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THE CLINICAL SIGNIFICANCE OF ELECTRICAL IMPEDANCE DETERMINATION IN THYROID DISORDERS*

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Interest in the relationship between the phase angle of the electrical impedance of the human body and thyroid disturbances has been prompted by the recent work which Brazier (1), (2), (3), (4) has reported in England. During the past year the American Goiter Society granted Brazier its first award for her contribution to the study of thyroid disorders. Furthermore, at the present time an apparatus of the type described by Brazier is being offered for sale in England as a diagnostic instrument for use in thyroid disease. According to the publication of this author it is possible to follow the clinical course of thyroid disease very accurately, using this electrical measurement as the basis for the estimation of thyroid activity. Since impedance values are little affected by food, activity, menstrual cycle and so forth, it appeared that this measurement might offer decided advantages over metabolic rate determinations.

The earliest attempts to measure the impedance of the human body were made with direct current. Using a direct current, the impedance offered by the body to the current has but a single component, namely, the resistance. However, when an alternating current is employed, the body conducts the current as would a circuit containing both a resistance and a capacitance. In other words it exhibits both resistance and reactance. The ratio of the values of these two components is a property of the tissues under observation. Brazier believes this property to be a function of thyroid activity. The ratio of the reactance to the resistance Brazier defines as the "Impedance Phase Angle." Inasmuch as this ratio is not represented by an angle in conventional electrical engineering practice we shall avoid the use of this expression. Instead we shall follow the notation, already well established, in which this ratio is designated as the factor "Q."

The method of making electrical contact to the body recommended by Brazier involves immersing the arms to the elbows in saline solution. It is claimed that by thus making the area of the surface tissues relatively large their effect upon the impedance measure is negligible. That this is far from true has been demonstrated by Horton and VanRavenswaay, who have developed a method for measuring separately the impedances of the surface sheath and of the internal tissues. The method used by them involves the use of four electrodes which, in effect, form the terminals of a multiple branch electrical network. Certain of the branches being due solely to surface tissues and others solely to internal tissues the evaluation of

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each may be effected by computation from measurements of the impedances between the several possible pairs of terminals. There has also been developed an impedance comparator, employing the principle of the alternating current potentiometer, by which it is possible to obtain by direct measurement the values of the

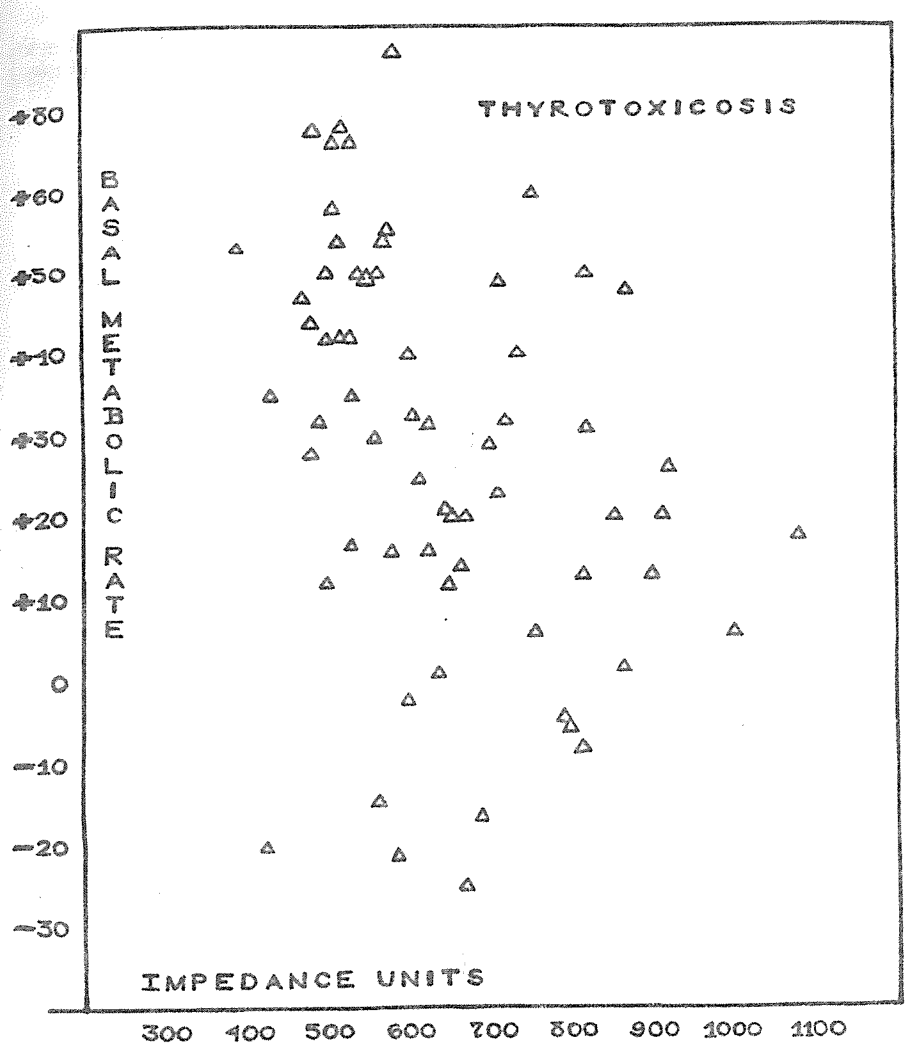

Fig. 1. Impedance values of treated and untreated thyrotoxic patients at different metabolic levels.

resistance and of the reactance components of the surface sheath areas under each of two electrodes and of the internal tissues joining these areas.

Data obtained by the four electrode method, both with the comparator and by the direct measurement on the several electrode pairs, lead to the following conclusions. A detailed discussion of this part of the work is given in another paper (5).

(1) The characteristic curves showing the variations of the impedance components with the frequency for the surface sheath are markedly different from those for the internal tissues.

(2) The value of Q for the surface sheath, at 10 kilocycles, may vary between

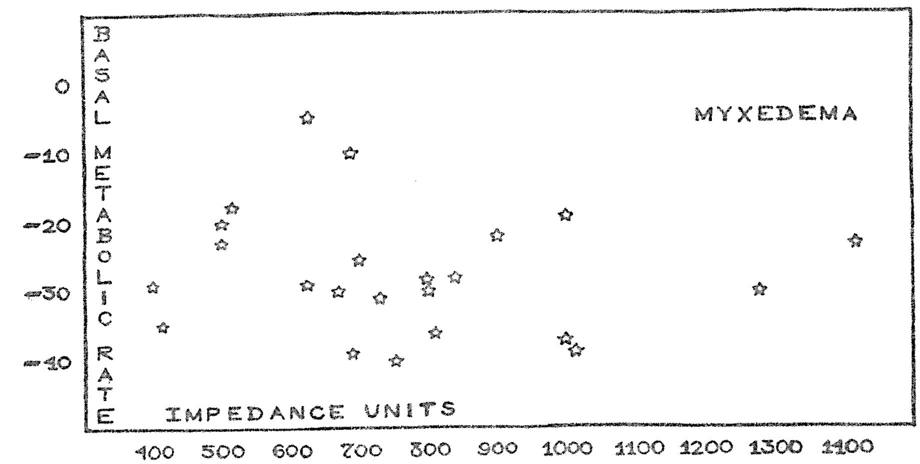

Fig. 2. Impedance values of treated and untreated myxedematous patients at different metabolic levels.

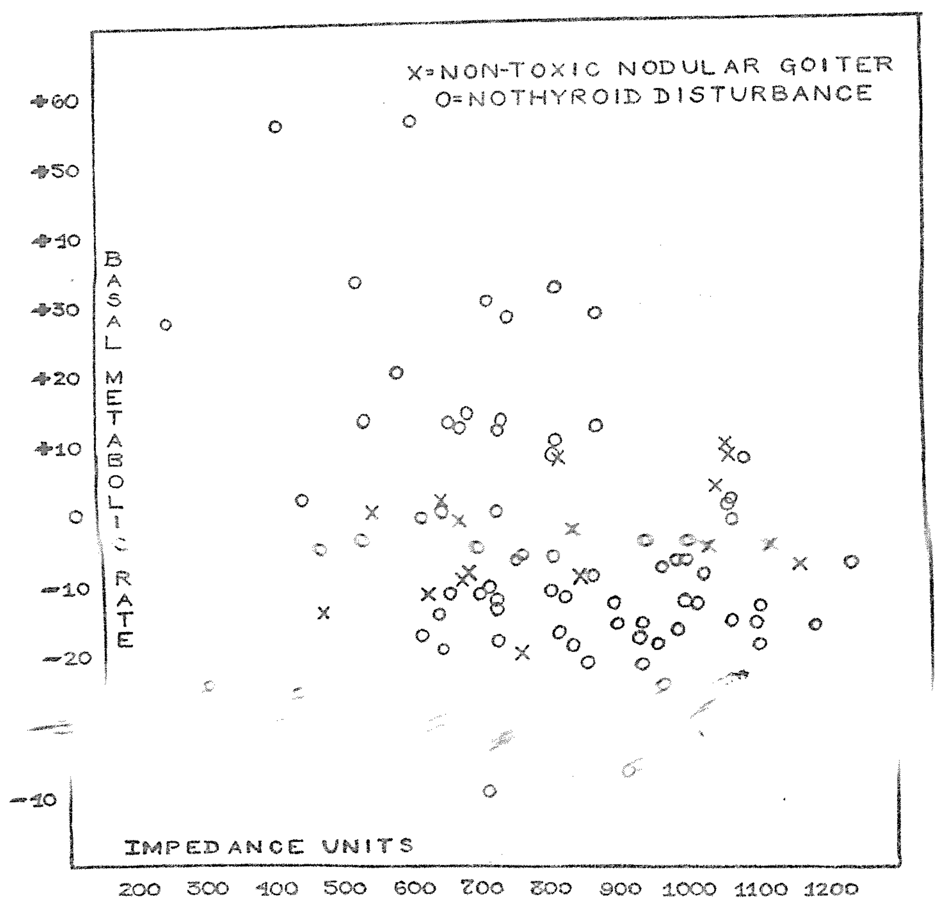

Fig. 3. Impedance values in patients with non-toxic goiter, non-thyroid disorder and no demonstrable disease.

1 and 4 for different individuals. It may vary by a factor of 2 for different positions on the surface of a given individual. It may also vary by a factor of 2, or more, over a period of several days for a given area.

(3) The value of Q for the internal tissues, at 10 kilocycles, may vary between 0.04 and 0.14 for different individuals. It appears to vary but little (less than 10 per cent) with the portion of the body included between the electrodes for a given individual. With persons in normal health the change over long periods of time

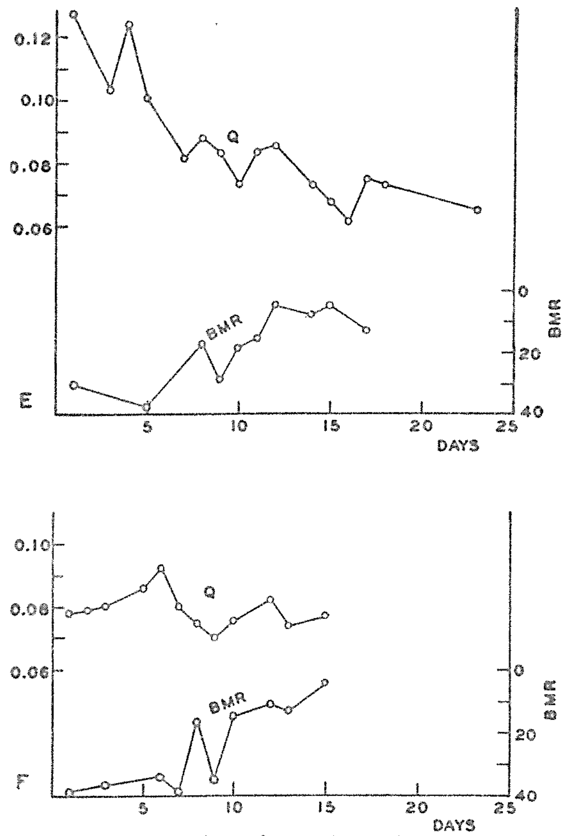

Fig. 4. The course of impedance values and metabolic rate determinations in two typical cases of myxedema (E,F) on thyroid therapy.

is, in general, less than 10 per cent. With pronounced changes in pathological condition it may change by as much as a factor of 2.

(4) Using representative values for the impedance components of the internal and surface tissues, per unit length of arm, the total impedance of an immersed arm, between the electrolyte and the internal tissues lying in the plane of the electrolyte surface, has been computed. The results show that of the total impedance measured by the immersion method the portions of the arms below the surface of the electrolytes contribute less than 10 per cent of the resistance and nearly 50 per cent of the reactance. As a consequence the values of Q given by the immersion methods are, in general, from 50 to 100 per cent greater than the values for the internal tissues alone. They are obviously greatly affected by changes in the impedance of the surface sheath.

The conclusions outlined above suggest strongly that any study of possible correlations between electrical impedance and pathological conditions should consider the surface sheath and the internal tissues separately. In the clinical investigation which forms the subject of this report, the electrical constant to which particular attention has been given is the ratio of the reactance to the resistance components or the impedance of the "internal tissues," measured between band electrodes placed on the upper arms.

This report is based upon a study of 220 individuals, representing more

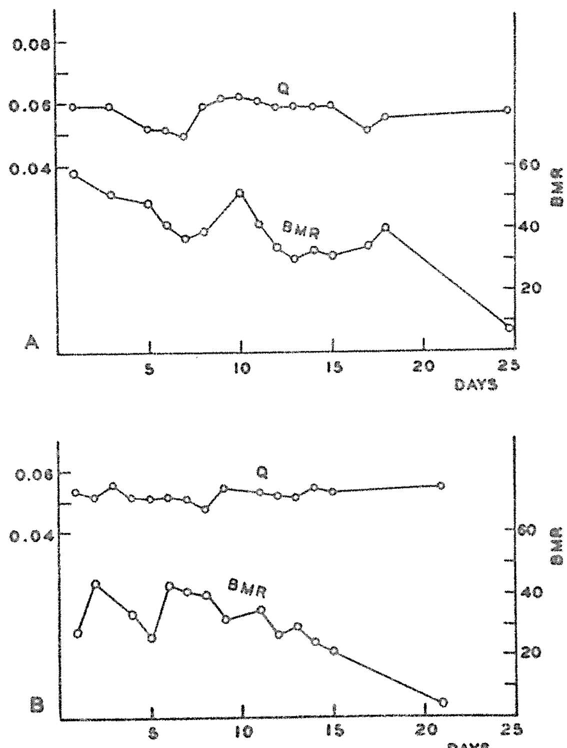

Fig. 5. The course of impedance values and metabolic rate determinations in two typical cases of thyrotoxicosis (A,B) under treatment by iodine and subtotal thyroidectomy.

than 700 impedance records accompanied by simultaneous basal metabolic rate determinations in nearly every instance. The cases were grouped as follows.

Thyrotoxicosis	63
Myxedema	25
Non-Toxic	18
Non-Thyroid Diseases	72
Normal Individuals	42

The plan of study included a general survey of all cases with particular reference to thyroid function as measured by basal metabolic rates and clinical symptomatology. Cases were studied at various stages of therapy in order to ascertain any correlation of impedance values with the metabolic level. This study included observations on thyrotoxic patients at untreated levels, after

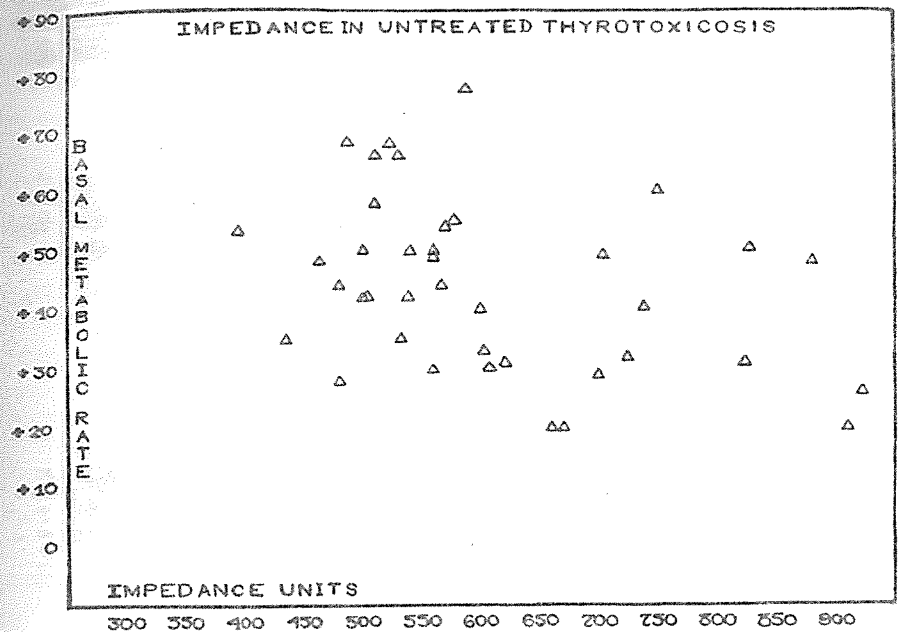

Fig. 6. The impedance values on thirty-nine cases of untreated thyrotoxicosis.

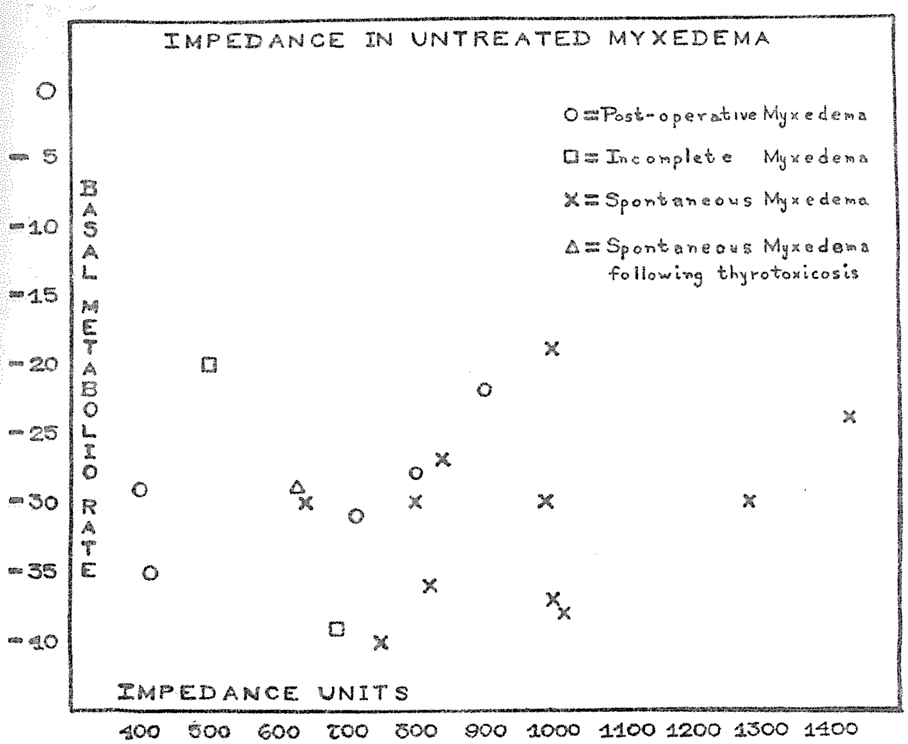

Fig. 7. The impedance values for eleven cases of spontaneous, complete myxedema and eight cases of other types of hypothyroidism.

iodine therapy had been instituted, and at varying intervals following thyroidectomy as well as myxedematous patients before and after the administration of thyroid preparations.

Figure 1 presents data on individuals with thyrotoxicosis at various levels of therapy. Figure 2 presents similar data for myxedematous individuals, while figure 3 gives the values for individuals with non-toxic goiter, with non-thyroid disorders, and those with no demonstrable disease. It is apparent from figures 1, 2 and 3 that there is but little correlation between actual metabolic levels and impedance values.

Cases of thyrotoxicosis and myxedema under therapy showed the usual marked acute changes in their metabolic rates and clinical status. In most instances these alterations were not accompanied by significant changes in impedance values. However, in isolated cases studied over long periods, i.e. six to twelve months, there was a tendency for the high values of myxedematous patients to decrease and for the low values of thyrotoxic patients to increase. Case E in figure 4 indicates a decrease in impedance values in a patient with myxedema on thyroid treatment whereas Case F in figure 4 showed no change in impedance value despite entirely analagous conditions.

Figure 5 shows little change in the impedance values of 2 characteristic cases of thyrotoxicosis (A, B) under iodine treatment and following sub-total thyroidectomy despite marked alterations in their metabolic rate. From these charts, which are representative of the total number of cases followed, it is apparent that great alterations in metabolic rate may occur in the course of treatment of the two groups without regular changes in simultaneously recorded impedance values.

The third part of the study was carried out to ascertain whether the impedance determinations in untreated patients could be used as a diagnostic technic in thyroid disease. Figure 6 illustrates the impedance values obtained on 39 cases of untreated thyrotoxicosis. The range of impedance values for this group was from 0.0400 to 0.0910. As indicated in figure 7 the range of impedance values for untreated, complete, spontaneous myxedema (11 cases) was from 0.0650 to 0.1400. Other hypothyroid cases varied from 0.0400 to 0.0900 (8 cases). One case of spontaneous myxedema following the untreated course of thyrotoxicosis had an impedance value of 0.0620. The variation in impedance values for normal individuals, for individuals ill with non-thyroid disorders, and for cases of non-toxic nodular goiter was from 0.0200 to 0.1175.

Thyrotoxicosis	0.0400-0.0900
Spontaneous, complete myxedema	0.0650-0.1400
Other hypothyroid states	0.0400-0.0900
Non-thyroid diseases	0.0200-0.1200
Normal individuals	0.0420-0.1110

For convenience in charting we have in all cases omitted the decimal point in the calculated values of internal impedance; i.e. 0.0910 equals 910 units.

The charts indicate some tendency for the thyrotoxic patients to have low impedance values whereas the myxedematous patients have an opposite trend toward higher impedance values. Neither of the groups was uniform in its distribution. This fact coupled with the wide range in values for normal individuals and non-thyroid patients vitiates the use of the impedance determination as a diagnostic technic in thyroid disorders.

DISCUSSION

It is important to re-emphasize the fact that the technic used in this study permitted the independent determination of the *internal impedance*. Previous reports on impedance have been based upon a technic in which the contributing components (surface sheath and internal impedance) have not been separated.

Recent data published by Robertson and Wilson, (6), using the Brazier technic failed to confirm many of Brazier's conclusions in regard to the diagnostic significance of impedance determinations in thyrotoxicosis and myxedema. Our own observations made with this method resulted in similar conclusions.

Experimental studies which we have made on animals as well as patients have indicated a remarkable constancy of the impedance value. Studies designed to alter impedance have further emphasized this constancy. Factors such as time of day, ingestion of food, smoking, mild exercise, and prolonged rest in human subjects have produced little or no alteration in the impedance value. Experiments upon cats in which the blood supply to the region studied was obliterated, the nerve injured, NaCl and $CaCl_2$ infused, different layers of the tissue dissected, resulted in very little alteration of the impedance values. Such constancy points toward the existence of compensatory mechanisms in tissues which preclude marked variations in impedance.

The marked variation in impedance values among normal individuals, however, would seem to indicate that there are factors operating in the human body which may alter this electrical quantity. Body weight and surface area seem unimportant in determining impedance values. Up to the present we have been unable to identify any such factors with the possible exception of the level of thyroid activity. We suspect the possible effect of thyroid activity upon the impedance value because of the tendency for the thyrotoxic and myxedematous patients to have widely differing values. This fact may be of academic interest and of bio-physical significance, but certainly it is of little value in aiding the clinical diagnosis of thyroid disease.

SUMMARY

A satisfactory technic has been evolved by Horton and VanRavenswaay for the determination of the internal impedance of the human body as separated from the impedance of the surface sheath.

The internal impedance for any normal individual remains remarkably constant from day to day. Internal impedance varies but little after the ingestion of food, after muscular exercise, and with other factors which alter the metabolic rate.

Using the Horton-VanRavenswaay technic, untreated thyrotoxic patients show a wide range of impedance values (0.0400 to 0.0999). A large percentage of the untreated thyrotoxic patients have low impedance values.

The impedance values in untreated spontaneous myxedema cases range from 0.0650 to 0.1400. The majority of these cases have high values.

Marked alterations in metabolic rates in thyrotoxic and myxedematous patients under treatment are not regularly associated with changes in impedance.

A comparative study of basal metabolic rate and impedance determinations indicate that the latter is of little clinical significance in the estimation of the level of thyroid activity.

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