was observed in 8 of

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**Fig. 2.** A 26 year old Negro. Electrocardiograms on 8-10-54 and 8-27-54 were normal. Marked T-wave inversions, V₂ through V₅, followed hyperventilation and disappeared after Pro-Banthine. The tracing of 11-8-54 was normal and marked inversions of T waves in V₃ and V₄ followed hyperventilation.
the 11 patients studied (fig. 2). One patient showed only partial blockade and two patients showed no change. In these two patients, only 5 mg. of Pro-Banthine were given because of marked tachycardia. Previous studies have indicated that at least 15 mg. are necessary to abolish the hyperventilation effect. There were no other untoward effects of Pro-Banthine.

3. Potassium Salts

The oral administration of potassium salts consistently abolished the hyperventilation reflex within 30 to 60 minutes in the 6 patients studied (fig. 3). There was no evidence of potassium toxicity.

4. Psychiatric Evaluation

The prevalence of autonomic instability, tension and anxiety and marked hypochondriac tendencies, found in our earlier series, was confirmed in the present group of 37 patients. The patients were generally shy, passive-dependent and inhibited with marked inner tension. They showed an inability, or at least a marked disinclination, to express their feelings. Most had palmar hyperhidrosis, some dripped with sweat and many admitted extreme tension and palpitation during the interview. Diarrhea and frequency of urination were noted by a number of patients when
under tension. The unsuccessful nature of the patients’ defense against anxiety was striking. Their relations with others had a distinctly immature flavor. Compulsive compliance was the most common method of handling aggressive feelings. It would appear that the “juvenile pattern” in the electrocardiogram has its emotional counterpart in a particular form of “juvenility” of personality.

**Discussion**

Much stress is placed on the diagnostic and prognostic significance of isolated T-wave inversions.1-6 Indeed, one of the principal criteria of an abnormal exercise test is a reversal in polarity in the precordial T waves.7-9 Such T-wave inversions have been observed as a benign “juvenile pattern” in apparently normal, young, Negro males. This pattern is nevertheless frequently misinterpreted as showing coronary, myocardial, or pericardial disease.

The overt “juvenile pattern” has been found in approximately 10 per cent of adult Negro males, though it is relatively rare among Caucasian males.7 It appears from the present study that the pattern is latent in both Negro and Caucasian males. The latent form can be demonstrated by subjecting the patient to a brief period of hyperventilation. With this technic it was found in 13 per cent of the Negro and 9.5 per cent of the Caucasian patients.

It has been suggested that the T-wave inversions during hyperventilation were due to respiratory alkalosis.10-14 The promptness with which the pattern follows initiation of hyperventilation and the appearance of the pattern during inhalation of high concentrations of CO2 exclude this mechanism.

The hyperventilation effect may be explained as a vagal reflex arising in the thorax, similar to the Hering-Breuer reflex. Support is given to this concept by the blockade of the effect by Pro-Banthine or potassium.

Psychiatric evaluation of these patients showed them to be tense, immature, and emotionally disturbed. They expressed much inner hostility, yet exhibited external passivity, and they met stressful situations with compulsive compliance. The T wave therefore might well be regarded as the “stress segment” of the electrocardiogram.

**Summary**

The electrocardiograms of 350 normal adult males were studied following brief hyperventilation.

In 37 patients, T-wave inversions were observed in two or more of the precordial leads. This phenomenon is regarded as a latent “juvenile pattern.”

Psychiatric evaluation of these patients revealed them to be tense, immature and emotionally disturbed. “Juvenility” is expressed in their personality structure as well as in their electrocardiogram.

Respiratory alkalosis was excluded as the underlying mechanism by observation of the pattern during forced breathing of high CO2 atmospheres.

The hyperventilation effect is believed due to a vagal reflex. Support is given this concept by demonstration of the blocking effect of Pro-Banthine and potassium.

Caution is advised in interpreting isolated T-wave inversions as indicative of organic heart disease, particularly in emotionally disturbed, tense individuals. It is proposed that isolated T-wave inversion be deleted as a criterion for a “positive” exercise test.

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**Summario in Interlingua**

Le electrocardiogrammas de 350 normal adultos masculae eseva studiata post breve hyperventilation. In 37 subjectos, inversiones del nunda T eseva observate in 2 o plus derivationes precordial. Iste phenomeno es considerate como un latente “configuration juvenil.” Le evaluation psychiatric del subjectos revelava que illes eseva tense, immatur, e emotionally disturbate. “Juvenilitate” es manifesto in le structura de lor personalitate tanto ben como in lor electrocardiogramma. Alcalosis respiratorii eseva exclusite como mecanismo subjacente proque le configuration se
observava durante la respiración forzada de aire a alto contenido de CO₂. Le efecto del hiperventilación es debite in nostre opinion a un reflexo vagal. Iste conception es supportate per le demonstration de un efecto bloqueante de Pro-Banthina e kalium. Nos recommanda prudentia in interpretar isolate occurrentias de invertite undas T como indication de organic morbo cardiac, specialmente in tense e emotionalmente disturbe individuos. Nos propose que le currentia isolate de invertite undas T es supprimate como criterio de “positivitate” in tests de exercitio.

REFERENCES


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