A PRACTICAL METHOD OF ROENTGEN-RAY DOSAGE WITHOUT THE AID OF A RADIOMETER

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For the past two and a half years this method has been in vogue in various hospitals, clinics, and offices throughout the country. The primary reasons for its adoption were the lack of supply of reliable radiometers and the ease and practicability of its application as compared with the intricate and exacting detail necessary for the proper use of various radiometers.

The method can be used with any standard interrupterless machine and Coolidge tube. It is not necessary to standardize each outfit, for one who is familiar with the apparatus ought to master the technic of this method in a very short time, so that he can set and maintain the four factors constantly throughout the time of exposure.

The standard of all roentgen-ray dosage is known as the erythema dose; in other words, the quantity of roentgen-ray necessary to produce an erythema of the skin in from ten to fourteen days after exposure.

The amount of radiation reaching the skin of the part exposed is determined by four fundamental factors: the voltage, expressed as K V or kilovolts; the milliamperage or current, expressed as M A or milliamperes; the time, expressed as T in minutes, and the distance, expressed as D in inches from the target of the tube to the skin. Voltage, or K V, is very often expressed in the number of inches between the spark gap terminals which relatively correspond to the number of kilovolts. The actual determination of the spark gap is obviously just the amount of pressure or voltage that gives a spark across the terminals without the tendency to arc and which, at the same time, maintains the milliamperage desired in the tube.

The analysis of these four factors necessitated maintaining three of them constant throughout the exposure, and varying the one under investigation. Thus maintaining 3 Sp G 3 M A for five minutes at a distance of 8 inches produced an erythema in the usual time, ten to fourteen days, over an area of the chest which happened to be covered with hair. The third week after exposure the hair came out and showed no signs of returning at the end of six months. Another area of the chest was exposed and given 3 Sp G 3 M A at a distance of 8 inches for four minutes instead of five minutes. In this area the hair fell out during the third week, and had all returned by the fourth month after exposure.

The latter formula, namely, 3 Sp G 3 M A, four minutes with 8 inch distance, we will call one skin unit. This, then, is the dose required

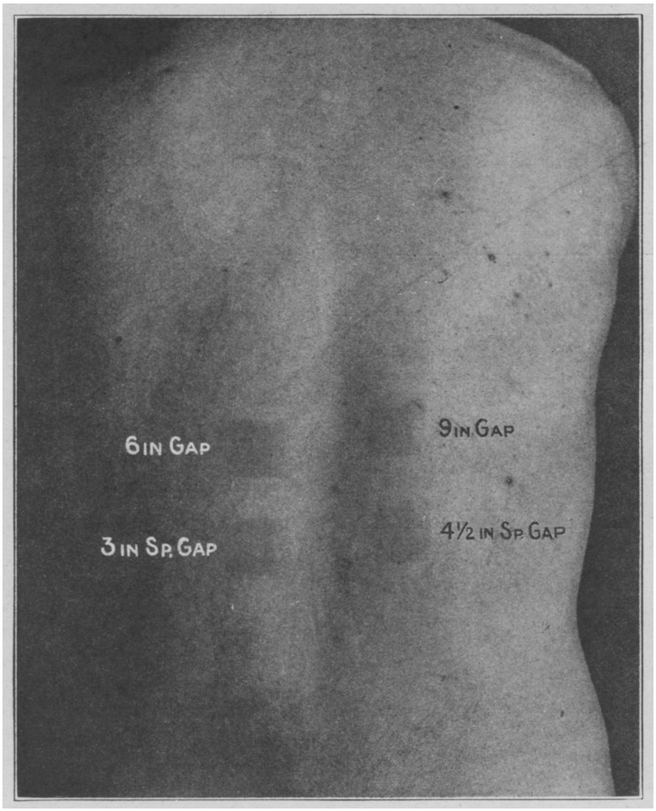

Fig. 1.—Four areas of patient's back treated with the roentgen ray.

for the treatment of ringworm of the scalp, thus insuring the return of the hair, whereas if five-minute exposures were used the hair would not return, and a certain amount of permanent baldness would ensue.

If a pastil were placed 8 inches from the target of the tube and the factors 3 Sp G 3 M A and four minutes' time given, the color produced on the pastil would correspond to one on the scale of a Holzknecht radiometer which, expressed in Holzknecht units, would be 4 H, because Holzknecht readings were originally all made at half distance.

By using the pastils and a Holzknecht radiometer it has been found that if you double the time, the voltage, or milliamperage separately, maintaining the other three factors constantly, that you will double the dose when the roentgen-ray is used without a filter. Also by placing two pastils, one at full distance, and the other at over half the distance from the target of the tube to the skin, that the pastil reading at the half distance will be four times that of the one placed on the skin or full distance, therefore inversely to the square of the distance, the same as the law of light.

3 Sp G	3 M A	8 D	2 minutes = ½	skin unit
6 Sp G	3 M A	8 D	2 minutes = 1	skin unit
3 Sp G	6 M A	8 D	2 minutes = 1	skin unit
3 Sp G	3 M A	16 D	4 minutes = ¼	skin unit
3 Sp G	3 M A	8 D	4 minutes = 1	skin unit

The dose, then, of 1 skin unit, which we have adopted as our standard for unfiltered roentgen-ray therapy, would be expressed as follows:

$$\frac{3\text{ Sp G}\times 3\text{ M A}\times 4\text{ minutes}}{8\text{ inch}\times 8\text{ inch}}\quad\text{or}\quad\frac{3\times 3\times 4}{8\times 8}\quad\text{or}\quad\frac{3\times 3\times \cancel{4}}{8\times \cancel{8}_{2}}=\frac{9}{16}$$

The standard formula for an erythema dose would be:

$$\frac{3\text{ Sp G}\times 3\text{ M A}\times 5\text{ minutes}}{8\text{ inch}\times 8\text{ inch}}\quad\text{or}\quad\frac{3\times 3\times 5}{8\times 8}\quad\text{or}\quad\frac{45}{64}$$

In order to prove the actual working of the above formulas, let us take the factors as expressed in the above list.

1. If $\frac{3\text{ Sp G }3\text{ M A }2\text{ minutes}}{8\text{ inch D}\times 8\text{ inch D}}$ is used, what is the dose?

$$\frac{3\times 3\times \cancel{2}}{8\times \cancel{8}_{4}}=\frac{9}{32}$$

$$\frac{3\times 3\times 4}{8\times 8}=\frac{36\ /\ 4}{64\ /\ 4}=\frac{9}{16}\quad\text{the standard or one skin unit}$$

$$\frac{9}{32}\div\frac{9}{16}\quad\text{or}\quad\frac{\cancel{9}}{\cancel{32}_{2}}\times\frac{\cancel{16}}{\cancel{9}}=\tfrac{1}{2}\text{ skin unit}$$

2. With 6 Sp G instead of 3 Sp G, other factors remaining constant, the process would be:

$$\frac{\cancel{6}^{3}\times 3\times \cancel{2}}{8\times \cancel{8}_{\cancel{4}_{2}}}=\frac{9}{16}$$

$$\frac{9}{16}\div\frac{9}{16}=\frac{\cancel{9}}{\cancel{16}}\times\frac{\cancel{16}}{\cancel{9}}=1\text{ skin unit}$$

3. With 6 M A instead of 3 M A, other factors remaining constant, thus:

$$\frac{3 \times \overset{3}{\cancel{6}} \times \cancel{2}}{8 \times \underset{\underset{2}{\cancel{4}}}{\cancel{8}}} = \frac{9}{16}$$

$$\frac{9}{16} \div \frac{9}{16} = \frac{\cancel{9}}{\cancel{16}} \times \frac{\cancel{16}}{\cancel{9}} = \text{ 1 skin unit}$$

4 With 4 minutes' time instead of 2 minutes' time, the result would be:

$$\frac{3 \times 3 \times \cancel{4}}{8 \times \underset{2}{\cancel{8}}} = \frac{9}{16}$$

$$\frac{9}{16} \div \frac{9}{16} = \frac{\cancel{9}}{\cancel{16}} \times \frac{\cancel{16}}{\cancel{9}} = \text{ 1 skin unit}$$

5. With 16 inches distance instead of 8 inches and 4 minutes' time with 3 M A and 3 Sp G, the result is.

$$\frac{3 \times 3 \times \cancel{4}}{16 \times \underset{4}{\cancel{16}}} = \frac{9}{64}$$

$$\frac{9}{64} \div \frac{9}{16} = \frac{\cancel{9}}{\underset{4}{\cancel{64}}} \times \frac{\cancel{16}}{\cancel{9}} = \text{ ¼ skin unit}$$

Now let us take the factors as given under 1 but assume that you want to use 3 Sp G 3 M A and 8 inches distance, and desire to give ½ of a skin unit and do not know how much time to use.

$$\frac{3 \times 3 \times T}{8 \times 8} = \frac{9}{64}$$

The standard for 1 skin unit is $\frac{9}{16}$; for ½ of a skin unit it would be $\frac{9}{32}$

If, then, $\frac{9}{64}$ represents all of the factors except time, and $\frac{9}{32}$ equals ½ skin unit, $\frac{9}{32} \div \frac{9}{64} = \frac{\cancel{9}}{\cancel{32}} \times \frac{\overset{2}{\cancel{64}}}{\cancel{9}} =$ 2 minutes' time.

With the factors expressed in 2 what would the Sp G be using 3 M A 2 minutes' time at 8 inches distance to produce 1 skin unit?

$$\frac{\text{Sp G} \times 3 \times \cancel{2}}{8 \times \underset{4}{\cancel{8}}} = \frac{3}{32} \quad \frac{9}{16} = \text{ 1 skin unit, therefore,}$$

$$\frac{9}{16} \div \frac{3}{32} = \frac{\overset{3}{\cancel{9}}}{\cancel{16}} \times \frac{\overset{2}{\cancel{32}}}{\cancel{3}} = \text{ 6 Sp G}$$

With the factors expressed in 3, what would the M A be using 3 Sp G for 2 minutes' time and 8 inches distance to produce 1 skin unit?

$$\frac{3 \times \text{MA} \times \not{2}}{8 \times \underset{4}{\not{8}}} = \frac{3}{32} \quad \frac{9}{16} = 1 \text{ skin unit, therefore.}$$

$$\frac{9}{16} \div \frac{3}{32} = \frac{\overset{3}{\not{9}}}{\not{16}} \times \frac{\overset{2}{\not{32}}}{\not{3}} = 6 \text{ M A}$$

With the factors expressed in 4, at what distance would it be necessary to place the patient from the target of the tube to produce 1 skin unit using

3 Sp G 3 M A 4 minutes' time?

$$\frac{3 \times 3 \times 4}{D \times D} = \frac{36}{D \times D} \quad \frac{9}{16} = 1 \text{ skin unit, therefore.}$$

$$\frac{36}{D^2} \div \frac{9}{16} = \frac{\overset{4}{\not{36}}}{D^2} \times \frac{16}{\not{9}} = 2 \sqrt{\frac{64}{D^2}} = \frac{8}{D} \quad D = 8 \text{ inches distance}$$

The distance required to produce one skin unit is found by dividing the product of the three known factors by the standard formula for one skin unit $\frac{9}{16}$ instead of dividing the standard formula $\frac{9}{16}$ by the fraction with unknown distance as exemplified in obtaining the other factors.

The determination of distance and the number of skin units are both obtained by the same method.

From the foregoing calculations it is evident that the dose of unfiltered roentgen ray can be accurately and easily determined for both fractional and massive dosage. When all four factors are known the product of their formula divided by the product of the standard formula for one skin unit, namely, $\frac{9}{16}$, will indicate the dosage in skin units. When, however, any one of the four factors is unknown and the other three decided on, the product of the standard formula for one skin unit, namely, $\frac{9}{16}$, divided by the product of the three known factors, indicates the unknown factor for one skin unit. When distance is the unknown factor, note the exception to this rule.

Owing to a proportionately large filtration of the ray generated below a 3 in gap or 3 Sp G by the glass in the Coolidge tube the above rule of unfiltered dosage does not apply.

This method of estimating roentgen-ray dosage is also applicable in determining the number of plates that can be taken of a given case without the production of a permanent alopecia or roentgen-ray burn.

For instance, how many plates or exposures can be made of a frontal sinus or anteroposterior diameter of the head without producing an epilation or erythema of the scalp? The formula or factors for such an exposure might be as follows:

Sp G	M A	D	T
$5\frac{1}{2}$	25	18 in.	10 sec.

This means that the plate is 18 inches from the target of the tube and in this instance the scalp is 10 inches from the anode. In order to find the dosage which the scalp will receive the formula must be changed from 18 inches to 10 inches.

Sp G	M A	D	T
$5\frac{1}{2}$	25	10 in.	10 sec. = $\frac{1}{6}$ of a minute

$$\frac{5\frac{1}{2} \times 25 \times \frac{1}{6}}{10 \times 10} = \frac{275/12}{100} = \frac{11}{48}$$

Take the standard formula for an erythema dose:

$$\frac{3 \times 3 \times 5}{8 \times 8} = \frac{45}{64}$$

Divide the erythema dose by the dose for each exposure:

$$\frac{45}{64} \div \frac{11}{48} = \frac{45}{\not{64}_{\not{16}_{4}}} \times \frac{\not{48}^{\not{12}^{3}}}{11} = \frac{135}{44} = 3\frac{3}{44} \text{ plates}$$

Thus three plates with these factors would not cause an erythema, but may produce a temporary alopecia.

By dividing the product of the factors of the standard formula for an erythema dose, namely, $\frac{45}{64}$, or one skin unit $\frac{9}{16}$, by an exposure formula, provided the skin distance is taken instead of plate distance, the roentgenologist can determine the number of plates he can make without producing an erythema or temporary epilation.

Four areas of a patient's back were treated with the following factors for each area:

$$(1)\quad \frac{3 \times 3 \times 5}{8 \times 8} = 1\frac{1}{4} \text{ skin unit}$$

$$(2)\quad \frac{3 \times 6 \times 2\frac{1}{2}}{8 \times 8} = 1\frac{1}{4} \text{ skin unit}$$

$$(3)\quad \frac{3 \times 4\frac{1}{2} \times 3\frac{1}{3}}{8 \times 8} = 1\frac{1}{4} \text{ skin unit}$$

$$(4)\quad \frac{3 \times 9 \times 1\frac{2}{3}}{8 \times 8} = 1\frac{1}{4} \text{ skin unit}$$

The photograph of the patient taken ten days after treatment demonstrates that all the areas coincide, yet in two of them, namely, (2) and (4), the spark gap or Sp G is doubled and one-half the time taken for exposure that was given in (1) and (3) respectively. It therefore follows that if the Sp G is doubled and the time reduced one-half, the same degree of erythema will be produced, other factors remaining constant.

From the standpoint of quality of the roentgen ray in the above experiment the formula with 6 Sp G and 9 Sp G should give a very large proportion of penetrating rays as compared with the 3 Sp G and 4½ Sp G. Hence one would expect that these penetrating rays derived from the higher Sp G would pass through the skin, and it would take much longer to produce the same erythema as was produced by the 3 Sp G and 4½ Sp G formulas which give a large proportion of rays of low penetration, and naturally would be quickly absorbed in the outer layers of the skin and quickly produce a burn.

By actual experiment the reverse proves true. For it took just one-half the time to produce the same biologic effect in the doubled Sp G doses (6 Sp G and 9 Sp G) as it did in the 3 Sp G and 4½ Sp G formula.

It is, then, apparent that quality of the ray and absorption of the rays of long wave have little to do with the biologic effects in the skin. On the other hand, it seems that the factor which determines this effect is solely the quantity of roentgen ray reaching the skin, for it is obvious that a high Sp G produces more rays that reach the skin than the same dose with a low Sp G or spark gap.

We published the original communication establishing the principles and practical application of this method for both filtered and unfiltered dosage in the June issue of the *American Journal of Roentgenology,* 1917. Since then Drs. MacKee[1] and Wise[2] have, in their respective papers, pointed out the efficacy of this method in the calculation of roentgen-ray dosage in dermatology.

1. MacKee, George M.: Arithmetical Computation of Roentgen Dosage, J. Cutan. Dis. **37**:783 (Dec.) 1919.
2. Wise, Fred: Roentgen-Ray Treatment of Widespread and Generalized Diseases of the Skin, J. A. M. A. **73**:1491 (Nov. 15) 1919.