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THE VALUE OF RECENT REFINEMENTS IN APPARATUS: PRELIMINARY REPORT

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Ever since the experimental therapeutic use of the roentgen ray was stimulated by the recognition of its occasional accidental, associated action on cutaneous structures, the medical press has constantly contained a generous literature describing the therapeutic value of the agent and the proper methods of its application. For many years there were almost as many technics of application and measurement as there were operators, with the result that the popularity of the agent was as fluctuating as were the results obtained from its usage. As is the history with many discoveries, out of the confusion that first clouds true values there emerged a general principle which, if conscientiously adhered to and tempered by judgment and experience, brought about a fair percentage of favorable results. Thus, while indefinite in many respects, the so-called fractional method of treatment for many years was the recognized technic. Briefly, this method was one by which maximum effects were gradually obtained by the administration of small doses, repeated at short intervals, and continued over a long period of time. Somewhat later, results favorably comparable to the foregoing were obtained by adherence to a principle differing radically from the preceding. By the later method, the maximum effect of the rays was obtained at one sitting and the dose not repeated for an extended period. To this technic the term "massive dosage" has been given. With this growing tendency toward larger dosage, an increasing demand for greater accuracy of estimation arose. It would now seem one has at his disposal a method meeting these requirements—that of MacKee's mathematical estimation of roentgen-ray dosage. In spite of this epoch-marking work, one still hears voiced by others, or meets in his own experience, an occasional variation in expected clinical results, for which mathematical factors cannot be called to account.

Heretofore, such variable factors as tissue tolerance, individual susceptibility, age, complexion, and especially idiosyncrasy, have been the explanations offered for the foregoing variations. However, treatment governed by the application of available and established facts has apparently fairly satisfactorily overcome most of these influences.

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Regarding the exact status and definite influence of idiosyncrasy, the literature of those most experienced in the work reveals a significant variance of opinion. With the development of the new short-ray therapy, special apparatus, theoretically more accurate, has become available. Incidental to the use of this apparatus, possible mechanical inaccuracies of previous apparatus have been revealed, over which mathematical formulas have no control. It is on the possible influence of such a factor that the present study has been undertaken.

During the practical and scientific investigations following Roentgen's original communication, an increasing interest centered about the development of new exciting apparatus and instruments of precision or of measurement. As a result of this work, it was the custom for a number of years to estimate the quantity of radiation affecting a given tissue mass by establishing various so-called constants. These included milliamperage, spark gap, number of interruptions per second, distance from anode to skin, etc. Before the present degree of perfection was attained in tubes and transformers, this was a difficult and even hazardous procedure; so much so in fact that a feeling of dissatisfaction existed generally. With Kienbock's work establishing the law that "the degree of reaction depends upon the quantity of X-ray absorbed by the skin," and later a law stating that "the intensity of the rays varies inversely as the square of the distance," the so-called direct method of measurement of quantity was developed. This was accompanied by Holzknecht's announcement of the chromoradiometer in 1902. The original instrument was not a success, and was soon withdrawn from the market. The principle, however, modified by various workers and applied to different instruments still exists as the direct method of dosage measurement, applied by either the photographic or chemical method.

Parallel with, and even preceding, this progress, there developed a so-called indirect method of measurement. As before mentioned, this estimation depended for its accuracy on the factors of voltage, milliamperage, time and distance. In the beginning it proved so unreliable that it soon gave way to the direct technic. With the advent of the interrupterless transformer and the Coolidge tube, however, the practicability and flexibility of the method rapidly became so evident that it soon reached, and has since maintained, an application perhaps more universal than that of the method by which it was formerly replaced.

With a proper appreciation and a practical method of simple arithmetical computation, it appeared that little was left to be desired, providing the foregoing factors of milliamperage, voltage, time and distance were always and invariably to be relied on as constants during any given operation. Naturally, the possibility of variation in the factors of time and distance is obviated. In the past, fluctuations in

clinical results seemed more easily explained on the basis of individual variation rather than by any possible change in the value of factors of milliamperage and voltage. Regarding the former, one has only to watch the dial of the meter in many cases to see how rarely it is at rest; while up to the present the estimation of voltage has seemed satisfac-

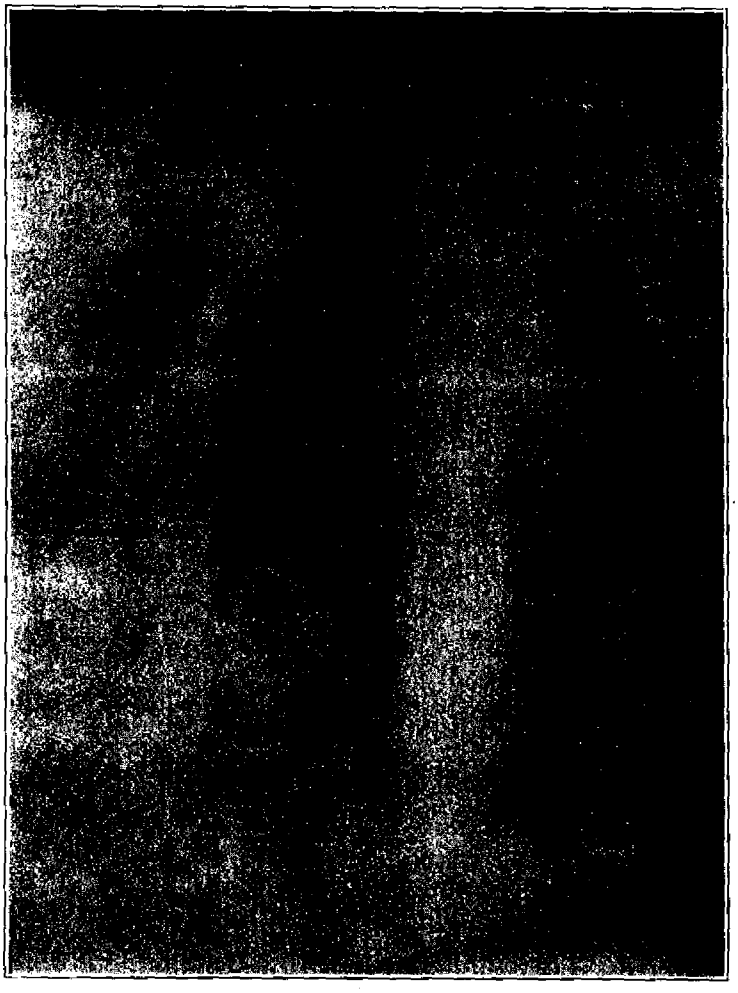

Fig. 1.—Left, erythema dose, spark gap estimation; right, erythema dose, sphere gap estimation. These reactions developed simultaneously and remained practically equivalent throughout the period of treatment.

torily accomplished by the point spark gap. An investigation of the recognized standard requirements for this instrument is of interest. It is to be noted that it should be equipped with needle points; that these should be changed after each spark over; and that they should be approximated in a very definite manner. Finally, it is also to be

noted that even under such conditions the readings may be influenced by temperature, humidity, altitude and surrounding objects. Furthermore, given the standard conditions, it seems to be the consensus of technical opinion that the reliability of the instrument is subject to serious question above a potential of 50,000 volts. It is thus to be seen that the instrument on the ordinary machine falls far short of these requirements; that there may well be wide variations in machines of the same and different manufacutres. In proof of such theoretical considerations, Ullmann,[1] using the ordinary point gap, was able to show kilovolt fluctuations as high as 30 per cent., occurring with equivalent factors, but applied to different machines. If such voltage variations are possible with the point gap, it seems not unusual that unexpected clinical results may well occur with an explanation of voltage fluctuation as applicable as those hitherto offered.

As a result of this lack of uniformity in testing results from various laboratories, and a growing realization of the possible causes of error in the point gap method of estimation, especially with high voltages, electrical engineers have rather recently developed an instrument known as the sphere gap. This likewise is required to meet certain standards of construction, but apparently these standards are fairly easily satisfied, even under conditions of office or institutional practice. In addition, the corona discharge, and the influence of humidity, altitude, etc., apparently objections to the point gap, are to a large extent avoided. In other words, theoretically at least, the sphere gap would seem to be an instrument available for practical purposes and capable of giving us accurate information regarding one of the dosage factors which are so essential to constant clinical results. In addition, the fluctuations in the milliamperage may now be satisfactorily controlled by the so-called stabilizer. With these two improvements at our disposal, it would appear that previous possible variations in dosage factors were, to a large extent, eliminated, and that by their usage more constant clinical results might be predicted and obtained.

For this preliminary work, twenty-six persons have been used, the exposures being made purely experimentally, and not for the treatment of any existent disease condition. These persons were chosen at random from dispensary material, without reference to age, sex, complexion, etc. In other words, an attempt was made to imitate an ordinary office

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1. Ullmann, H. J.: Am. J. Roentgenol. **8**:195; American Institute of Electrical Engineers Standard, 1922, pp. 20 to 23. Farnsworth, F. W., and Fortescue, C. L.: The Sphere Gap, Tr. A. I. E. E. **32**:733 to 737, Pt. 1. Chubb, W. L., and Fortescue, C. L.; Tr. A. I. E. E., **32**, Pt. 1. Peek, F. W.; Skinner, C. E.; Sandsford, Jr., J. A.; Steinmetz, C. P., and Others: Discussions, Tr. A. I. E. E. **32**, Pt. 1. Peek, F. W.: Dielectric Phenomena in High Voltage Engineering, pp. 87 to 116.

Fig. 2A

Fig. 2B

Fig. 2.—Left, erythema dose, spark gap estimation; right, erythema dose, sphere gap estimation. *A*, eight days following exposure. Note absence of reaction on left. *B*, slight reaction on left after fourteen days. Present at eight days on right.

or dispensary practice, and at the same time to provide opportunity for influence of individual variation. For the most part, each person received multiple exposures, with two sets of factors: $\frac{6sp\ 2ma\ 3t}{8d}$ and $\frac{6sp\ 4ma\ 1\frac{1}{2}t.}{8d}$. In every instance the stabilizer was used. All exposures were made in parallel, and so far as possible all conditions were identical, except that of voltage estimation. In one series the point gap was used, in the other the equivalent kilovoltage as measured by the sphere gap. The patients were observed usually at from three to four day intervals. Because of the outstanding features, and because the work is still under progress, the results only at certain intervals are included.

The intervals arbitrarily chosen for observation were the seven and eight day period and the fourteen day period; that is, the presence or absence of definite color change at these intervals following exposure formed the basis of the readings enumerated below. This, in the first place, excluded the complications of the early so-called "electric reaction" sometimes observed, and at the same time excluded those reactions delayed longer than the usual time between exposure and physical response. No case was included in one group or the other unless a definite color change was present. If the presence of such a change was still questionable at the tenth day, but present at the fourteenth, the result was included in the latter group.

Observed with these points in mind, it was found that certain cases reacted definitely at the end of one or both intervals following exposure. These were clear-cut reactions and were classed as positives. The second group of cases, as would be expected, reacted doubtfully at the end of the first period, but these cases were easily classed as definite reactions at the fourteenth day. The third group were indefinite throughout, and so far as clinical results might be concerned, were considered negative. Finally, some developed only the faintest possible change at the fourteenth day. Adhering to these criteria, it was found that out of the total, or twenty-six cases, receiving an erythema dose as estimated by the point gap, only twenty-one, or approximately 81 per cent., presented the expected clinical reaction at the end of the usual seven to ten day period. Following this group through, one case that had only the faintest suggestion previously, at the fourteenth day presented sufficient color change, making a total of 22 or 85 per cent. In addition, however, an interesting occurrence became manifest in that one of the patients who had a strongly positive reaction at the seventh day, at the end of the fourteenth day presented a distinct dermatitis. The fact that this occurred, in spite of personal supervision and every precaution, is at least suggestive of certain possibilities. The remaining four cases, incidentally of various ages, showed no visible color

change throughout the period of observation. In other words, the expected clinical results were obtained in only 85 per cent. of the cases treated, in spite of most conscientious attention to the factors on which the dosage was based.

Passing to the reactions resulting from the use of the sphere gap, it was found that observation during the seven to ten day period revealed twenty-four, or 93 per cent., who presented definite reactions. The remaining two were suggestive, but could not be included, although four days later one of these assumed the appearance of a definite erythema. In other words, the percentage of positive results resulting

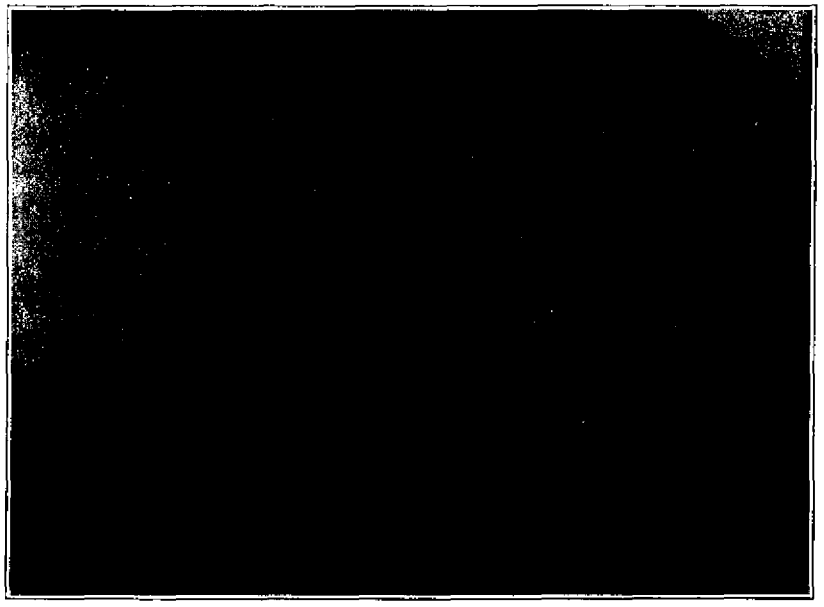

Fig. 3.—Left, erythema dose, sphere gap estimation; right, erythema dose, spark gap estimation. Note absence of reaction on right fourteen days after exposure, while definite reaction is present on the left

from the use of the sphere gap at the end of the fourteenth day was 96. What would seem to be even more important, however, was that the type of reaction was decidedly more constant, better defined, and subject to much less question than the varying degrees observed in the former cases. The accompanying Figures 1, 2 and 3 show some of the variations observed. In brief, then, it was found, under the conditions of the foregoing experiment, that certain variations are possible, even though the factors on which we are accustomed to depend were as constant as personal care could make them. Further, while neither method is without fluctuation, the use of the sphere gap apparently makes possible a decidedly higher percentage of positive experimental

clinical results and a gratifying steadiness. While a similar series of clinical experiments on various apparatus might well not give parallel results, the laboratory findings of Ullmann and the clinical findings herein given, indicative of the possible advantage of the sphere gap in its relation to clinical effects, make for its more universal application. By such universal application, the present objections to certain methods might well be obviated, and a country wide standardization of technic made possible. The lack of such a standardization unfortunately has seriously handicapped the progress of an agent which has, and still does, receive much undeserved criticism, but to which is due an unquestioned place in modern therapeutics.

SUMMARY AND COMMENT

It may be seen that the alternating periods of optimism and pessimism through which the roentgen ray has passed have been largely due to the relative accuracy of particular methods of control in vogue at a given time. In the beginning, there was the rational theory that the extent of the biologic effects of this unusual form of energy should be predicted by a proper estimation of certain factors. Because of mechanical imperfections, the method was for a time replaced by phbtographic and chemical procedures. It was soon found, however, that even this method required a personal expertness in the judgment of rather fleeting color changes, which made the method practicable only for those with a properly directed and unusual experience. With greater perfection in apparatus, the older method again assumed the place of choice. Depending, as it does, on the factors of milliamperage, voltage, distance and time, and based on the knowledge that these may be mathematically computed, it leaves little to be desired and finds easy and practical application in the ordinary busy routine. An explanation of many of the present variations and disappointing results, it would seem, must be sought rather in mechanical details of construction than in present methods of dosage estimation. In the foregoing, it is hoped one important source of such errors is established, and a practical method of its elimination suggested.

CONCLUSIONS

1. Under the conditions of the foregoing experiment, variations in voltage estimation may, and do, occur, of sufficient magnitude to cause corresponding variations in clinical reactions.

2. The possibility of variations such as the foregoing is apparently lessened by kilovolt estimation, using the sphere gap.

3. The foregoing method of kilovolt estimation applied to formulas herein discussed is suggested as a step toward a more satisfactory standardization in our present technic.