Solidography.¹⁾
A Method to Take a Radiogram of the Body in
Three Dimensions.*

(Study on the Rotatography.)

4th Report.

By

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Since the discovery of X-ray by Prof. Roentgen, the Roentgen-stereoscopy was invented in order to get the radiographical knowledge of the body in three dimensions and the Radioplastik of Dr. Palmier²⁾ has been undertaken in 1929 for the same purpose. From another stand of view, we tried to get an image of the solid body by the roentgenography of a new device. We should like to name this new radiographical method "Solidography".

Construction and Technique of the Solidograph.³⁾

In order to take a solidogram, we designed and constructed two rotation-tables A and B as shown in Fig. 1. We arranged rotation-axes of two rotation-tables and the focus of the X-ray tube so as to be in one plane. Here these rotation-axes are vertical to the level, but the central X-ray inclines 15 degrees to the table of the rotation-table B. The table of the rotation-table A is 50 cm. in diameter and on the center of the table a chair is placed. We regulate the height of that seat with a jack attached to the rotation-table. The table of the rotation-table B is 30 cm. in diameter. And on it are horizontally placed sheets of films, which are piled into a cubic block. The rotation-table A and rotation-table B rotate with the same angular velocity by the belt pulley of the electric motor smoothly and with uniform velocity. The distance between the tube-focus and the rotation-axes of the rotation-table A is calculated 150 cm. and that of the rotation-axes of two rotation-tables 50 cm. In order to

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Fig. 1. Solidograph in action.

T: tubefocus
 D: Bucky-Potters diaphragm
 S: slit
 T_A : rotation table A
 T_B : rotation table B

protect the patient from the X-ray injury and to remove the scattering of X-ray we placed two lead slits and a Bucky-Potters diaphragm in front of the patient. The motorswitch, X-ray switch and diaphragm starter are connected electrically. The solidograph is operated as follows.

Let a patient sit on the seat of the chair on the rotation-table A and fix him to the chair with a bandage.

Darken the room and examine fluoroscopically whether the organ or focus of the body hits to the position of the filmblock or not. If it does not, elevate or lower the chair by the jack and adjust the position of the organ or the focus.

Ask the patient not to move, then switch on the starter of the Bucky-Potters diaphragm and the electric motor at the same time. The X-ray switch works with them automatically. When the rotation-table rotates from 0 degree to 360 degrees, then the motor is switched off and at the same time the X-ray switch comes off, too, automatically. Thus the solidography is finished.

Theoretical Consideration.

To prove geometrically that on the rotation-table B exists the three dimensional image similar to the actual body on the rotation-table A;—

Let the distance between the tubefocus F and axis of the rotation-table A be “a” and the distance between the axis of two rotation-tables

Fig. 2. Diagram of the geometrical consideration on the solidography.

be "b" as shown in Fig. 2. Join the tubefocus F and the rotation-center C_2 of the film on the rotation-table B. Let FC_2 intersect the axis of the rotation-table A at point C_1 . Through this point C_1 draw a plane g^2 parallel to the film. Join tubefocus F and any point P_1 on this plane g^2 and let the extension of this line meet to the film at P_2 . In the triangle FC_2P_2

$$\frac{C_1P_1}{C_2P_2} = \frac{a}{a+b} \quad (\because C_1P_1 \parallel C_2P_2)$$

$$\text{Hence } C_2P_2 = \frac{a+b}{a} \cdot C_1P_1 = \text{const.}$$

In this operation the angular velocity of two rotation-tables is equivalent. Therefore the point P_2 is always placed on the extension of the line FP_1 during the operation. Now the point Q, which is not on the plane g_2 , may be placed on the line FP_1P_2 at one moment of the rotation, but it strays away from this line next moment of the rotation. Therefore the point Q superimposes as one point not for the whole course of the rotation but only for a moment and is naturally blurred. Now we learned that only the horizontal layer of the body, corresponding with the plane g_1 , is imaged on the film, which is laid horizontal on the rotation-table B.

Next, let a plane g_2 be parallel to the plane g_1 and take a point P_1' in the plane g_2 so that P_1P_1' is parallel to the axis of the rotation-table A. Join the tube-focus F and the point C' , which is the intersection of the plane g_2 and the axis of the rotation-table A. Let a plane g_3 , which contains the point C_2' (the intersection of FC_1' with the rotation axis of the rotation-table B), be parallel to the plane g_2 . Let extension of the line FP_1' intersect to the plane g_3 at the point P_2' .

$$\text{Then} \quad \frac{C_1'P_1'}{C_2'P_2'} = \frac{a}{a+b} \quad (\because C_1P_1 // C_2P_2)$$

$$\text{Hence} \quad C_2'P_2' = \frac{a+b}{a} C_1'P_1'$$

$$\text{Simillary} \quad C_2P_2 = \frac{a+b}{a} C_1P_1$$

$$\text{Here} \quad C_1'P_1' = C_1P_1$$

$$\text{Hence} \quad C_2'P_2' = C_2P_2$$

Because points P_1 , P_1' , P_2 and P_2' are placed in a plane, $P_2'P_2$ is parallel to $C_2'C_2$.

Moreover $P_2'P_2 // P_1'P_1$ ($\because P_1'P_1 // C_1C_1'$, $P_2P_2' // C_2C_2'$)

$$\text{Therefore} \quad P_2'P_2 = \frac{a+b}{a} P_1'P_1, \quad C_2'P_2' = \frac{a+b}{a} C_1'P_1'$$

If we take many planes $g_4, g_5, \dots, g_n$ on the rotation-table A in such a way, we find out that planes $g_4', g_5', \dots, g_n'$ are arranged on the rotation-table B regularly after this formula. Since a body is considered as a group of thin layers, piled horizontally with infinite small distance, this formula is naturally applicable in the case of radiographing of the body. From this we see that on the rotation-table B there exists an X-ray image similar to the actual body on the rotation-table A. The X-ray image is, however, enlarged $\frac{a+b}{a}$ times as the original body.

EXPERIMENTAL.

Model Experiment.

To prove experimentally that the result gained from geometrical consideration is correct.:

We prepared beforehand a model and a film block. The model was a barium block in the shape of two eggs combined (Fig. 3, Top. left) The filmblock was constructed by pilling one hundred and twenty sheets of film, 3×4 cm. in size and packed by light-proof paper. We placed the model on the rotation-table A and the filmblock on the rotation-table B so that each film lay horizontal.

We put on the switch of the starter of the rotation-table and tubecurrent. When the rotation-tables rotated from 0 degree to 360 degrees we put out the X-ray switch. We unbound this film-block and developed each film. And on each film there was imaged corresponding transection of the body as shown in Fig. 3 Bottom. When we piled up these sheets of films in the original order, we were informed that there existed the three dimensional image of the body similar to the actual body. In order to demonstrate this actually, we cut out the figure of the X-ray

Fig. 3. Model and solidogram.

Top left: model. Barium block in the shape of two eggs combined.

Top right: solidogram

Bottom: eighty eight sheets of film imaged transsection of the body respectively.

image from every film and piled up in the original order, then we got a film block quite similar to the actual body. (Fig. 3, Top. right.) This plastic is, however, enlarged at the ratio of $\frac{a+b}{a}$.

Human Body Experiment.

To prove experimentally that this method will bear the application for the human body:—

An adult person, lifting his right foot over the left knee, was stood on the rotation-table A. Accordingly he stood there on his left foot. We piled twelve sheets of film. The film was, however, separated from each other 3 mm. in distance. This pile was packed as a block and laid on the rotation-table B. We adjusted the lower part of the left leg to the film block as shown in Fig. 4, left. We rotated the rotation-tables and exposed. The exposure technique went as follows. Tube-focus and rotation-table A-distance 129 cm., Rotation-table A and rotation-table B distance 29 cm., electric voltage: 80 KV., tube current: 30 mA., exposure

Fig. 4. Solidogram of the left lower leg.

Top: Normal roentgenogram of the lower part of the left leg. Two lines showing the solidographed position.

Bottom: Solidogram. Skin, tibia and fibula are shown.

time: 10 sec.

We got twelve crossgrams at one exposure. On these films several transections of the leg were imaged. Previously we prepared twelve sheets of gelatin plate, transparent and 3 mm. thick. Out of these gelatin plates we cut out the figures corresponding to those of the X-ray images of skin, tibia and fibula on the twelve films.

We piled up these gelatin figure plates as they were and then got a plastic of the lower part of the left leg. This plastic is shown in Fig. 4 right. Thus we got the information of the organ in the body roentgenographically with three dimensional knowledge.

SUMMARY.

We arrange a tube focus and rotation axis of two rotation-tables A and B in one plane and make the central X-ray incline to the table of the rotation-table B fifteen degrees. We place the body on the rotation-table A. And on the rotation-table B we place a film-block. Irradiating the X-ray, we rotate the two rotation tables synchron from 0 degree to 360 degrees. Then on the film-block on rotation-table B we get the three dimensional X-ray image similar to the actual body on the rotation table A.

We proved this not only theoretically, but also experimentally.

We named this method of getting the three dimensional X-ray image "the solidography."

References.

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