ROTATION RADIOGRAPHY

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CONTENTS

Preface

Rotation Radiography is the common name for our several original methods whereby the X-ray tube and film are both rotated accurately in the same direction from 0° to 190° around a certain point during exposure. There are various kinds of combinations between modes of rotation of tube and film. I have been studying Rotation Radiography since 1945 in an effort to devise as many modes of rotation and rotation combinations as possible. Twelve types of modes of rotation have so far been classified. Up to the present time fortysix papers have been published by us and by our co-workers in our Department on the investigation, theory, technique and clinical significance of Rotation Radiography. In this book all these data are enumerated and presented as compactly as possible for the purpose of clarifying the meaning of Rotation Radiography.

In October 1955 I was invited by Professor Dr. Vallebona to take part in the Third International Lecture Course on Stratigraphy held at Genoa, Italy, where I read a paper describing my investigations on Rotatory Cross Section Radiography, a type of Rotation Radiography. After closing the Course I was given the opportunity to inspect advanced radiology in Europe and the United States by support of the Ministry of Education of Japan and China Medical Board of New York, Inc. I felt keenly then the great necessity to put into circulation the results of our research work so that they could become current in Japan and throughout foreign countries. For this reason I have decided to publish something about the investigations developed originally in Japan contributing something to all those having interest in this field of radiology.

It is with pleasure that I acknowledge my indebtedness to Dr. Yoshihiko Koga, professor of Tohoku University, my teacher during my assistanship there and who found the name "Rotation Radiography" and to Dr. Masanori Nakaizumi, Professor Emeritus of Tokyo University, one of the world pioneers in Rotation Radiotherapy, for their sympathetic encouragement to me during these investigations. Further, I take this opportunity to express my appreciation to Dr. Tamotsu Oyama, and other gentlemen who so kindly suggested changes in my manuscripts written in both English and German. I thank Mrs. Miriam L. Mayland for her help in reviewing some English texts.

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Shinji Takahashi

Chapter I

Rotation Radiography in General

1. Development of Rotation Radiography

For determining diseased states within the body directly by the eye, the best method is undoubtedly an autopsy examination. In the living states, however, there is no method other than a radiologic examination for inspecting the internal state. Nevertheless, radiography, when compared with autopsy, falls far behind in its abilities of thorough exposure and determination of the diseased focus. In inspections by X-ray examination, for instance, there is no color sensation, and microscopically detailed examinations are also not possible, though recently color radiography[68), 69)] and enlargement radiography[70),71)] have received attention. These aspects will not be dwelt upon here as they are irrelevant to the theme of this book.

There are found to be other defects. They are that, though examinations have to be made actually on a living body, the results obtained do not possess the concept of the body itself. It is because in radiography the three dimensional human body is projected on a flat film of only two dimensions.

However, it cannot be said that attention has not been paid to this lack of one dimension in normal radiography.

Attempts have so far been made to make clear this dimension, i. e. the sense of depth. For example, the resort to stereography is one such attempt. But though stereography may make possible the three dimensional view of the interior of the body by stereoscopy, it is merely a visual sensation. It is therefore by no means easy to know accurately and in detail the dimension of depth by this radiography. Again it has not been possible to view stereoscopically such organs as the heart, kidneys and stomach which produce homogenous shadows.

As another method for knowing in detail the state of depth, tomography[72], which attempts to show the different layers parallel to the body axis, has been employed. But with tomography so far employed it has not been possible to know by simple means the dimension of depth, especially as expressed directly and concretely by the radiographic method of cross section of the body.

On the one hand, in order to dislodge diseased foci lying deep in superimposed shadows, attempts to expose the diseased foci by means of radiography from different directions have been made from early times over a wide clinical field. However, in such examination, as no systematic planning has been made, it has not been possible to state definitely the absence of diseased foci when such could not actually be radiographed. In other words, only when the focus was radiographed, was it possible to affirm the presence of disease.

Lastly, in order to record the movements of the viscera within the body, a method so far used has been the roentgen kymography[73]. But this has been limited to radiography of movements that run parallel to the body axis. Recording of movements in the direction of depth, namely in the cross sectional direction, is not possible.

Thus the existing methods of X-ray examination have not proved satisfactory in presenting actually the state of the interior of the body, as it has been possible for us to determine with the naked eye that presented by autopsies.

What is the underlying cause for this ?

The answer seems to be that in existing methods of X-ray examination, the general rule has been to keep the tube and the subject at rest, or within a limited range of movements, and hence, make all examinations statically.

In view of these we tried to adopt a method whereby in radiography the X-ray tube is made to move freely, generally to rotate around the living body. We termed such a method *Rotation Radiography* (*Rotationsröntgenographie or Rotatographie*), because in Rotation Radiography the X-ray tube and film are rotated around the subject to be examined through a certain point in the same direction from 0° to 190° while radiography is being carried out.

The aim of Rotation Radiography is to make clear the dimension of depth of the subject examined, and thus to discover the diseased focus or to help in the diagnostic discrimination of the disease. The reason why is that, when the X-ray tube is rotated around the subject, the subject can be examined three dimensionally and thus, renders possible the detection and separation of diseased foci in vescerae and their interrelationships, while these are not demonstrable in normal radiography taken, for instance, in the anteroposterior direction due to superimposition of X-ray images. A further reason lay in the desire to make clear cross sections of diseased lesions or the viscera itself. This becomes possible only when the X-ray tube is rotated sufficiently over all areas of the subject to be examined.

In undertaking Rotation Radiography, identical results are obtained whether the tube and film are rotated around a definite point as an axis, and the human body is kept at rest between the tube and film, or the tube and film are kept at rest and the human body is rotated in the opposite direction. The reason is that the tube and body lie relatively in a reversible relation as regards the rotation.

In Rotation Radiography, though the X-ray tube is rotated around the subject to be examined, the methods of rotation can vary. For example, the method will depend on whether the film, that is stabilized, rotates with the tube, or rotates with the tube during rotation by itself on a different axis. Hence depending on the method of radiography employed, the results of radiography will differ, and at the same time the aims of radiography must also differ.

Thus, based on the aims of radiography we have classified this *Rotation Radiography* into four, namely, *Rotation Sighting Radiography*, *Cross Section Radiography*, *Solidography* and *Rotation Kymography*. These, when compared with existing methods of radiography, will correspond respectively, to normal radiography, tomography, stereography and roentgen kymography. But Rotation Radiography will make available findings that are not possible by existing methods.

The various types of Rotation Radiography have not, of course, been devised simultaneously. They were developed in sequence.

In 1944 *Koga* tried to obtain better results by using a new radiographic technique in examination of the hilum of the lung. His device was as follows; a patient was placed on a rotation table and a series of radiograms of the chest were taken from several directions. The principle was similar to our Rotatory Photoroentgenography in Rotation Sighting Radiography. Koga termed his method for the first time ***Rotation Radiography.*** The device, however, showed no further developement and was not published due to the unfavorable circumstance of the War.

Since 1945 we have attempted to develop this Rotation Radiography.[66] It has been our conviction that Rotation Radiography should be carried out by an accurate procedure with sufficient range of rotation. In 1946 the theory of ***Rotation Sighting Radiography***[3] was published by us for the first time, and some reports on its clinical use followed immediately.[7][8][9][10][16][17][42]

From Rotation Sighting Radiography were developed two radiographic methods of ***Continuous Rotatography***[2][50] and ***Discontinuous Rotatography***[1][50] in 1946, which enabled us to know the cross section of the body.

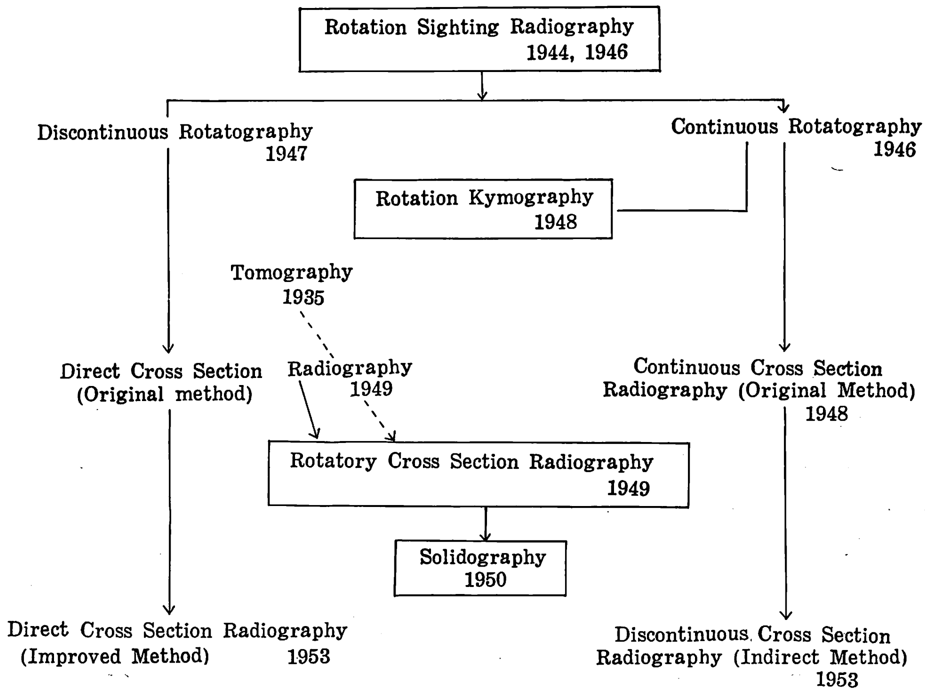
From these two methods were devised our further five radiographic methods for taking cross sections of the body, such as, ***Direct Cross Section Radiography***[15][50] (1949), ***Continuous Cross Section Radiography, Original Method***[4][50] (1948), ***Rotatory Cross Section Radiography***[13][48] (1949), ***Direct Cross Section Radiography, Improved Method***[58] (1953) and ***Discontinuous Cross Section Radiography, Indirect Method***[63] (1953) successively.

Rotatory Cross Section Radiography, however, had been studied independently form us in foreign countries, too, such as, by ***Vallebona*** (1948), ***Gebauer*** (1949) etc., though it was impossible for us to know of them because of the postwar inconveniences in communication. In our country ***Shimazaki, Akaboshi***[35] published their devices for the principle of Rotatory Cross Section Radiography 5 months after our publication.

Continuous Rotatography led to ***Rotation Kymography***[53] in 1948 and Rotatory Cross Section Radiography led to ***Solidography***[49][52] in

1949. Now in Table 1 will be shown a Diagram of the relationship in development of various kinds of our Rotation Radiography in chronological order (Tab. 1).

Table 1



It has been found possible to unify the several types of Rotation Radiography, and conduct radiographies with one single apparatus, as common to all types is the method of rotating the X-ray tube around the patient at rest.

For this we manufactured for trial a *Universal Rotatograph* (Fig. 1). This apparatus possesses a rectangular iron frame, and on an upper frame a rack for installing the tube, and on a lower frame another rack for the film, are attached. Unrelated to this rectangular frame, and almost vertically below the X-ray tube, is placed the radiographic table, on which the subject to be examined is placed in the recumbent position. There is attached a goniometer to the apparatus. The reading of the goniometer is set at 0° when the central

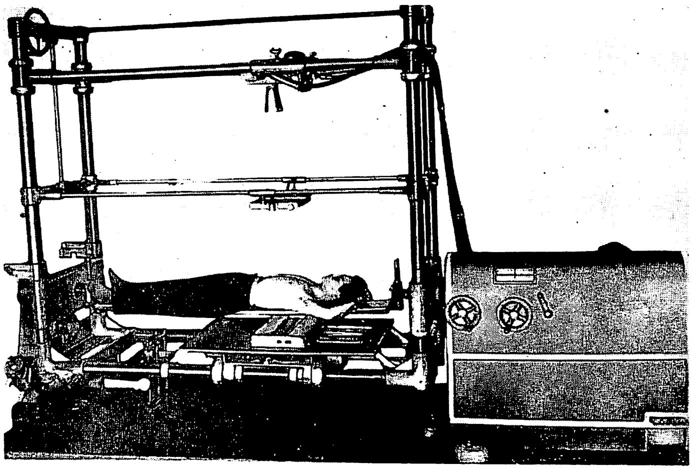


Fig. 1: Universal Rotatograph in action

X-ray is horizontal. The reading is 90°, when vertical. The rectangular frame has a rotating axis attached to the lower part of the vertical frame in order to rotate freely through 0° to 190°. The frame can be rotated by hand and stopped at the desired position. It may also be rotated smoothly and at uniform speed by an electric motor. Though the frame rotates freely, the radiographic table is kept unrelated to this and fixed at a definite position. Therefore, during radiography the subject remains at rest. When the film rack is attached at the position shown at the left bottom and right bottom of Figure 2, the X-ray tube is set in a position such that it will make an angle of 20° or 15° with the film surface (Fig. 2). Under such a condition Rotatory Cross Section Radiography and Solidography can be undertaken. When the X-ray tube and the film are attached in the position shown at the left top and right top of Figure 2, Rotation Sighting Radiography, all types of Cross Section Radiography (with exception of Rotatory Cross Section Radiography), and Rotation Kymography become possible.

If the film is placed in the position shown at the top of Figure 2, the radiographic table is placed as previously mentioned vertically below and kept horizontal during rotation of Rotatograph, and the tube rotated through 60°, the apparatus can be used for the ordinary

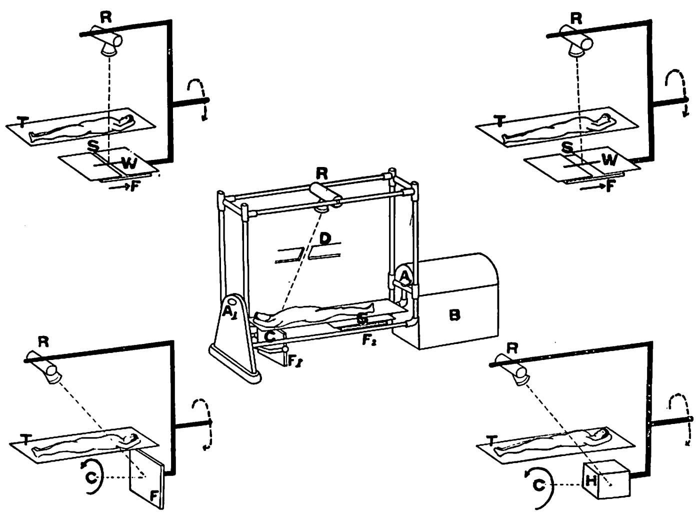


Fig. 2: Various modes of application of the Universal Rotatograph for Rotation Radiography

R: X-ray tube, D: Diaphragm, T: Radiographic table, S: Lead Slit, F: Film, W: Lead Diaphragm, C: Rotation Center of Film, H: Box Cassette.

circular arc movement tomography (tomograph of Grossmann type)[72]. If a Radiograph is made at the same position as the above, and another is taken with the tube moved through 10°, stereoscopy becomes possible. Further, with the tube at rest, normal radiography and kymography can be undertaken.

Thus, *Rotation Radiography can be regarded as an expansion of the usual radiographic method.*

2. *Basic Technique and Characteristics of Rotation Radiography*

The special feature of this radiography lies in the rotation of the X-ray tube around the subject accurately, through a sufficient range. By a sufficient range of rotation is meant the state where the subject can be inspected and analyzed from all directions completely. When the rotation is not accurate, this type of radiography will not be accomplished, and in this respect differs from existing methods of radiography or skiascopy taken from various directions. When an accurate rotation is made in Rotation Radiography, there will exist laws between the X-ray image of the subject and the rotation center.

A. Relation between Subject and Rotation Center in the X-ray Image[2)3)50)]

In Rotation Radiography the X-ray tube is rotated around a fixed axis, and the subject to be examined is radiographed in a static position. Thus the tube focus, the subject, rotation center, and X-ray image must automatically be governed by certain laws, and this will be the base of Rotation Radiography. An attempt was made to investigate this relationship theoretically and experimentally.

As experiments, here, become not only easy but also more readily explanable when the tube and film are kept fixed and the subject is rotated around a certain central point, a description will be made with the conditions kept as such. Accounts will be made, as shown in Figure 3, in the order of X-ray tube, the rotating table bearing the subject a slit in the lead diaphragm, and the film that moves perpendicularly from top to bottom (Fig. 3). The slit in the lead dia-

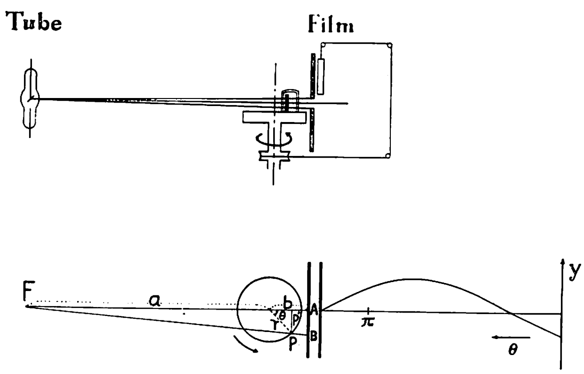


Fig. 3: Sketch of the radiographic apparatus for model experiment for studying the laws governing the Rotation Radiography

phragm has a breadth of 1 mm in the horizontal plane and is situated directly in front of the film. At the intersection of the extension of the line joining the tube focus and the rotation center of the rotatory table, a wire is passed over across the diaphragm slit. When this wire appears on the X-ray picture, it will indicate the rotating axis of the rotatory table, and will represent a standard for reading.

Hence this is termed *the standard line* (*Grundlinie*).

The rotation of the rotatory table and the movement of the film are made to act in unison accurately and smoothly. During exposure to X-rays the rotatory table is rotated. In this arrangement of the radiographic apparatus only a portion of the subject, cut by the horizontal plane containing the tube focus and the diaphragm slit, will be radiographed. Hence when a (wire) subject is held vertically on the rotatory table, it will appear on the radiogram as the image of a point.

When rotated this rotation table, an X-ray image of a curved line will be obtained, and this line will be regarded as due to the arrangement of numberless points, each of which is an X-ray image of the point taken from different directions respectively (Fig. 4).

A. Point

a. Case of one Point

If now we consider the case where the point rotates around the rotation center, a curved line representing the point will be imaged that is mingled with the standard line on the X-ray picture. If now the length of the standard line is l, and the rotation angle is θ, the length of the standard line l will be proportional to the rotation angle θ. Therefore, when the standard line is taken as the abscissa, the abscissa will indicate the rotation angle θ. And the line lying vertical to this standard line, i. e. the ordinate will indicate the distance of the subject from the central X-ray in the case of the X-ray

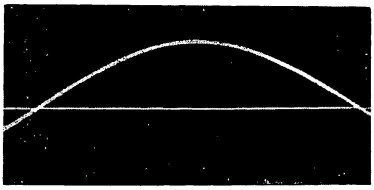


Fig. 4: Rotation Rodiogram of one point

beams being regarded as parallel to each other (Fig. 3).

If now we consider the point to be r distant from the rotation center, as shown in Figure 3, there will result a geometrical relationship:

$$\frac{FP'}{FA} = \frac{PP'}{AB}$$

$$\frac{a+r\cos\theta}{a+b} = \frac{r\sin\theta}{y}$$

From this equation there will be obtained:

$$y = r\sin\theta\,\frac{a+b}{a+r\cos\theta} \qquad \cdots\cdots \text{(I, 1, i)}$$

where r=point-rotation center distance; a=focal spot-rotation center distance; b=rotation center-film distance, and θ=rotation angle.

y is an odd function of θ, and is a periodic function with period 2π. That is, y is symmetrical about the origin. If $y_1=f(\theta_1)$, and $y_2=f(2\pi-\theta_1)$, then $y_2=-y_1$. As $\sin n\pi$ is equavalant to 0, and $\cos n\pi$ is equavalent to ± 1, curve y will intersect the abscissa θ at every π rotation ······ (I, 1, ii).

If the X-ray tube is sufficiently distant from the rotation center as between the rotation center and the film, then this curve will approach $y=r\sin\theta$. ······ (I, 1, iv)

Then actual angle φ between the line joining the point to the rotation center and the central X-ray is represented by the angle φ counted on the abscissa. ······ (I, 2, i)

b. Case of two Points

In case of two points taken by Rotation Radiography, there will appear two curves on the radiogram (Fig. 5). ······ (I, 3, i)

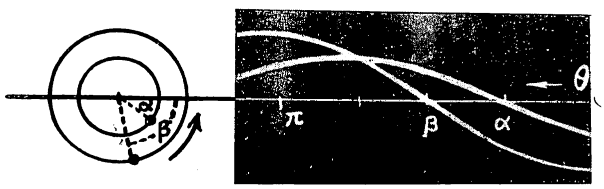


Fig. 5: Rotation Radiogram of two points

These two curves will cross each other once when θ is being developed from 0° to π. ······ (I, 3, ii)

The actual angle φ between the two lines joining the two points to the rotation center is represented by distance between points α and β produced by intersection of the two curves with the abscissa θ. ...... (I, 4, i)

c. Case of n Number of Points

N number of points arranged on a straight line, will result on radiograms with n number of curves, and these curves will intersect at one point (Fig. 6). ...... (I, 5, i)

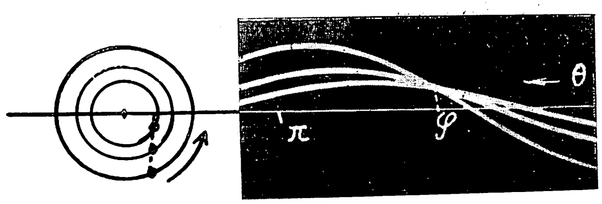


Fig. 6: Rotation Radiogram of three points arranged on a straight line

The coordinate φ of this intersecting point read on the abscissa will represent the rotation angle from the position of the start to the position where the tube focus comes to line exactly on the straight line of these points. ...... (I, 5, ii)

When n number of points are arranged to form a convex polygon with n number of vertices, the radiogram will appear as n number of curves, which intersect each other. The number of the intersecting points will be $\frac{1}{2}n(n-1)$ in the range of rotation from 0° to π (Fig. 7). ...... (I, 6, i)

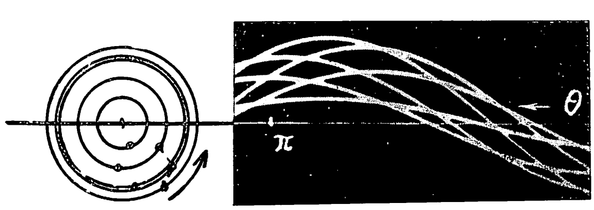


Fig. 7: Rotation Radiogram of n points

Of these intersecting points n numbers will lie at the margins of this curve group and $\frac{1}{2}n(n-3)$ intersecting points will be within the curve group. ... (I, 6, ii)

Of these number of points, the point F situated farthest away from the center, and point N situated most close, represent respectively the maximum values of the internal and external margins of the curve group. ··· (I, 6, iii)

The points contained within the convex polygon do not partake in the formation of the shape of the margins of the curve group. ··· ··· (I, 7, i)

B. Straight Line

a. Case of one Straight Line

A straight line becomes a curved zone on the radiogram, and the margins of this zone converges to point. ··· (I, 8, i)

This point is termed a *convergent point* (Fig. 8).

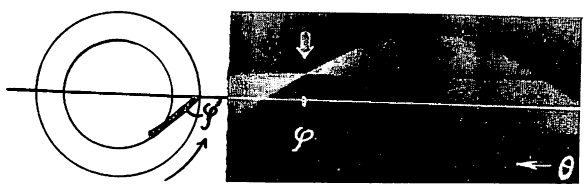


Fig. 8: Rotation Rodiogram of one straight line. ↑ : convergent point

A convergent point represents the following view, that breadth becomes gradually narrowed from both margins of the curve with simultaneous darkening of the shadow of the curved zone till it attains a point. At this part the margin of the curved zone becomes interrupted or discontinuous.

b. Case of two Straight Lines (Fig. 9)

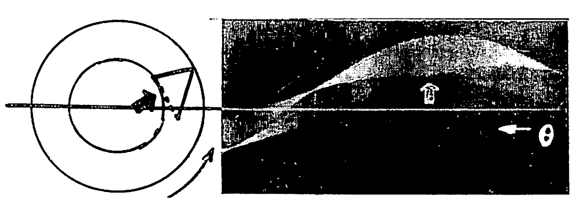


Fig. 9: Rotation Radiogram of two straight lines. ↑ : nodal point

There will be two straight lines a and b representing the subject radiographed. The angle or the complementary angle between the two lines will be taken to be α. In such a case, α will be considered as distance α between two convergent points on abscissa θ. ··· (I, 8, ii)

c. Case of n Number of Straight Lines

When two tangents are drawn from the rotation center to a convex polygon with n number of sides, then the polygon is, with respect to a line joining the two points of contact, divided into the part with n_1 number of sides as well as the part with n_2 number of sides. Depending on whether n_1 (or n_2) sides are present on the same side as the rotation center or on the opposite side, n_1 (or n_2) number of straight lines will appear on the inner or outer side of the curved zone as n_1 (or n_2) number of convergent points. ··· (I, 9, i)

C. Curved Line

Convex closed curves will appear on radiograms as curved zones with continuous, smooth and dark rims (Fig. 11). ··· (I, 10, i)

D. Imaginary Straight Line

An imaginary straight line is arbitrarily drawn between the two extremities of a concavity, if such a concavity exists on the out line of a plane, straight or curved lines.

Such an imaginary straight line is imaged as a *nodal point* on the radiogram (Fig. 9). ··· (I, 11, i)

The curved zone becomes discontinuous at the site of the nodal point. ··· (I, 11, ii)

The nodal point is the one where the margin of the curved zone becomes discontinuous, like as in the case of the convergent point. But the darkness of the shadow does not become enhanced as it approaches the point, as it does in the case on the convergent point, and always remains homogenous.

E. Plane

a. Case of one Plane

A plane becomes a curved zone on the radiogram. The darkness of the curved zone differs with the ordinate, but the total sum of the darkness at an optional abscissa θ is constant. (I, 12, i)

b. Small Convexity on the Margin of a Plane

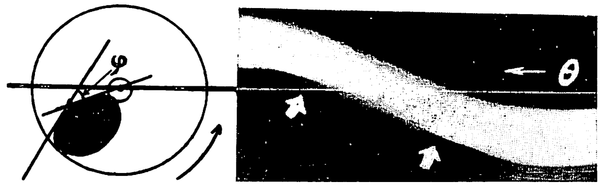


Fig. 10: Rotation Radiogram of a small convexity on the outline of a plane (↑ ~ ↑)

When small convexities are present on the contour of a plane and two tangents are drawn from the top of the small convexity to the plane, and if these two lines correspond to the direction of X-rays after rotation of φ_1 and φ_2, there will be formed continuous light margins at the margins of the curved zone from φ_1 to φ_2 (Fig. 10). ... (I, 12, ii)

c. Case of two Planes

If there are two planes, and one plane A is contained within B, then the curved zone A will be contained within the curved zone B on the radiogram, and the two zones will always be superimposed and not be separated from each other (Fig. 11). ... (I, 13, i)

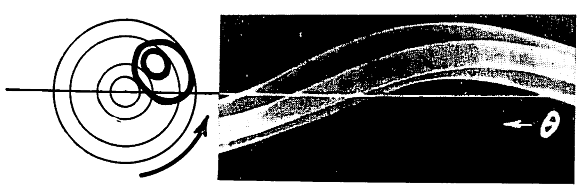


Fig. 11: Rotation Radiogram of two closed convex curved line

When plane A lies outside plane B, the curved zone A, as θ develops from 0 to π, will separate itself once from curved zone B (Fig. 12). ... (I, 13, ii)

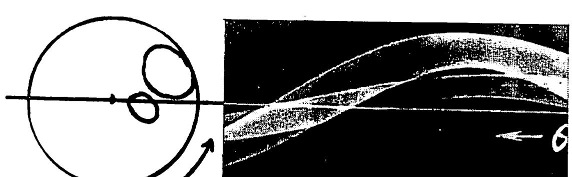


Fig. 12: Rotation Radiogram of two closed curved lines separated from each other

B. Range of Rotation in Rotation Radiography

A sufficient range of rotation is meant a rotation of the tube from 0° through 190°.[3]

As it is clear from laws (I, 1, i—iii) in Rotation Radiography, the range of rotation from 0° to 180° should be sufficient for radiography of a point. Nevertheless, in the case of a subject which has certain dimensions, rotation of this degree is not sufficient. Let us consider the reason. If now we take a case where the tube and film is at rest and a static subject rotates between them, and straight line A will be contained within the subject (Fig. 13).

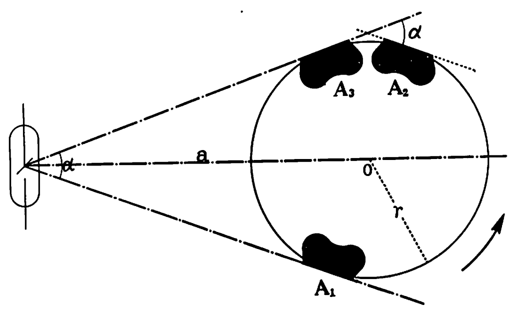


Fig. 13: Schema accounting for sufficient range of rotation at Rotation Radiography

In order to inspect this line from all directions, it is necessary to know how much the range of rotation of the subject should be the most suitable. According to the geometrical consideration, the X-ray tube should be rotated from the first position A_1, through the second position A_2 (180° rotation) to the final position A_3. Thus, the rotating angle required for this straight line to correspond again to the direction that initially corresponded to the direction of the X-ray will be $\pi+\alpha$.

If this line occupies the position A_2 at the beginning of radiography, so the rotating angle required will be only $\pi-\alpha$.

If the distance between tube focus and rotation center is a, and the straight line is contained within the circle of radius r, then it should follow the relationship $\frac{\alpha}{2} = \sin^{-1}\frac{r}{a}$, where a is measured generally about 100 cm, and r can be in the case of the human body less than 10 cm. Then, there will be obtained the value of $\alpha \doteqdot 11°$.

Thus in Rotation Radiography of human body, if the rotation angle is 190°, every organ in the body can be inspected from all directions and all contours of cross sections will become delineable. Such is necessary and is satisfied by Rotation Radiography.

The following four chapters will describe in detail the four main types of Rotation Radiography. First descriptions will be made of the theory, apparatus and technique of Rotation Radiography respectively. These will be followed by an explanation of the benefits in diagnosis, as well as in actual application in the healthy and diseased for concrete determination of the sites of diseased foci and state of such.

Chapter II

Rotation Sighting Radiography

Rotation Sighting Radiography (*Rotationstreffenröntgenographie*) is a type of Rotation Radiography. Rotation stopped every time at an angle previously determined, and the static subject is exposed to X-rays successively. From a film thus obtained the state of the internal viscera and diseased foci are interpreted.

The previously determined angle is termed the ***discontinuous rotation angle*** (***Diskontinuierliche Rotationswinkel***). This angle, as will be described later, is adjusted to a suitable degree according to the state of the diseased foci to be examined. In this radiography the *standard line* appears as an image.

As Rotation Sighting Radiography is usually used in serial radiography, a long film will have to be used. The subject has to be kept strictly in a static position. Therefore a horizontal Universal Rotatograph is usually employed (Fig. 1 and 2). At the rotation axis a goniometer is attached. When the line joining the tube focus and the rotation axis is vertical, the reading of the goniometer is set at 90°.

In the case of Rotation Sighting Radiography of the chest, however, it is more convenient for an upright Rotatograph employed (Fig. 18 and 19).

1. *Reading of Rotation Sighting Radiogram*[3)50)]

A Rotation Sighting Radiogram consists of a series of radiograms taken from different directions successively. Each of the radiograms is, however, nothing more than a normal radiogram, but differs from the normal radiogram in that, they are organically joined together by the standard line and are arranged according to the discontinuous rotation angle. Characteristic interpretation of Rotation Sighting Radiogram will become possible from the laws governing Rotation Radiography (I, 2, A).

However, what was stated there was a basic theory for Rotation

Radiography where the tube was rotated continuously. The very thin parts of a subject appear numerously there, and can be taken as the images of thin layers of the subject serially arranged along the standard line on the radiogram. In Rotation Sighting Radiography the X-ray pictures are taken discontinuously, and all radiograms are not one thin layer but pictures of the entire subject itself. Hence in interpreting this type of radiograms there should be applied the laws of Rotation Radiography. To that, however, only one part or one layer of the concerned subject is arbitrarily taken and that part or layer shall be observed as continuously as possible.

In Rotation Sighting Radiography a line is imaged not as a point, as described former, but as a line on the radiograms respectively. Nevertheless, when a special portion of the subject, such as the end or middle point of the line is concerned, the law of Rotation Radiography becomes applicable when the discontinuous rotation angle is made sufficiently small, because the bent line joining these points approaches a curve as in the case of Rotation Radiography.

Thus, the state of the internal viscera will be demonstrated roughly but sufficiently to establish a correct diagnosis as described below.

A. Position

The position of the subject to be examined is determined from the concept of polar co-ordinates. Here the pole is the rotation axis, and the initial line corresponds to the central X-ray. The vector moves counter clockwise.

a. Position of a Point

When the subject is a point, the position is determined by the radius vector r and argument θ. r is the maximum value of this curve (in this case of Rotation Sighting Radiography it is a bent line, but it shall be regarded as a curve in approximation), while θ can be measured as the angle covered by development of the curve till it intersects the standard line (I, 2, i).

b. Position of a Layer of the Subject

Draw two radius vectors r_1 and r_2 with arguments φ_1 and φ_2, where φ_1 (or φ_2) can be measured as the distance between the original point and the point where the outer (or inner) margin of the curved zone intersects the abscissa (I, 2) (Fig. 14).

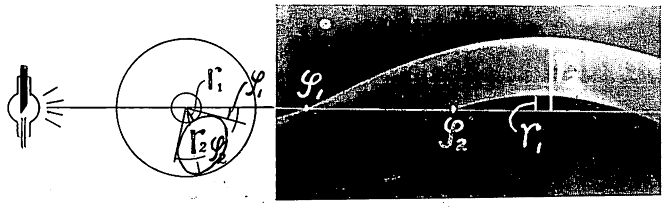


Fig. 14: Schema of reading a Rotation Radiogram of plane

Arcs are then darwn with radius vectors r_1 and r_2, in which r_1 and r_2 will represent the maximum values of the outer and inner margins of the curved zone. ⋯ (I, 1 a. 2)

Here, r_1 and r_2 also represent respectively the farthest and nearest points as regards the rotation center (I, 6, iii).

Thus, with the radius vectors and arcs, a sector can be drawn and the plane or the layer will lie within this sector.

When the curved zone always contains the standard line, the cross section of the subject lies within the circle of the radius, r being the maximum value of the margin of the curved zone (I, 6).

B. Contour

The outline of a cross section of a subject can be known from the state of the margins of the curved zone.

a. Layer of the Subject Contoured with Oval Closed Curve.

When the margin of the curved zone is sharp, smooth and continuous, the outline of the cross section will be an oval closed line containing no cavity or straight line (I, 10, i).

b. Layer of the Subject Contoured with Straight Line

When the margin of a curved zone has a convergent point at the coordinate φ, the outline of the cross section will include a straight line (I. 8, i).

c. Layer of the Subject Contoured with Closed Line with a Concavity

When there exists a nodal point at φ of the margin of the curved zone, there will be a concavity in the cross section outline (I, 11, i).

The imaginary straight line follows the direction of the X-ray at the nodal point of φ (I, 8, i).

d. Layer of the Subject Contoured with Closed Line with a Small Convexity

When the margin of a curved zone has an unsharp, poorly contrasted narrow zone from φ_1 to φ_2 on the abscissa the outline of the cross section will include a small convexity. When two tangents were drawn from the vertex of this convexity, the angle, or its complementary angle will be measured as $\varphi_2-\varphi_1$ (I, 12, ii).

The chances for the convergent point or nodal point not to be radiographed will be often if the degree of discontinuity of the rotation angle is markedly increased.

C. Structure

When the shadow of the curved zone is uniform in density, the layer of the subject is composed of a substance that is homogenous to X-ray, and when it is composed of a curved zone with a mixture of several dark and light zones, the layer consists of substances that differ in their X-ray absorption coefficients (I, 12, i).

D. Relation

a. Layers of two Subjects Separated from Each Other

When two curved zones do not overlap with each other between φ_1 and φ_2, the cross sections of two subjects separated at the range of rotation from φ_1 to φ_2. The distance between two subjects is measured as the maximal distance between two curved zones (I, 13, ii).

b. One Layers Being Contained within the Other

When a curved zone is always included within the other, then a cross section will be contained within the other cross section (I, 13, i).

As stated above, the state of the layer of a subject i. e. the cross section of a subject can be made out roughly from Rotation Sighting Radiography, when the laws for Rotation Radiography are employed.

It will be possible to demonstrate not noly the state of the layer of the body, but the state of the subject piled up. Because, on a Rotation Sighting Radiogram there will be an image of the subject itself. It will be indispensable, here, to rotate the subject through a range of rotation angle from 0° to 190°, for demonstration of the location, contour or construction of the subject. At present, however, there can be obtained radiograms of cross sections by other means directly.

The practical applications of Rotation Sighting Radiography have great significance in the discovery of diseased foci. For this, how much discontinuity should be taken? If *discontinuity of rotation* is small and rough, there will occur the possibility of missing the small lesions.

Next will be considered the margin of error of discovering these lesions.

2. *Possible Margin of Error in Diecovering Diseased Foci by Rotation Sighting Radiography*[1]

First will be considered what meaning the discovery of diseased foci imaged on Rotation Sighting Radiography possesses.

When a radioopaque object with a small convexity in the outline of a cross section is taken by Rotation Sighting Radiography, the convexity will be recognized on the radiogram, if it lies within the rotation angle $\varphi_1-\varphi_2$ (I, 12) (Fig. 10).

Again when two separated radioopaque objects, small and large, are radiographed, the small one will not be recognized within the range of rotation angles of $\varphi_1-\varphi_2$ and $\varphi_1'-\varphi_2'$ (I, 13, ii).

In other words, the presence of the small object will not be confirmed on the radiogram when the rotation angles lie within $\varphi_1-\varphi_2$ and $\varphi_1'-\varphi_2'$, and only at the position $\varphi_2-\varphi_1'$, will the small object be discovered.

Next then, let us consider the possibility of the subject to be missed by Rotation Sighting Radiography. Let the subject be Q, and for its radiography the tube focus be F, and the X-ray image of Q on the film be ab (Fig. 15).

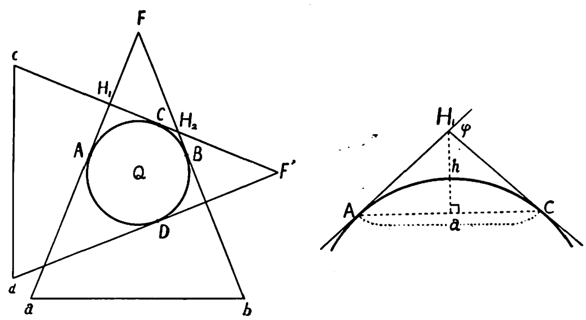


Fig. 15: Schema of margin of error in discovering a subject by Rotation Sighting Radiography

In such a case the possibility of missing the subject will be the area $\varDelta Fab-Q$. If now a radiogram is taken again with the X-ray tube moved from position F to position F', the possible margin of error in discovering will be greatly narrowed. In other words, if the contact point of the X-ray with the body Q is taken to be C, D, and the intersecting points of $F'C$ with FA and FB to be H_1 and H_2 respectively, the ranges of error will be narrowed to the parts encircled by $\overline{AH_1}$, $\overline{CH_1}$, $\widehat{AC}$, and $\overline{CH_2}$, $\overline{BH_2}$ and $\widehat{BC}$. Hence, if now the discontinuous rotation angle (that rotates through F to F') is made small, and the discontinuity of rotation is increased in frequency, this range of error will be further narrowed. When the maximum and minimum ranges of missing are considered, it will be noted that, as shown in Fig. 15 right, missing will not arise if the outline of Q is the bent line AH_1C itself. But, if it is not so, the greatest error will occur when arc $\widehat{AC}$ is straight line $\overline{AC}$ of the equilateral triangle with $2\pi-\varphi$, where φ is the discontinuous rotation angle, h the height of the triangle, and a the length of the base.

Then there will be a relationship:

$$\tan\frac{\varphi}{2}=\frac{2h}{a},$$

and it follows:
$$h=\frac{a}{2}\tan\frac{\varphi}{2}$$

As the outline of Q is originally not known, it should be considered that the margin of error in missing is distributed in area of AH_1C. When AC is a bent line AH_1C, the margin of error would be minimum. On the other hand, when AC approaches from $\widehat{AC}$ to $\overline{AC}$, the range of error approaches the maximum. In such a case the margin of error $h=\frac{a}{2}\tan\frac{\varphi}{2}$ shows the maximum value.

In this formula a is a numerical value determined approximately by anatomical data. For example, for the optic canal the length of the canal is about 10 mm and the inner diameter about 5 mm, and for the sella turcica the width of the dorsum is approximately 15 mm. Hence for an en facé image of the optic canal, there will be permissible up to 0.3 mm of unsharpness in the X-ray image of the border or outline of the foramen. For this, according to the above formula, the discontinuous rotation angle φ should be 7°. And for the profile image of the sella turcica this discontinuous rotation angle φ should be 5°. Here, the margin of error in diagnosis is considered as 0.3 mm. And an X-ray image below 0.3 mm in size can be regarded as negligible usually. If a focus over 0.3 mm in size is present, it can be caught as findings by the naked eye. Thus, it will help locating a diseased focus whether it is abherent to or situated close to the outline of the subject. When the outline of the cross section is a convex closed curve, a profile image (renal pelvis, sella turcica) has to be taken, and when the subject has a tubular opening or gaps, an en facé image has to be taken. In such cases the margin of error should be first computated for determining the range of the discontinuous rotation angle.

Thus, in establishing a diagnosis by Rotation Sighting Radiography it is possible to know the margin of error previously. This is the *first characteristic* of Rotation Sighting Radiography.

3. *Clinical Applications of Rotation Sighting Radiography*

When it becomes necessary to discover a diseased focus, normal radiography is the most convenient method and so is usually employed. However, in case of radiography of organs in a special part of the body, normal radiography taken in the conventional manner is sometimes of no use. It might be well for only a trained X-ray technician to exhibit his skill, though such technical ability can be mastered only with difficulty. Further it must be mentioned that the state of organs within the body vary anatomically. Hence, it can be said that it is not proper to take radiography of these organs by a single normal radiography. Successive serial radiography made by Rotation Sighting Radiography will make possible even without expert skill to show positions and sizes of foci clearly. This is the *second characteristic.* The above are the two main characteristics of Rotation Sighting Radiography when applied clinically.

Next mention will be made of actual experiences obtained by Rotation Sighting Radiography.

A. Renal Pelvis[9)]

With the Rotation Sighting Radiography the superimposed images of organs or diseased foci become separated and individually observable. Thus, numerous findings become available. As an example radiography to the renal pelvis will be described. A Rotatograph of the horizontal type (Fig. 1) was employed, and the size of the radiogram was 18.3×14.2 cm. Exposure to X-ray was made with the goniometer reading at the following projections, 30° to the recumbent patient, and with the discontinuous rotation angles of 20°. When the directions of projection were changed, the exposure conditions had also to be changed, because the thickness of the body varied usually at each projection. This was accomplished by adjusting the voltage empirically according to the formula.

$XkV = 56 + (D - 17)$: where D is the thickness in cm of the body at each projection.

On forty one healthy persons (the number of kidneys radiographed was forty four) radiograms of the renal pelvis were taken after intravenous injections of opaque media (Fig. 16 and 17).

The results showed:

a) Irrespective of the inclination which the neck of the renal calyx might make with the body axis, the calyces could be taken from all

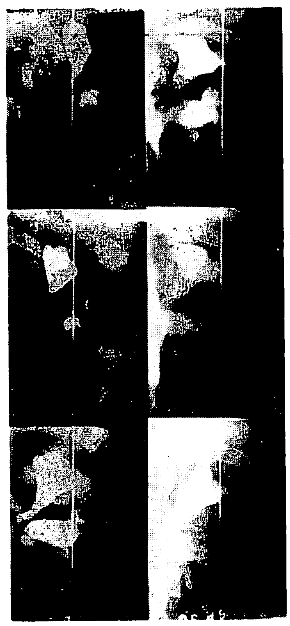


Fig. 16: Rotation Sighting Radicgram of renal pelvis

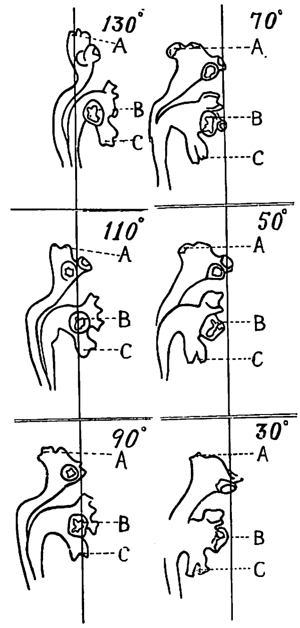


Fig. 17: Schematic representation of Fig. 16, showing separation of calyces

directions, and thus the findings were caught in the best consitions for observation, when this method was used.

b) Comparisons were made of the number of calyces that were interpreted by this method and by usual methods of normal radiography. The number of calyces that was completely isolated and observed was 8.1 ± 0.25 by the former method and 4.9 ± 0.34 by the latter method. That is to say, by Rotation Sighting Radiography the number of calyces seen increased by 11.5%, and the number of isolated calyces that became discernable increased by 65.3%, when compared with existing methods of normal radiography.

c) The type of calyx was classified into tubular, cupshaped, mortar-shaped and irregular. Of the isolated 267 calyces, 146 (54.7%) were tubular, 60 (22.5%) were cup-shaped, 47 (17.5%) were mortar-shaped, and 14 (5.2%) were irregular in shape. Such classification of the calyx will become possible only when observations are made from different angles and directions.

d) The distance between the renal hilum and the skin surface of the back was calculated from Rotation Sighting Radiograms, and it was found that the average for 40 examined was 8.1 ± 0.28 cm, with a maximum of 11.4 cm, and a minimum of 4.4 cm. Highest frequency distribution was noted in the 8.0 to 8.9 cm range.

e) Inclination angles of the kidney, i. e. the angle of inclination presented by the longitudinal axis of the kidney in a sagittal plane, showed an average of $146.3^\circ \pm 1.9^\circ$ for 37 kidneys examined, with a maximum of 165° and a minimum of 120°. The majority showed an inclination angle from 150° to 159° (17 cases).

B. Rotatory Photoroentgenography of Chest[7)8)]

In order to discover foci in the chest which were missed by normal radiography, and also for differential diagnosis, Rotation Sighting Radiography was performed. The photoroentgenographic technique was employed here to economize in film. The apparatus used, as shown in Fig. 18, was a normal photoroentgenography unit with an attachment of a rotating table between the tube and fluoroscopic screen (Fig. 18 and 19). The subject to be examined stood on the rotation table with the left side of the chest in contact with the fluoroscopic screen, and this position was taken to be 0°. Rotation was made

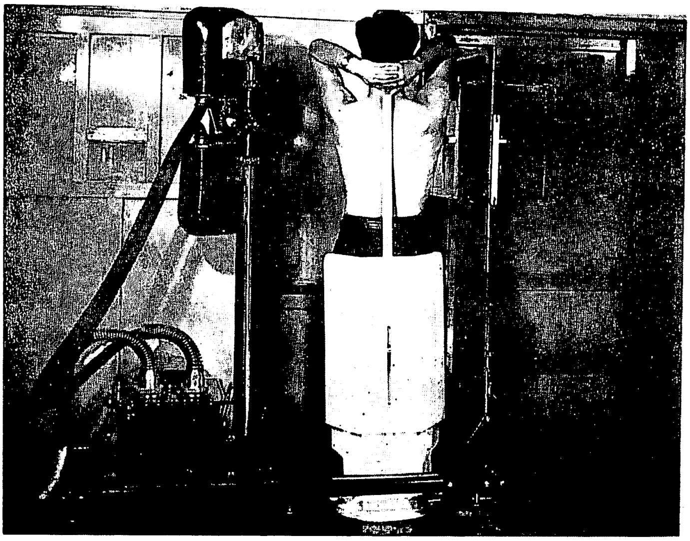


Fig. 18: Rotatory Photoroentgenographic apparatus in action

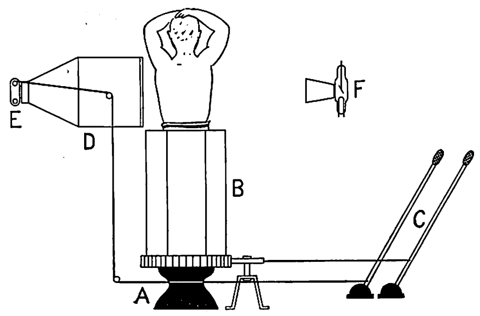


Fig. 19: Sketch of Rotatory Photoroentgenographic apparatus
F: X-ray tube, A: Rotation table, C: Remote controller of rotation

clockwise when seen from above, and pictures were taken at every 20°, and at 90° in the postero-anterior projection by Rotation Sighting Radiography. Exposure time was adjusted according to the following formula,

$$T = \frac{1}{10}(D-8)$$

where D was thickness of chest in cm according to respective projection, and T exposure time in second.

The findings of 1679 cases of Rotatory Photoroentgenogram were compared with their corresponding normal photoroentgenograms taken in the postero-anterior projection (Fig. 20). The clinical significance of *Rotatory Photoroentgenography* (*Indirekte Rotationsaufnahme*) was thus classified into five groups, as follows.

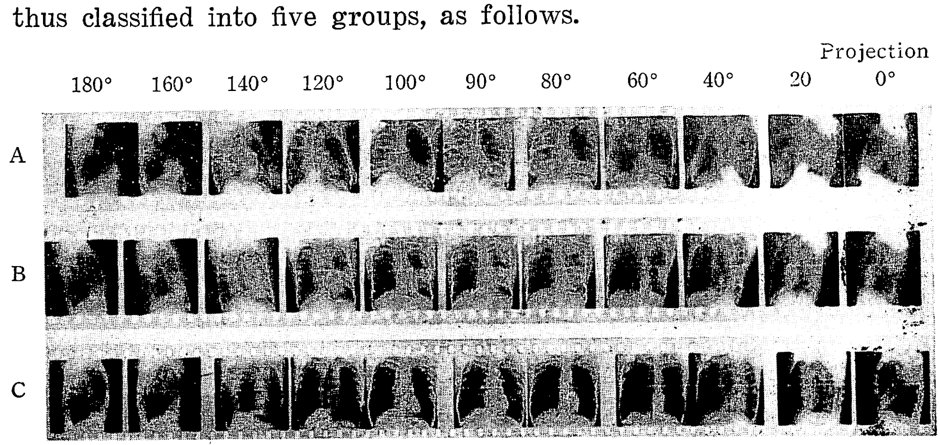


Fig. 20: Rotatory Photoroentgenogram of the chest
A: Cavitation in the right upper lung, B: Serothorax, C: Normal

Group A consisting of cases whose findings were not seen by normal postero-anterior radiograms but discovered by this method.

Group B including cases that contributed to the differentinal diagnosis.

Group C were cases in which the positions and sizes seen by normal radiograms were deciphered concretely and precisely by this method.

Group D consisting of cases in which the foci could not be discovered by normal postero-anterior, but discovered by this Rotatory Photoroentgenography taken at one of the four directions (40°, 60°, 140° or 180°).

Group E consisting of cases in which Rotatory Photoroentgenography did not help diagnosis.

When the records of these cases consisting of both sexes and ages ranging from 7 to 70 years were examined, 1258 (74%) were found to be abnormal and the remaining 421 (26%) to be free. The abnormal cases (1258 cases) were then classified according to type of disease particularly for its clinical significance (Tab. 2).

Thus this method of radiography helped to discover 2.9% new

Table 2

Disease. \ Group	A	B	C	D	E	Total	%
Hilar tuberculosis	19	27	263	3	18	330	26.2
Tbc of the lung field	7	73	472	7		550	44.4
Pulmonary tumor		9	27			36	2.9
Pleurisy	2	60	121	11	1	195	15.9
Heart disease		8	26			34	2.7
Arteriosclerosis	7	18	47			72	5.7
Other diseases	1	2	18		11	32	2.6
Total	36	197	974	21	30	1258	100.0
Without findings						421	
Percentages	2.9	15.6	77.3	1.7	2.4	100.0	

diseased foci, and contributed to the differential diagnosis of 15.6% of diseases of the chest. The percentages of cases that benefited from this method of radiography amounted to 97.6% of the 1258 cases.

C. *Sella Turcica*[16][17]

For measurement of size of the sella turcica, it is indispensable to get a true profile image of the sella in which both anterior and posterior clinoid processes overlap respectively. When it becomes necessary to know the destructive or abnormal states of the different parts composing the contour of the sella, it is desirable to observe dynamically radiograms to the sella taken from several slightly different directions. For this purpose Rotation Sighting Radiography is suitable. Hence this method of radiography was performed on 33 healthy adults. In radiography, the lead plate was placed immediately in front of the film, and the field irradiated was made to a size of 15×6.1 cm. Five exposures were made at the position of the goniometer readings of 80°, 85°, 90°, 95° and 100° (Fig. 21 and 22).

Fig. 21: Rotation Sighting Radiogram of sella turcica

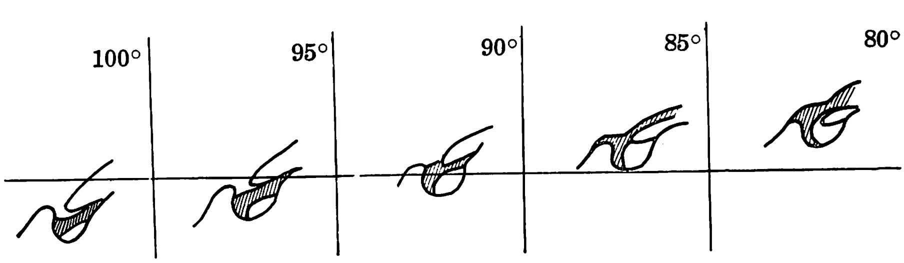


Fig. 22: Schmatic representation of Fig. 21, showing bridge formation between tuberculum clinoideus anterior dextra and that of posterior

a) When the above technique for taking sella turcica was used, the states of the anterior and posterior clinoid processes, the faces of the dorsum and contour of the floor became sufficiently observable.

b) The view of the anterior wall as well as the lateral edge of the hypophyseal fossa were taken as a single and smooth outline in all 33 cases. It became clear moreover that only when overlapping of the right and left edges of the anterior wall or dorsum of the sella had not been made accurately, the outline appeared double or treble.

The frontal aspect of the dorsum of the sella, i. e. the posterior wall, also appeared single and smooth in all cases.

c). When the lateral edges bordering the sides of the base of the sella turcica were superimposed, the outline of the base of the sella turcica presented a single and smooth outline. When the left and right sides of the base of the sella were not projected overlapped, the outlines of the base was imaged double.

d) The various dimensions and sizes of the lateral sides were computed by the distance from skin surface to sella turcica according to the readings of Rotation Sighting Radiography (I, 1), and the values obtained were converted into actual ones.

The antero-posterior diameter of the sella turcica showed a maximum of 2.08 cm, a minimum of 0.97 cm, and an average of 1.59 ± 0.25 for 33 cases.

The distance from the tuberculum sella to the extremity of the dorsum was maximum 1.51 cm, minimum 0.75 cm, with an average of 1.13 ± 0.17 cm for 33 cases.

The depth of the sella in relation to antero-posterior diameter showed a maximum of 1.14 cm, minimum of 0.7 cm, and an average of 0.94 ± 0.16 cm for 33 cases.

The depth of the sella in relation to tubercle sella and dorsal extremity distance was maximum 1.01 cm, minimum 0.64 cm, and average 0.80 ± 0.10 cm for 33 cases.

The size of the lateral side of the sella turcica was 1.12 cm^2 (maximum), 0.49 cm^2 (minimum) and 0.81 ± 0.17 cm^2 in average.

e) The distance between the left and right clinoid processes was 3.4 cm maximum, 2.1 cm minimum and 2.57 ± 0.40 cm average for 33 cases.

f) The thickness of the dorsum at the thickest part was 0.92 cm (maximum), 0.25 cm (minimum), and the average was 0.56 ± 0.19 cm for 33 cases. At the thinnest part the thickness was 0.66 cm (maximum), 0.08 cm (minimum) and the average 0.31 ± 0.12 cm for 33 cases.

D. Optic Canal[10]

It is indispensable to get an accurate en facé view for determining the size and shape of the opening of the optic canal. This is because that the opening differs individually in the direction of the canal, and thus this Rotation Sighting Radiography becomes logical to be used.

A Universal Rotatograph was employed with the opening in the lead plate made to a size of 30.5×10 cm. The general direction of the optic canal was determined by our method[67].

i). X-ray tube and the film are so arranged that the central X-ray is perpendicular to the center of the film laid horizontally.

ii). A line joining the meatus acusticus externus and angulus occuli lateralis of the opposite side of the concerned optic canal is drawn, and a triangle with this line as base is drawn. Let the base angles be 110° at the meatus acusticus externus and 35° at the angulus occuli lateralis. The vertex of this equilateral triangle termed point A. ($\angle A = 35°$)

iii). A point (termed B) at the margin of the lower eyelid is taken, 8 mm distant from the angulus occuli lateralis of the same side of the concerned optic canal.

iv). The patient is laid prone on the radiographic table and point B is adjusted at the foot of the central X-ray to the film.

v). Next, point A is adjusted on the vertical line from the tube focus.

By means of this method the diameter of the opening of the optic canal is imaged at maximum size according to the direction of the central X-ray.

Exposures were then made with the tube directed at angles of 80°, 85°, 90°, 95°, 100° to the body axis, and the group of films was termed Group A. A similar series of exposures was made at directions vertical to the body axis, and that of the films was termed Group B.

The optic foramina of 34 healthy adults, a case of disease of the pituitary gland, and a case of night blindness were examined by Rotation Sighting Radiography, and it was found that:

a). The actual sizes and shape of the inner diameters of the opening of the canal was obtained (Fig. 23 and 24)

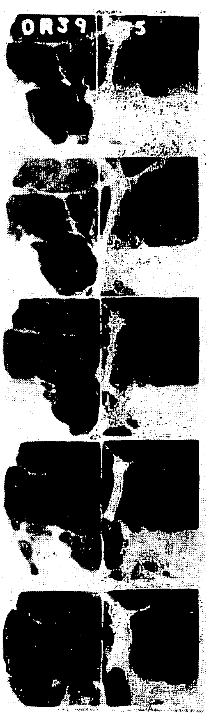


Fig. 23: Rotation Sighting Radiogram of the optic canal

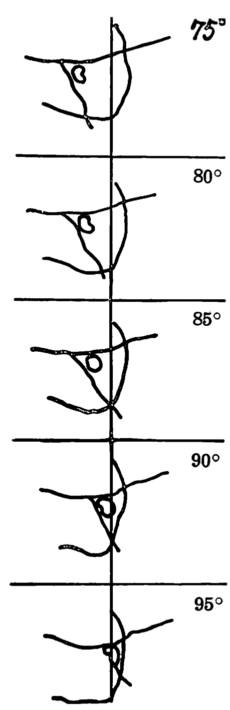


Fig. 24: Schematic representation of the optic canal of Fig. 23, showing the isthmus formation

b). The foramen of the optic canal was easily differentiated from the circular image produced by the superior orbital fissure or the ethomoid cells. It was learned that the maximum diameters of the foramina differed individually and their en facé images was obtained according to the direction of X-ray.

It was seen from the table that, when the optic canal was taken accurately from the front at 90° by our technique, the frequency of obtaining an en facé image of the optic canal was maximal, but even with deviations of 5° to 10° in positioning of the subject the maximum size of the optic canal was also observed (Tab. 3).

Table 3

Direction of central X-ray / Film group	80°	85°	90°	95°	100°
A	4	6	18	5	1
B	5	6	20	4	0

In our 34 cases the range in size of the optic canal was from 5.4 to 5.0 mm (28 cases). The average was 5.2 ± 0.2 mm. The longitudinal diameter showed a maximum of 6.4 mm, minimum 4.4 mm, with highest frequency distribution between 5.6 to 5.2 mm (29 cases). The average was 5.5 ± 0.2 mm.

c). The internal dimensions of the normal optic foramen were (5.5 ± 0.2) cm × (5.2 ± 0.2) cm in actual size.

Chapter III

Cross Section Radiography

Cross Section Radiography (*Querschnittsaufnahme*) is a type of Rotation Radiography which clarifies the cross section of the body by radiography. Cross Section Radiography has been studied by us since 1946, and seven types of radiography gradually developed. Cross Section Radiography is the common name for these seven types. At first an attempt was made to construct indirectly an outline of the cross section of a subject by X-rays, but later Rotatory Cross Section Radiography developed as the fifth method of radiography delineating the cross sections directly.

These seven methods of radiographic technique of a cross section developed one after another. Each of them has features of its own. Therefore, they will be described individually, followed later by a detailed description especially of the Rotatory Cross Section Radiography.

1. Various Types of Cross Section Radiography and Their Developnent

A. Discontinuous Rotatography[1)5)6)50)]

Discontinuous Rotatography developed originally from Rotation Sighting Radiography. The apparatus and operation are similar to that of Rotation Sighting Radiography (Fig. 2, top right).

To begin an examination the tube and cassette are set still at goniometer reading of 0°, and an exposure is made. The tube and cassette arms are rotated, usually through 20 degrees, and the film slides 10 mm into the cassette holder sufficiently to bring an unexposed part of film beneath the diaphragm slit and a second exposure is made. The arms again are rotated, the film is moved to a new part and a third exposure is made. This is repeated through an arc of 200°. The film is then developed (Fig. 25).

Fig. 25: Discontinuous Rotatogram of the chest

Now, the relationship between X-ray image and subject will be considered when Rotation Sighting Radiography is made at an appropriate discontinuous rotation angle (usually one of 20°).

In radiography the X-ray being tangential to the subject forms an X-ray image of the outline of the body on the film. This will be in the same condition, when the outline of the body is joined to the outline of the X-ray image by a straight line or pencil tracing. If a rotation table, carrying a subject on it, rotates around a fixed point between a fixed X-ray tube and films from 0° to 190°, that straight line or the pencil tracing will touch all outlines of the cross section of the subject. Hence, if now a drawing paper is set in place of the subject it will be possible to have an actual sized cross section image of the subject on the drawing paper.

Actually when Rotation Sighting Radiography is made with the aim of obtaining such a figure, the breadth of the lead slit placed in front of the film is narrowed to 1.0 cm, and radiograms are taken at intervals of 20° through a range of from 0° to 200°. The reason why radiography is made on one film from all directions is to facilitate drawing of the figure and economize in film. By such means there will result a radiogram with gradations that remind one of the usual kymography. Through the middle of the film will be imaged the standard line (Fig. 25).

The figure can be drawn by means of the operation as shown in Figure 26.

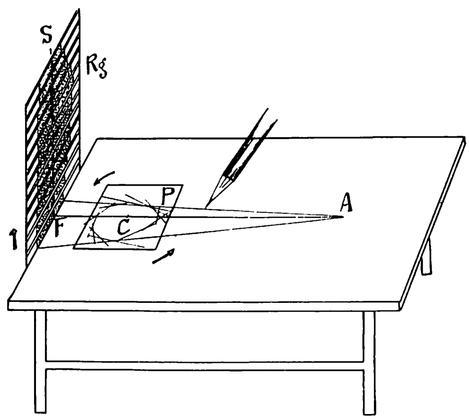


Fig. 26: Schema of the method of reconstructing an outline of cross section from a Discontinuous Rotatogram
A: Point representing the location of the tube focus at radiography
C: Point representing the rotation center
F: Point representing the location ot the film at radiography
Rg: Discontinuous Rotatogram, S: Standard line

The X-ray image of Rotation Sighting Radiogram will appear larger than actual size, but the cross section that is drawn on the paper is of acutal size. This cross section obtained is angular in shape (Fig. 27, top). However, if the discontinuous rotation angle is made sufficiently small, a smooth outline in actual size becomes possible. The cross section figure thus obtained by this *Discontinuous Rotatography* (*Diskontinuierliche Rotatographie*) is very sharp in contour, but for drawing, for example, the cross section figure of every pulmonary marking from a chest radiogram is laborious, and as a result it will be difficult to draw the small part of the organ thoroughly by this method. It can not be further disregarded that there is a possibility of thinking subjectively when drawing the cross section.

B. Continuous Rotatography[2)50)]

In Discontinuous Rotatography the procedure for obtaining the cross section figure is indirect, and moreover drawing is apt to be influenced by subjectivity. So, though the cross section image is not shown concretely, an attempt was made to obtain the curved zone

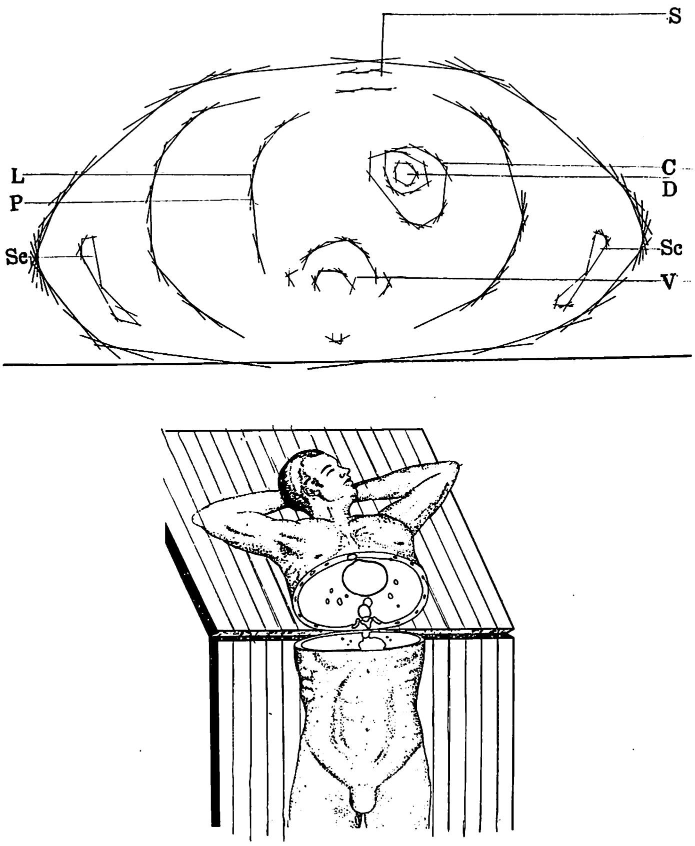


Fig. 27: Top: Drawn cross section of the chest from the Disc. Rotatogram of Fig. 26
S: Sternum, L: Collapsed lung, P: Pleura, Sc: Scapula,
C: Outer wall of the cavity, D: Inner wall of the cavity,
V: Spine
Bottom: Our mode of showing the cross section of the body since 1946

image representative of cross sections. This curved zone can be interpreted as the state of cross section by utilizing the laws that are refered to in the basic theory of Rotation Radiography. This corresponds to Discontinuous Rotatography taken at a discontinuous angle of 0°, in other words, Rotatography taken continuously. In this case the slit of the lead placed in front of the film is narrowed up to a breadth of 1.0 to 0.5 mm.

In this *Continuous Rotatography* (*Kontinuierliche Rotatographie*) both sharpness and contrast of the radiogram are very good (Fig. 28).

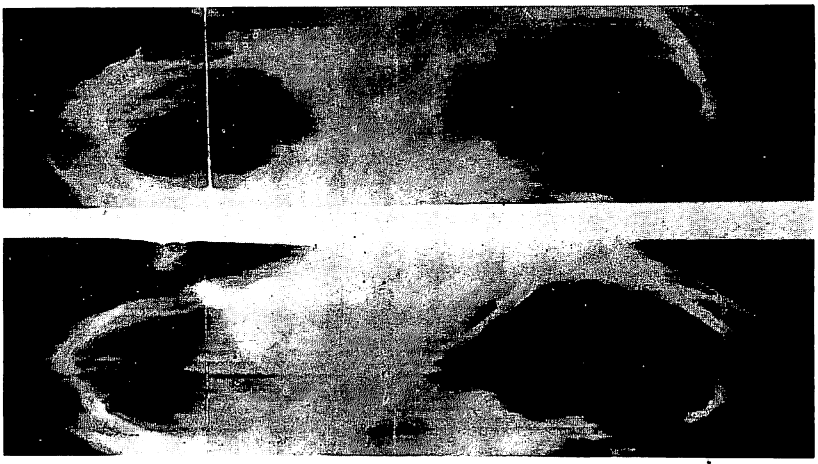


Fig. 28: Continuous Rotatogram of the chest
Top: Normal lung
Bottom: Lung tumor at the right hilum

It can not be denied, however, that the defects of Continuous Rotatogram as a Cross Section Radiography lie in the absence of concreteness in the concept of the cross section, and that there is need for skill in interpretation of this image.

C. Continuous Cross Section Radiography, Original Method.[4)58)]

In Discontinuous Rotatography for obtaining a cross section a subjective factor, namely the need for sketching, is present. So there was devised a method of cross section drawing objectively, i. e. photographicaly from the X-ray images of a Discontinuous Rotatogram, and such has been termed Continuous Cross Section Radiography.

Here, in place of the pencil tracing in the case of Discontinuous Rotatogram, reproduction of the cross sections was made from light beams. A wide aperture lens with little spherical aberration was used, and when light was applied to this lens from the back of the film (Fig. 29 and 30), the convergent point was made to strike the original site of the tube focus precisely. Also in this case there arose no need to draw the outline of the cross section one by one with a pencil, so in order to obtain a smooth outline of the cross section, it was decided to employ Continuous Rotatogram to begin with (Fig. 28). Next, the image C of the light source formed by the convex lens, the

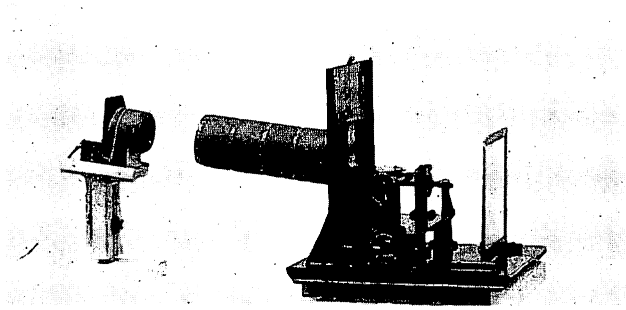


Fig. 29: Continuous Cross Section Radiograph (original method) in action

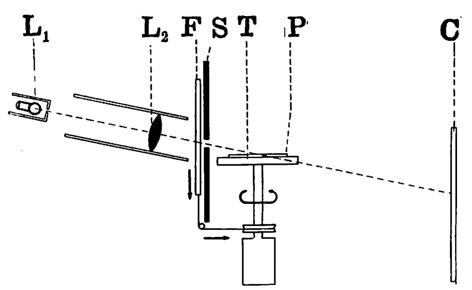


Fig. 30: Schematic representation of Fig. 29
L_1: Light source, L_2: Convex lens, F: Continuous Rotatogram, S: Slit, T: Turn table, P: Photosensitive plate, C: Convergent point of the lens

photosensitive plate P on the rotating table, Continuous Rotatogram F, a sheet of black papers with a horizontally opened slit and the convex lens L_2 were arranged in the above order. In this case the distance between the image of the light source, rotation center of rotating table, slit and Rotatogram were made to equal the distance employed for tube focus, center of rotating table on which the subject was placed, lead slit and X-ray film employed in the initial series of Continuous Rotatography. The light was made to strike the convex lens from a point light source, and this light that passed the lens was made to go through the Continuous Rotatogram and to be projected parallel to the photosensitive plate laid horizontally. Mechanism of sliding of the Continuous Rotatogram and rotation of the rotating table was made to act in strictly the same manner as in the case of original Continuous Rotatography. By the above means, instead of the pencil and paper in Discontinuous Rotatography, light rays and photosensitive plate played the rôle of the sketches obtained by Continuous Rotatogram. By making light to pass parallel to the surface to the photosensitive plate, contrast became poor, while minute irregularities or dusts on the surface of photosensitive plate produced very unfavourable effects on the cross section images. Hence light was projected to the plate at an angle of 7°. This is termed *Continuous Cross Section Radiography, Original Method* (*Kontinuierliche Querschnittsaufnahme*).

Continuous Cross Section Radiograms made by such reproductive operation produces a smooth and well contrasted cross section image that can be observed with satisfaction (Fig. 31 and 32). However, in

Fig. 31: Left: Normal radiogram of the lower arm
Right: Continuous Rotatogram

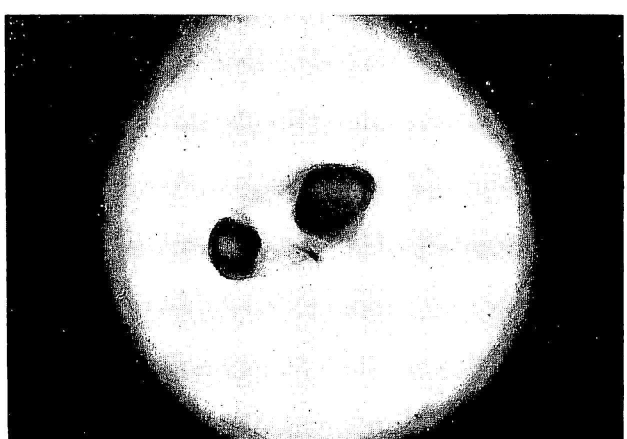


Fig. 32: Continuous Cross Section Radiogram, showing the cross section figure of the lower arm

this method, reproduction of the cross section outline is made indirectly. In addition, during reproduction, light is made to fall on the photosensitive plate at a slant, as theoretically considered, it has the defect of producing cross section images that are slightly blurred. In short, this Continuous Cross Section Rotatography can be considered to be more advanced than Discontinuous Rotatography, but there will be need for further improvement.

D. Direct Cross Section Radiography (Original Method)[50]

In radiography made to produce a cross section in concrete form, the question arises if it is possible to take directly the radiogram of the cross section instead of resorting to indirect procedures of reproduction.

It was mentioned above in the section on Discontinuous Rotatography that the outline of the X-ray image and the actual outline of the subject lay on a straight line of, such as, X-ray or pencil tracing. Hence, in that case, if a second rotating table whose rotating axis lay on an extension of the line joining the tube focus and the standard line was arranged, and if now the drawing paper was placed on the second rotating table, and if this table was made to rotate synchronously with the first rotating table, it should be possible to draw a sketch of the cross section by the same procedure.

The reason why the outline of the cross section of the subject, the outline of the X-ray image of the Discontinuous Rotatogram, and the outline of the cross section made on the second rotating table should be arranged on a straight line (X-ray, pencil tracing or light rays), is that if there exists such a relation between these three actually, there will be no need of a sketch in obtaining the figure of cross section by the method of Discontinuous Rotatography. In other words, without resort to Discontinuous Rotatography, it will be possible to take directly radiograms of cross section only by the procedure of placing the film on a second rotating table. The cross section image here may be constructed not angularly but smoothly, if continuous rotation of the turn table is possible.

However, the tube focus, the cross section of the subject to be taken and the film shall be arranged on the same plane here. The X-ray beam will be projected on the X-ray film with zero degree, in other words, X-ray beams are projected parallel to the film. Thus, the X-rays to be used for delineation of the outline of the cross section will reach film very small in dose.

As a result, there will arise the defect that the contrast of the radiogram will be poor. Such a result was experienced already in the case of Continuous Cross Section Radiography. It was necessary to make the projection of light on the film at an angle of 7° instead of at 0°. Taking into consideration the above mentioned experiences, it was taken the following steps. In order to improve the contrast of the radiogram of the cross section, X-rays were made to strike the film at a right angle instead of projecting them parallel to the surface of the film. For this, the film was placed on the second rotating table whose rotating board faced the X-rays at a right angle, and directly in front of this rotating table was placed a horizontal lead slit of 1 mm in breadth. The rotating axis of the rotating table was made

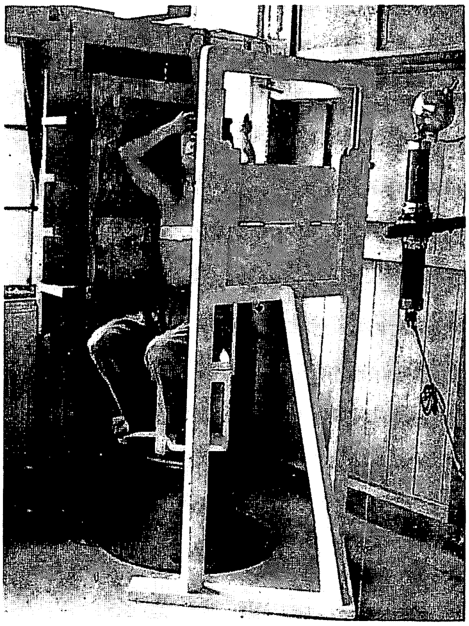


Fig. 33: Direct Cross Section Radiographic apparatus in action (original method)

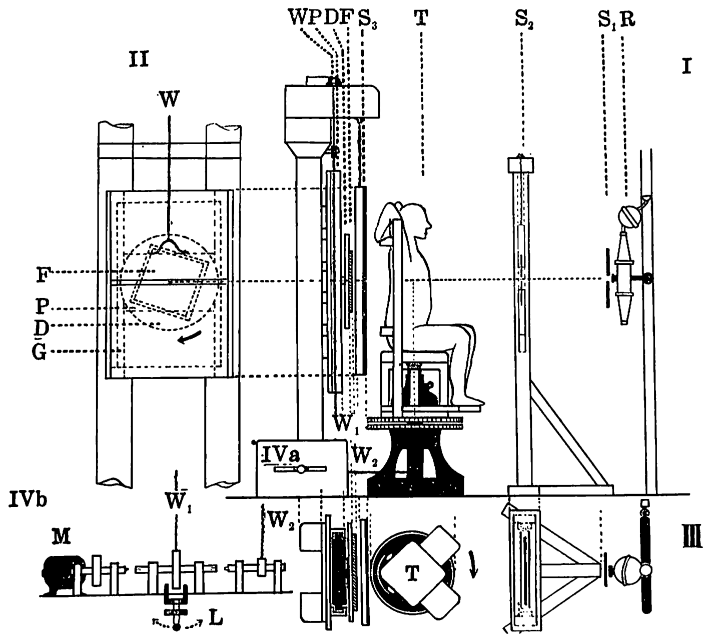


Fig. 34: Schematic representation of Fig. 33
R: X-ray tube, S_1: First slit, S_2: Second slit, S_3: Main slit, T: Rotation table, F: Film, D: Rotation Disc, G: Groove, W: Wire

to correspond with the direction of the line joining the tube focus and the standard line at the Discontinuous Rotatogram (Fig. 33 and 34). The rotating disc D slided smoothly behind the slit of the lead diaphragm along the vertical groove during the exposure. When the rotation table T bearing the subject to be examined rotated with a discontinuous angle of 20°, the rotating disc D on which the film was placed also rotated with the same discontinuous angle. Every time it did, the disc carrying the film was made to slide behind the lead slit and exposed to X-rays. By such means, while the rotating table rotated through 0° to 190° the X-ray images of the cross section of the subject were taken at a rather magnified scale on the film. The above procedure is termed *Direct Cross Section Radiography, Original Method* (*Direkte Querschnittsaufrahme, alte Methode*).

As the film faced perpendicularly the X-rays with no appreciable scattering because of the small narrow irradiation field, a radiogram with good contrast was obtained (Fig. 35). This method, however,

Fig. 35: Direct Cross Section Radiogram of the chest

was time consuming, and the subject was exposed to comparatively large doses of X-rays. In addition, the cross section of the body was imaged angularly in outline.

In this method parallel beams of X-rays were employed. As explained in the section on mechanism of taking the Continuous Cross Section Radiography the X-rays had to be projected on the surface of the film divergently. The X-ray beams were blocked at the position of the lead slit and projected on the film. Thus, it was regarded as X-ray beams projected parallel with each other on the film as the result of bending of X-ray at this position by sliding of film behind the slit. Because of this the images became unsharp, and this defect became greater as the distance of the subject from the rotation center increased. Hence, this method had to be restricted to radiography of comparatively small sized subjects, placed in the vicinity of the rotation center.

E. Rotatory Cross Section Radiography[13)14)48)51)]

In the above Direct Cross Section Radiography (Original Method) contrast was good in the radiogram obtained but there was the clinical disadvantage that the method was time consuming. So, in order to take radiograms with a simple procedure, even contrast was sacrificed to some degree, the idea arose that it might matter little if X-rays were made to strike the film with some inclination. The reason being that in the case of the original method of Continuous Cross Section Radiography, a device was made to make X-rays strike the photosensitive plate at a slant, and by so doing it was possible for us to shorten the time of exposure. Thus in that Direct Cross Section Radiography, the rotating table carrying the film and the one for the subject were both placed horizontally, and X-rays were made to strike the film surface from a position situated slightly above and inclined while the subject and film are rotated not only synchronously but continuously (with discontinuous rotating angle of 0°) through a range of from 0° to 190° (Fig. 1, 36 and 37). Here, in order to avoid unsharp-

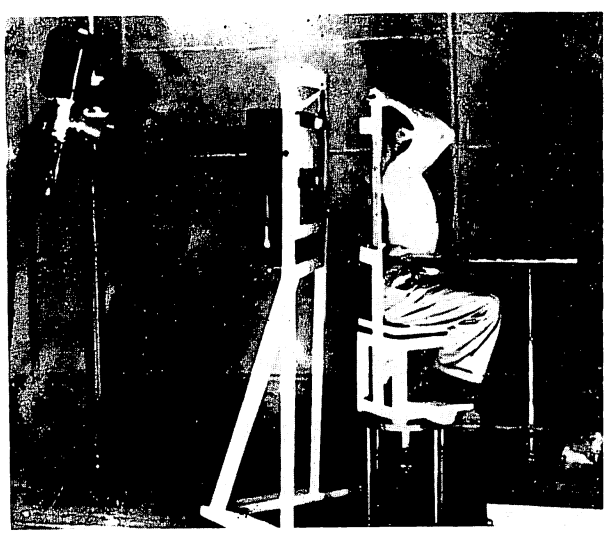


Fig. 36: Rotatory Cross Section Radiograph in action

ness and distortion of the image as much as possible, the angle of the X-ray beams to the film was made as small as possible. At first this inclination of the central X-rays to the film surface was adjusted to 5° or 8° at the most.[13] As the X-rays were projected or the film at an inclination, it was afraid at that time that shadows in thick cross sections would be superimposed because of the wide lead slit used and as a result the radiogram would be distorted and lack sharpness. However, in actual radiography made with an inclination angle of 5°,

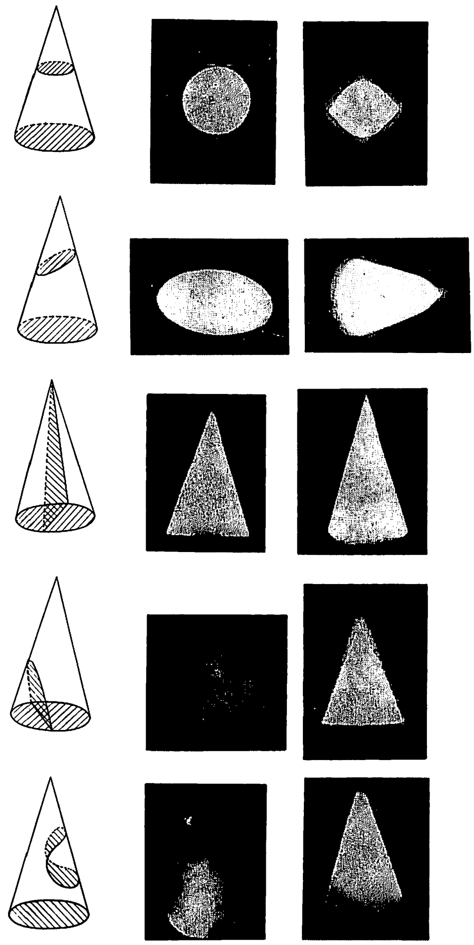


Fig. 37: Rotatory Cross Section Radiogram of a cone,
Left: Schema of the cross section to be required.
Center: Rotatory Cross Section Radiogram
Right: Distorted cross section figure taken by tomography.

though contrast was poor to some extent, the degree of sharpness was not worse than expected. When these results were considered later theoretically, it became clear that formation of the image of the cross section on the film was not influenced by the angle of inclination of X-rays, because the parts beyond the cross section required were found to be shaded according to the mechanism underlying the formation of section figure by tomography.

The method described above is our *Rotatory Cross Section Radio-*

graphy (*Rotationsquerschnittsaufnahme*) (Fig. 38, 39 and 40).

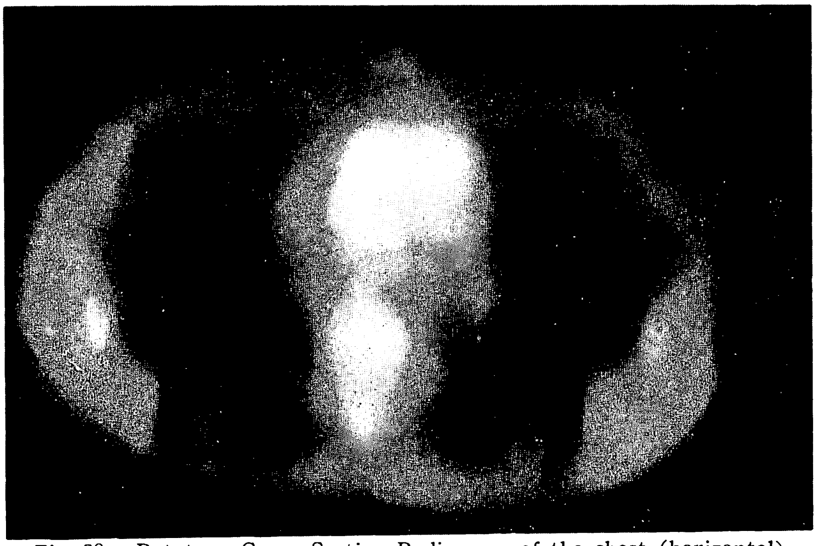


Fig. 38: Rotatory Cross Section Radiogram of the chest (horizontal)

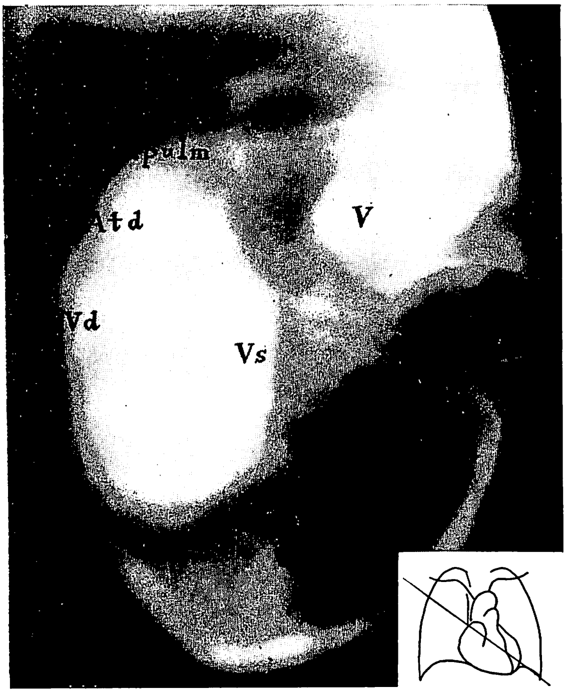


Fig. 39: Inclined cross section figur obtained by Rotatory Cross Section Radiography
A. pulm: Pulmonary artery, Atd: Right atrium, Vd: Right ventricle, V_s: Left ventricle, V: Spine, Bottom right: Schematic representation showing the plane radiographed

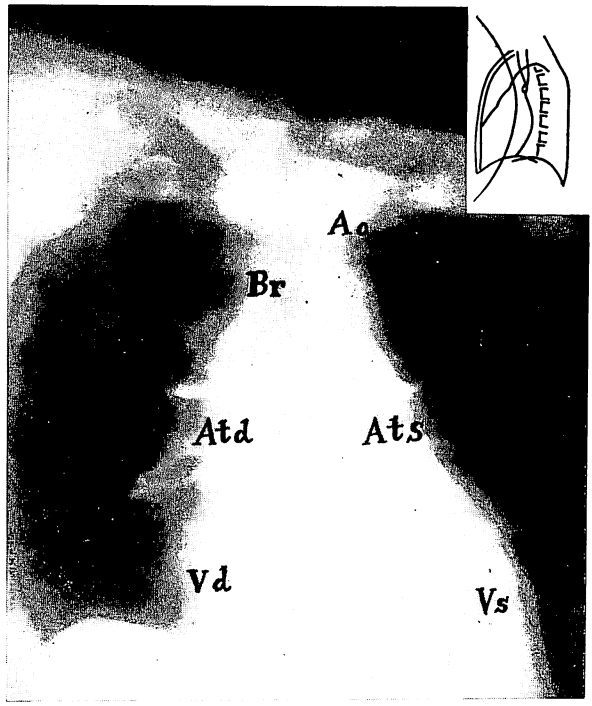


Fig. 40: Curved cross section figur obtained by Rotatory Cross Section Radiography
Ao: Aorta, Br: Bronchus, Atd: Right atrium, Ats: Left atrium,
Vd: Right ventricle, Vs: Left ventricle, Top right: Schematic representation showing the plane radiographed

This method is a new developement of our Rotation Radiography. It was found later that *Watson,*[83] *Vallebona*[74] (*Axiale transverse stratigraphy*) and *Gebauer*[78] (*Transversale Schichtauenahme*) etc. had also been developing the similar method based on tomography.

Rotatory Cross Section Radiography is simple to operate, and the subject to be examined is exposed to only a small dose of X-rays so that it is being used widely in clinical practice. In view of this, among the various types of Cross Section Radiography, special mention will be made of the details of this Rotatory Cross Section Radiography later.

F. Direct Cross Section Radiography (Improved Method)[15)63)]

In Rotatory Cross Section Radiography contrast of the radiogram was not so good and sharpness of the image was somewhat poor when compared with normal radiography.

In order to obtain radiograms with good contrast and sharpness, *Direct Cross Section Radiography, Improved method* (*Direkte Querschnittsaufnahme, verbesserte Methode*) was further devised. In the Direct Cross Section Radiography (Original Method), despite the need for exposing the film to divergent beams of X-rays, the rotating table carrying the film was made to move vertically behind the lead slit. As a result, the X-ray beams became parallel, and thus the X-ray images became unsharp. Therefore, an attempt was made to expose the film to divergent X-rays. Basically this method was similar to that of Direct Cross Section Radiography (Original Method), but here, the rotatory board of the rotating table carrying the film was made to face X-rays perpendicularly as it slided along the groove maintained at an angle of 45° to the horizontal plane (Fig. 41, 42). By such a procedure the rotating table T_2 rose to a height of "*a*" cm vertically as it slided up the inclination, which means that the film receded for a distance of "*a*" cm (Fig. 42). Hence the film placed on the

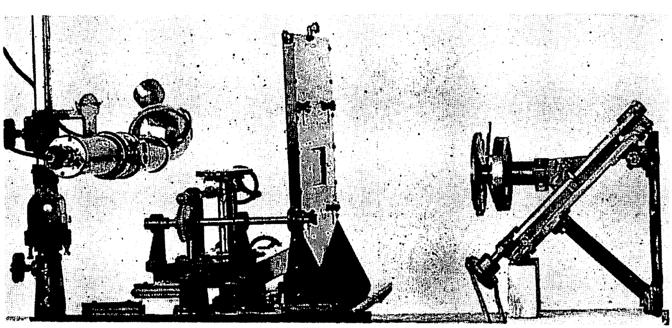


Fig. 41: Direct Cross Section Radiograph (Improved Method) in action

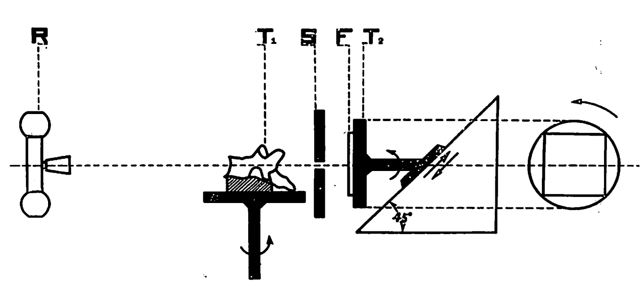


Fig. 42: Sketch of Fig. 41.
R: X-ray tube, T_1: First rotation table,
T_2: Second rotation table, S: Slit, F: Film

rotating table was perpendicular to the rotating table carrying the subject, i. e. the rotating boards of the two rotating tables were perpendincular to each other, and, further, the result was the same as when the film was exposed to natural divergent rays. Also by this method the film was exposed to X-rays perpendicularly to the surface so that the contrast was good. There was no factors for production of halos as by Rotatory Cross Section Radiography and thus sharpness was also good. The cause of unsharpness in this method was only that due to the slit (Fig. 42). Sharpness of the radiogram therefore

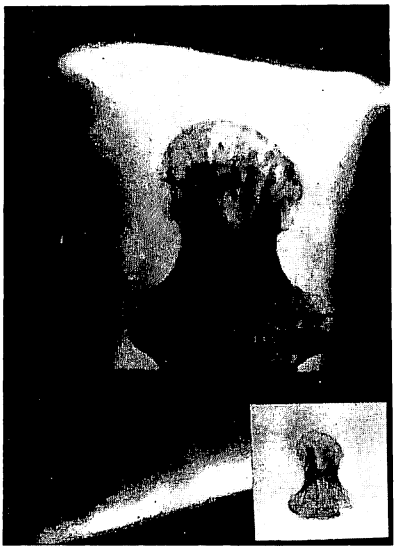


Fig. 43: Bottom right · Normal radiogram of the finger tip
Center : Direct enlargement radicgram (three times)

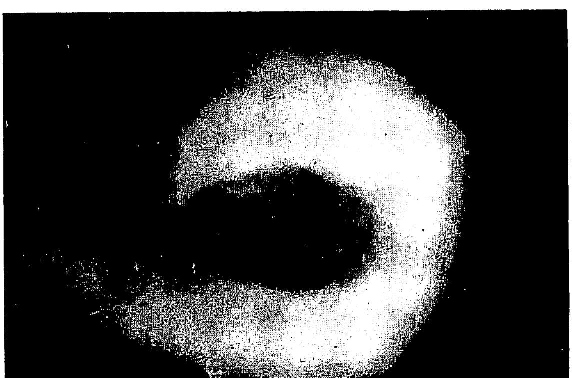


Fig. 44: Direct Cross Section Radiogram (enlarged directly three times) of the finger tip showing sharp X-ray image of trabeculation of the bone

became better as the breadth of the slit was made narrower. This method, however, was time consuming, so, when rapidity of operation was required, the clinical applications will be restricted.

G. Discontinuous Cross Section Radiography (*Indirect Method*)[21)43)63)]

In view of the above, further attempts were made to devise Cross Section Radiography with good contrast and sharpness of image, and, in addition, could be operated within a short time, i. e. one that could be used in the clinic. The method was similar to the Continuous Cross Section Radiography with some improvements. This was operated in two steps.

First, Continuous Rotatography was made.

Then, from the Continuous Rotatogram obtained the cross section was reproduced. The proceedure so far resembled that of Continuous Cross Section Radiography (Original Method). In the original method the light rays which were made to converge with a convex lens were thrown on the surface of the photosensitive plate with a slight inclination. By this inclination the radiograph obtained could not escape being somewhat unsharp, while contrast could not be said to be good. So attempts were made for the sensitive plate to face light rays perpendicularly and to diverge the rays as was done in the case of the original Continuous Cross Section Radiography. To accomplish this the rotating board of the table carrying the plate was made to face the light source. Also the rotation table was made to slide on an inclination at an angle of 45° to the horizontal plane (Fig. 45 and 46). When the rotation center of the rotating table lay on the axis of the light from the lens, the distance between the Continuous Rotatogram and the rotatin center of the rotating table and image of the light source, was made the same as the distance between the film and the tube focus and rotating table carrying the subject in Continuous Rotatography. The procedure was similar to that for Direct Cross Section Radiography. During sliding of rotation table up and down the photosensitive plate was exposed by the light beam passed through the concerned part of the Continuous Rotatogram. When exposure came out, the rotating board of the table was turned 5° and the

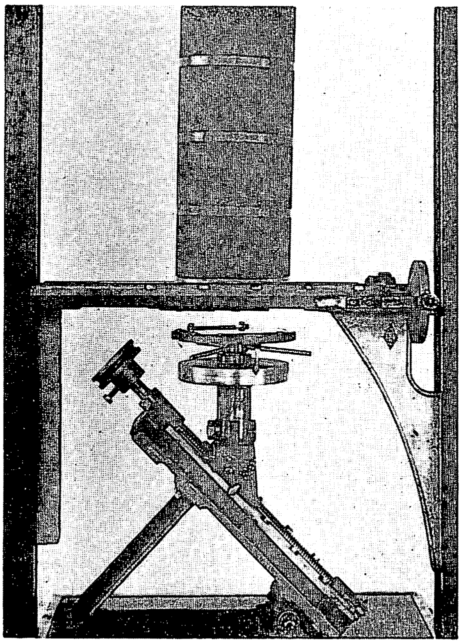


Fig. 45: Discontinuous Cross Section Radiograph in action

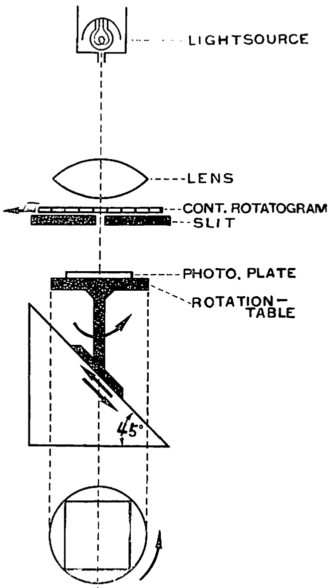


Fig. 46: Schematic representation of Fig. 45

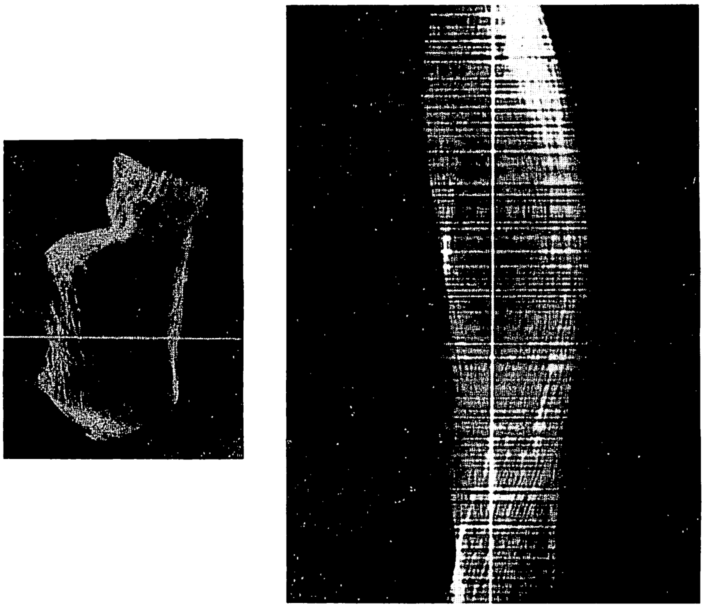


Fig. 47: Normal radiogram (left) and its Continuous Rotatogram (right) of the bone

Continuous Rotatogram was slid as the distance of 5°. Then it was repeated the exposure. This is termed *Discontinuous Cross Section Radiography, Inderect method* (*Diskontinuierliche Querschnittsaufname, Indirekte Methode*).

Sharpness and contrast of a cross section image thus obtained were good (Fig. 48). Here was also sharpness of images influenced mainly by the breadth of the slit. Contrast became better as the sensitive plate was made to face perpendicularly the light beams than made to face at a slant. The sharpness of image was made so

Fig. 48: Discontinuous Cross Section Radiogram of the bone

good that even indirect three times enlarged picture of this cross section image was obtained without loss of sharpness (Fig. 49). This method can be applied in the clinical practice. This type of clinical apparatus is now under construction in our Department. The results obtained will be detailed on the forthcoming paper of the Tohoku J. Exp. Med.

On reviewing the seven methods of Cross Section Radiography it will be seen that the underlying principles are in all cases those for Rotation Radiography. It is therefore requested that rotation be

Fig. 49: Discontinuou Cross Section Radiogram enlarged three times in directly, showing sharpness of the image of the trabeculation of the bone

accurate. And also that the range of rotation be in the range from 0° to 190°.

In Rotatory Cross Section Radiography, for the formation of the cross section image the principle of tomography was also employed, namely that the points on a plane needed are always made to image on the film, and points placed beyond the plane are shaded away as faint curves. Hence, when only such a principle of tomography is concerned, the range of rotation of the tube can be either 10°, 20°, or 360°. However, as the experiments shown in Figs. 13, this rotation requires a range of 0° to 190°, and such a range can be considered to be sufficient. With angles of 10° or 20° the range is obviously not sufficient and there results distortion of the cross section image. Also with a rotation range of from 0° to 190° the radiographs obtained are no different in quality from those taken with a range of more than from 0° to 190°. On the other hand, as described in the section of Direct Cross Section Radiography, even though the principles of tomography are not employed, a cross section image can be formed.

If now the seven methods of Cross Section Radiography are arranged in order, it will be seen that they evolved from the Rotation Sighting Radiography as shown in Table 1.

At present, the most advanced forms of Cross Section Radiography should be the Discontinuous Cross Section, Rotatory Cross Section and Direct Cross Section Radiography. When compared with each other these possess the following merits and demerits (Tab. 4).

Table 4

	Contrast	Sharpness	Enlargement	Distortion	Technique
Rotatory Crossgraphy	good	fair	possible	none	simple
Direct Crossgraphy*	excellent	excellent	possible	,,	complex
Discontinuous Crossgraphy	,,	,,	actual size	,,	comparatively simple

* not to be used clinically

2. *Rotatory Cross Section Radiography in Japan*[13)14)51)99)]

It has been made clear that there are seven methods of Cross Section Radiography. At present, however, Rotatory Cross Section Radiography is the method most widely employed clinically, so that special attention will be paid to it, here.

An explanation has already been given on the practical aspects of Rotatory Cross Section Radiography covering the theory, apparatus, technique of radiography and application in clinical practice. Many publications[62)74)-87),93)-98)] on this method have already appeared. Hence details of the general aspects of Rotatory Cross Section Radiography will be touched upon very slightly, and descriptions restricted to results obtained by the present author that have not so far received much attention, but which can be regarded as important.

In this methods of radiography,[13)51)] two rotating tables are set up, one away from the other. The tube focus is made to lie on the same plane containing the axes of the rotating tables. The subject is placed on the table nearest to the tube and the film is put on the other table.

The two tables are rotated sychronously between 0° to 190° during the X-ray exposure. When the cross section image in which no distortion can be seen is compared with the actual body, the image that results is enlarged in the ratio of $\frac{a+b}{a}$, where a is the distance between the tube focus and the subject table and b the distance between tables of the subject and film. The cross section of the subject radiographed will be a layer containing the point where the rotation axis of the table intersects the line joining the tube focus and the rotation center of the film.

This layer is parallel to the film. Therefore if the film is placed horizontally on the rotating table, a horizontal cross section of the subject will be obtained. If the film is placed on the table at a slant, then an inclined cross section is obtained and if the film is curved, a curved cross section will be obtained (Fig. 37, 39 and 40).

In Japan, Rotatory Cross Section Radiography differs from that in other countries in that it did not evolve from tomography but developed step-by-step from Rotatography, so that actually the apparatus and technique used in Japan can be said to be characteristic of this country. Therefore, first our apparatus and technique will be described.

A. Apparatus

a). Small Tube Inclination Angle

Inclination of the central X-rays towards the surface of an X-ray film (hereafter tentatively called, *tube inclination angle*) which is placed horizontally on the rotating table is usually made at an angle of about 15°. Such a small angle makes the layers of the cross section too thin for good contrast and sharpness. However, the use of a small angle helps to effectively remove most of the obstrcutive rib shadows which are responsible for many errors in diagnosis of the chest by Rotatory Cross Section Radiography. As the present writer believes that the most important step for correct diagnosis is to make Rotatory Cross Section Radiograms showing no obstructive shadows, the small inclination angle was used. This decision may have also been influenced by the fact that we started this type of radiography using tube inclination angles of 5° to 8° (III, 1, E), during the progress of our Rotation Radiography.

b). For Radiography of the Cross Section, a Normal Radiographic Unit is Attached.

When undertaking Rotatory Cross Section Radiography, a normal radiogram previously taken is not of much help in radiography of a cross section containing a diseased focus. This is because X-ray beams are not parallel each other, but divergent. In other words, the positions of the foci are not imaged the same as those placed on layers parallel to each other in the body.

A horizontal wire is affixed on the front surface of the casestte. This wire is adjusted to the position to be cross sectioned, then the film in the cassette is exposed to horizontal central X-ray. The above helps to confirm whether or not the diseased focus is in the cross section. If the normal radiography is made before or after Cross Section Radiography has been made, then the focus is in allignment with the horizontal line on this normal radiogram and it will become easy and certain to adjust the position of the focus on the horizontal plane to be cross sectioned.

c). Apparatus for Radiography of Inclined or Curved Cross Section

A stand with an inclined or curved surface is put on the radiographic table so that it can be easily removed. In other words, an inclined or curved holder for the film is put on the table. The center of this inclined holder is made to coincide with the rotating axis of the rotating table. When the inclined cross section of the subject is to be taken, normal radiography is first made. After this, the rotating table is turned 90°, and Rotatory Cross Section Radiography is made when the required inclined cross section (or curved cross section) is determined in this way.

In the writer's opinion, the inclined or curved cross section figure will be difficult obtained by existing tomography. When tomography is applied especially to the chest, a section figure with much distortion will be obtained due to obstructive shadows. The section figure here can present none existed within the body.

When undertaking an Inclined Cross Section Radiography it will be necessary to make rotation with the film in the inclined position, so that actually the surface of the film exposed will be that directly facing the beam of X-rays, i. e. that within a range of 180°. Therefore, X-ray exposures are made within this range of rotation. Also, the dose of X-ray on the surface of the film will vary with the rotation. In other words, the part exposed to X-ray will originally be almost parallel to the X-ray beam, gradually becomes perpendicular, to again become parallel. Therefore during 180° rotation, if the exposure is kept uniform it will not be possible to take clear radiograms of inclined cross sections, and the need arises to adjust the exposure so that all surfaces of the film receive uniform doses of X-ray.

Actually during 180° rotation the exposure conditions are changed five times, while 15 seconds are needed for rotating from 0° to 180°. Below will be an example of the radiography of the adult human heart made at an inclination angle of 30°. In keeping constant a tube current of 25 mA, kilovoltage of tube terminal is changed according to the angle of the central X-ray to the surface of the cassette at 90 kV from 0° to 40°, at 70 kV from 40° to 70°, at 60 kV from 70° to 110°, at 70 kV from 110° to 140° and at 90 kV from 140° to 180°.

d). Manufacture of Horizontal Type of Universal Rotatograph for Cross Section Radiography

For Rotatory Cross Section Radiography, an erect type of apparatus was produced for trial at first. However, in order to hold the subject in an easy position during radiography, there arose the need to have an apparatus that could take Rotatory Cross Section

Radiograms in a horizontal position. Such a horizontal type was therefore prepared for trial, and it is now being used in practice (Fig. 2, bottom left)

e). Variable Focus Tube

From the usual X-ray tube, a variable focus tube with a three-electrode vacuum tube is made in which the electron beam emitted from the heating filament is narrowed through a convergent effect phenomenon caused by a negative electric potential of the focusing cap. By usiug this tube the size of the focal spot can be changed freely. At present a focal spot with effective size 5×5 mm can be made up to 0.15×0.15 mm in the effective size. Radiography of the chest and neck is being made with a focal spot of 1 mm, and that of the head and abdomen with one of 2 to 3 mm.

B. Technique

a). Range of Tube Rotation

The tube was rotated from $0°$ to $190°$, especially in the horizontal Rotatograph. *Janker*[34] also published his views which agreed with our technique.

b). Exposure Time

An exposure time of 4 to 8 seconds is used. The reason is that if the rotation is made too fast, there might be occured contrary movement of the subject and also the rotating apparatus will be overtaxed.

Sharpness of the image is not so much lost through prolongation of the exposure time.

c). High Voltage Radiographic Technique[44]

Through high voltage radiography, the details of the pulmonary markings, the structure of the mediastinum and areas close to the pulmonary hilus become clear. Recently our attention has been paid to the fact that high voltage radiography with 140 kV easily removed the obstructive rib shadows on the radiogram of the chest even with the tube inclination angle of 30 degrees.

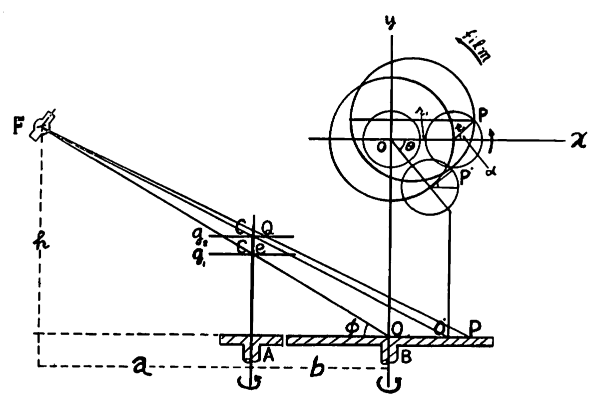
3. *Theoretical Consideration of Blurring of X-ray Images and Occurrence of Obstructive Shadows in Rotatory Cross Section Radiography*[13)18)57)]

Concerning the mechanism accounting for the occurrence of blurred images or obstructive shadows in Rotatory Cross Section Radiography, the writer studied this theoretically as well as experimentally, because of its importance as basics in this field. With reference to three cases a discussion will be made, namely: a) a point placed beyond the plane to be cross-sectioned, b) a curved line or a plane involved in a plane parallel to the plane to be cross-sectioned and c) a curved line or a plane involved in a plane inclined to the plane to be cross-sectioned.

A. A Point Placed beyond the Plane to be Cross-sectioned

In Rotatory Cross Section Radiography, a point, which is involved in the cross section, namely, the plane g_1 is imaged as one point. A point placed beyond this plane, however, is blurred into the locus of a circle. (*Wachsmann*[79)], *Takahashi*[13)], *Vieten*[86)]).

The position of the center of this circle is determined in the following way (Fig. 50).



Fig, 50: Diagram showing the mechanism accounting for the occurance of the blurred image in Rotatory Cross Section Radiogram of a point

The rotation center C of plane g_1 is projected on the rotation center 0 of the film as shown at the top right of Fig. 50, while the rotation center C_1 of the plane g_2 is imaged as point 0′ on the film.

Point Q on plane g_2 is projected on the film and imaged as point P. Rotating around point 0, Point 0′ itself is encircled by the rotating point P. Let 00′ be the abscissa x, and a line, intersecting at a right angle with 00′ at 0, be ordinate y. Let the inclination of $O'P$ to abscissa x be α. Let the length of OO' be r_1 and that of $O'P$, r_2. Let us first suppose that only the circle r_2 rotates around O' counterclockwise at an angular velocity of ω and that the film is kept stationary. Then the point (x, y) is determined by the following formulas:

$$x = r_1 + r_2 \cos(\omega t + \alpha)$$

$$y = r_2 \sin(\omega t + \alpha).$$

Next, suppose two new axes to rotate around the origin O counterclockwise at the angular velocity ω, then the point (X, Y) referred to the new axes will be:

$$x = X \cos \omega t - Y \sin \omega t$$

$$y = X \sin \omega t + Y \cos \omega t$$

Elminate x and y from the above formulas, and there will be obtained

$$(X - r_2 \cos \alpha)^2 + (Y - r_2 \sin \alpha)^2 = r_1^2$$

As this is the equation representing a circle, the coordinates of the center of a circle in this case are the point

$R(r_2 \cos \alpha,\ r_2 \sin \alpha)$ .... (III, 3, i).

If the center of this circle is required for drawing a figure, construct the parallelogram $OO'PR$, and the vertex R will result.

The radius $R(=r_1)$ of the circle is deduced geometrically from Fig. 50.

$$R = \frac{(a+b)e}{a \tan \varphi - e}$$ ...(III, 3, ii) (*Takahashi*[13], *Vieten*[87])

a: Target-body table distance

b: body table-film table distance

φ: inclination of the central X-ray to the horizontal film surface

e: distance between plane g_2 and plane g_1

Here, regarding the point involved in the cross section, namely, the plane g_1, e is equivalent to zero in this formula. Consequently the point is imaged as one point, because R assumes a value of zero.

B. A Line or Plane Involved in Plane g_2 parallel to the Plane g_1 to be Cross-sectioned.

A line or plane of lead of 0.1 mm thick was used for a object in the experiment.

a). A Line

A line may be considered as a one-dimensional arrangement of numerous points. When radiographed normally, it is imaged on the film as the line PQ. Any point R on this line PQ is blurred into a circle with the length of radius OO' and with the center corresponding to the vertex R' of parallelogram $OO'PP'$ (Fig. 51).

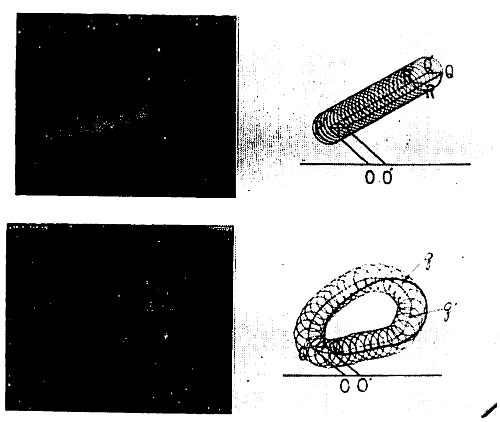


Fig. 51: Rotatory Cross Section Radiogram of a line placed parallel to, but beyond the plane to be cross sectioned
Top: Straight line, Bottom: Curved line

The center R' will draw a locus $P'Q'$, which is parallel to the line PQ. Therefore the line PQ blurs as numerous circles with their centers arranged on the line $P'Q'$ are drawn. The circles intersect with one another. The outermost brim of these circles corresponding to their envelope is deepest in shade because of superimposition. Therefore a line placed in the plane g_2 parallel to the plane g_1 is taken on the Rotatory Cross Section Radiogram as two lines parallel to each other.

The distance between the images of the two lines is $2R$. These lines are different in their appearance from the nucleus shadow or usual obstructive shadow in tomography. Accordingly, each of these is termed *line shadow* (*Linieschatten*) ························(III, 3, iii)

b). A Plane

A plane is, so to speak, a two-dimensional arrangement of lines. The blurred circle of points on the perimeter situated inside, at a distance of ΔR from the contour of the plane in question, intersects with the circle of one on the contour of the plane. So the density of the blurred area is made even from the outer side to the inner, and becomes homogenous (Fig. 52).

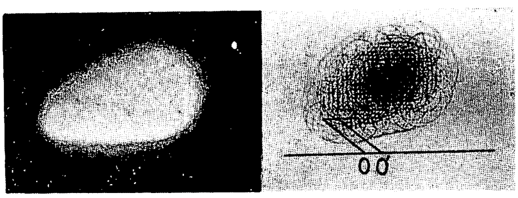


Fig. 52: Rotatory Cross Section Raciogram of a plane involed in a plane parallel to the cross section

In the zone $2R$ broad and just inside of the contour of the blurred area, there remains a deeper shadow caused by the concurrence of blurred circles at the center of the image. This area is called the nucleus shadow. ··(III, 3, iv)

C. A Line or a Plane Involved in a Plane Inclined and Intersected to the Plane to be Cross-sectioned

a). A Line

The line in this case is to be considered as an array of points in numerous planes piled at the variable distance e from the plane g_1. Then the length of radius R of a blurred circle is variable according to the position of the point, and the center of a circle moves its position according to the length of the radius as shown in Fig. 53. Thus, when a straight line is placed inclined to the plane to be cross-sectioned, the blurred shadow is imaged as two straight lines, *line shadows*, intersecting with each other. The intersecting point corresponds to the cross section of this line. ··················(III, 3, v)

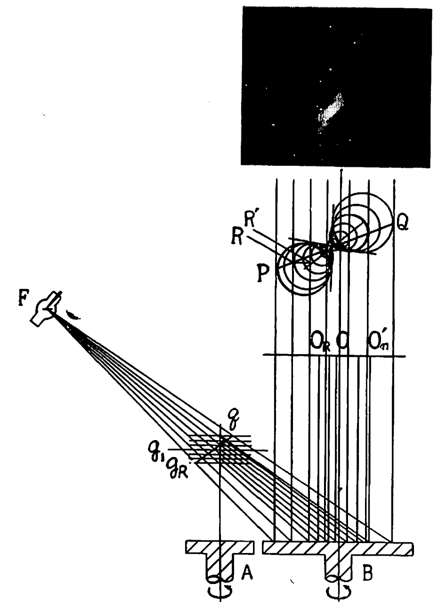


Fig. 53: Diagram showing the mechanism occurring the line shadow of a straight line inclined to the cross section

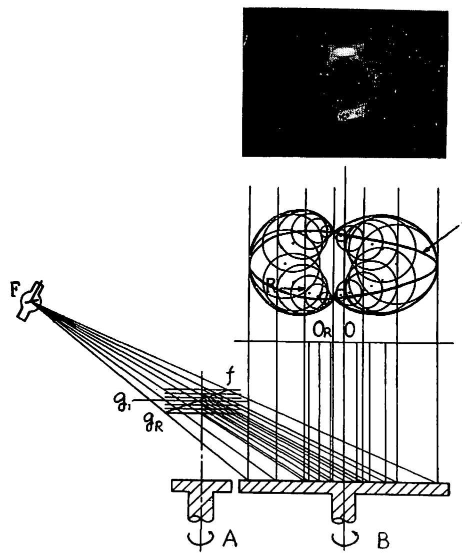


Fig. 54: Diagram showing the mechanism occurring the line shadow of a closed curved line inclined to the cross section

The intersecting angle of the two lines represents the inclination of the line to the plane cross-sectioned. ……………………(III, 3, vi)

When a plane involving a closed curved line f is inclined to the plane to be cross-sectioned and is taken by Rotatory Cross Section Radiography, this curved line is imaged as two closed curves of crescent shape (Fig. 54). This is another case of a *line shadow*. They are connected with each other or by each of their sharpened ends.

These two nodal points also correspond to the cross-sectioned points of the closed curved line.

b). A Plane (Fig. 55)

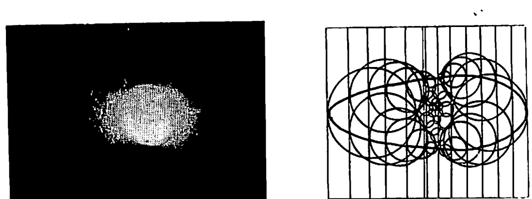


Fig. 55: Rotary Cross Section Radiogram of a plane inclined to the cross section

When a plane is inclined to the plane to be cross sectioned, it is blurred as shown in Fig. 55. The blurred X-ray image is homogenous in density and leaves a nucleus shadow at its center.

4. *Quality of the X-ray Image of Rotatory Cross Section Radiogram*

In vestigations it was first made to ascertain what factors most influence contrast, sharpness and exihibiting power, etc. in Rotatory Cross Section Radiogram. These were further compared with those of normal radiography and tomography, and their differences were discussed.

The apparatus used for this experiment was an erect type of Rotatory Cross Section Radiographic apparatus made for model experiment. (Fig. 56) The rotating boards of the two rotating tables

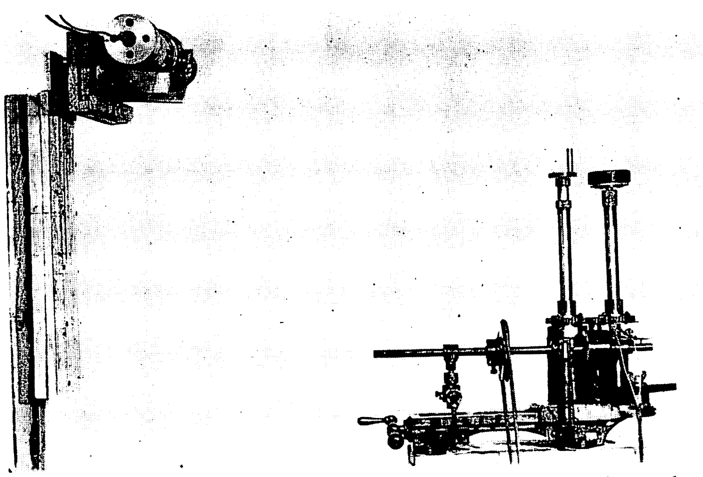


Fig. 56: Erect type of Rotatory Cross Section Radiograph for model experiment

can be elevated approximately to the level of the tube focus. The rotating board carrying the subject is adjusted to variable heights by a microelevator.

When the two rotating tables are made to rotate synchronously through $-30°$ to $+30°$, the procedure will correspond to that of a tomography characterized by an arc movement of 60° rotation of the tube where scale 0° corresponds to the direction of the central X-ray.

In the present experiment a tube having an effective focus of 5×5 mm and intensifying screen with sensitivity of 0.512 and with sharpness coefficient of 0.389 were used. The distance between tube focus and nearer rotating table was 67.2 cm, and the distance between the tube focus and the distant table was 74 cm.

A. Contrast[32)]

Contrast in a Rotatory Cross Section Radiogram is controlled by all the factors that influence contrast of a normal radiogram, but a specific factor of this type of radiography, viz, thickness of the cross section layer, also has some influence on contrast. For example, when the layer sectioned is thick, contrast of the radiogram is good and when the layer is thin, it is poor. Whether the layer is thin or not is determined by the degree of blurring.

If the points are placed outside the required cross section with the distance of e, blurring occurs with the arc of radius $R=\frac{(a+b)e}{a\tan\varphi-e}$ (III, 3, ii). In order to have a small value of R in relation to a certain e, the distance a between tube focus and subject should be relatively small in relation to the distance b between subject and film. Then the enlargement ratio of the X-ray image on the radiogram becomes great, and at the same time the penumbrae become also large with resultant blurring of the X-ray image. The tube inclination angle φ is an important factor for the length of R. Thus, to investigate the influence of the tube inclination, the following experiments were undertaken. As subject an aluminium cylinder with a diameter of 10mm and a length of 40 mm was used in an upright position. The film was placed horizontally and Rotatory Cross Section Radiography was taken with the inclination of the central X-rays to the horizontal film surface at angle φ of 30°, 15°, 10° and 8°. The exposure was so adjusted that the ground density of the film became 2.0, and the radiograms taken in this series together with the control films were developed at the same time. A microphotometer was used to measure the density of the X-ray image on the films, and the difference in density between the X-ray image of cylinder and ground density, i. e. the contrast, was examined (Fig. 57). The results are shown in Table 5.

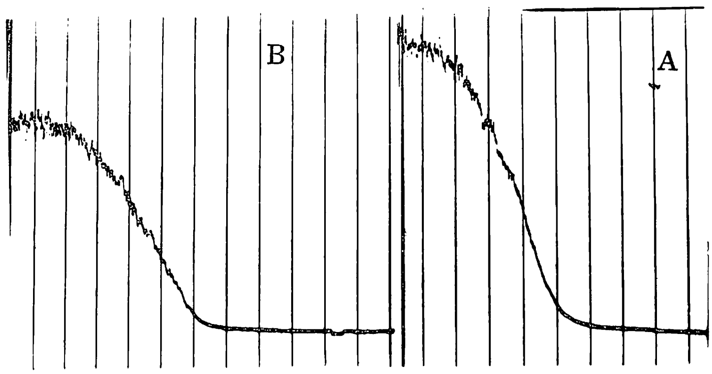


Fig. 57: Densograms of the Rotatory Cross Section Radiogram of an alminum cylinder taken with the tube inclination angle of 30° (A) and that of 15° (B).

Table 5
Contrast of Rotatory Cross Section Radiogram

Tube Inclination angle	F_4DB_1	D
30°	1.151	0.778
15°	0.851	0.501
10°	0.615	0.288
8°	0.500	0.159

In Tab. 5, column *D* indicates films exposed without intensifying screens, column F_4DF_1 representing the contrast of Rotatory Cross Section Radiogram taken with double screens. Contrast decreased as the inclination angle of the tube became smaller. Again, when Rotatory Cross Section Radiography was made at the same tube inclination angle, contrast was better when an intensifying screens were employed, as compared with that when it was not used.

Contrast in tomography was not so good as in normal radiography. Contrast of tomography was compared with that of Rotatory Cross Section Radiography. For this comparison, tomographies were made of the same subject under identical radiographic conditions using the same radiographic apparatus. The result of this experiment offers the following value of contrast at 40°, 60° and 90° of tube inclination angles in tomography (Tab. 6). Contrast value was obtained by comparing the density of an aluminum cylinder and the ground density of the film.

Table 6
Contrast of Tomogram

Range of tube rotation	F_4DB_1
40°	1.70
60°	1.68
120°	1.25

It can be seen here that contrast in tomography becomes worse as the range of tube rotation is increased.

When the results of Table 5 and 6 are compared, it will be noted that contrast of a tomogram made at a rotation angle of 60° is superior to that of a Rotatory Cross Section Radiogram taken at a tube inclination angle of 30°, when the same intensifying screens are employed, and that of tomogram at 60° is far superior to a Rotatory Cross Section Radiogram taken at tube inclination angle of 15°.

B. Sharpness

In Rotatory Cross Section Radiography, the same factors as those in normal radiography influence sharpness of the image. The following two special factors also influence sharpness in Rotatory Cross Section Radiogram.

a). Blurring Arising from the Mechanism of Formation of the Cross Section Images[23]

In Rotatory Cross Section Radiography, points outside the required cross section show a circlar blurring (III, 3, i), but when the blurring has a sufficient contrast to be recognized, then it is superimposed on the image of the cross section and forms a layer. This is the cause of lack of sharpness arising in X-ray images of this type of radiogram.

A brass cylinder with a diameter of 10 mm was subjected to Rotatory Cross Section Radiography at various tube inclination angles (30°, 15°, 10° and 8°), and the densities of the radiograms were measured by a microphotometer of recording type. In this experiment, the exposure was adjusted so that the ground density and the density of the cross section of the brass cylinder were 1.3 and 0.2 respectively, and sharpness was measured by the tangent of the *S*-shaped density curve (Fig. 58 and 59).

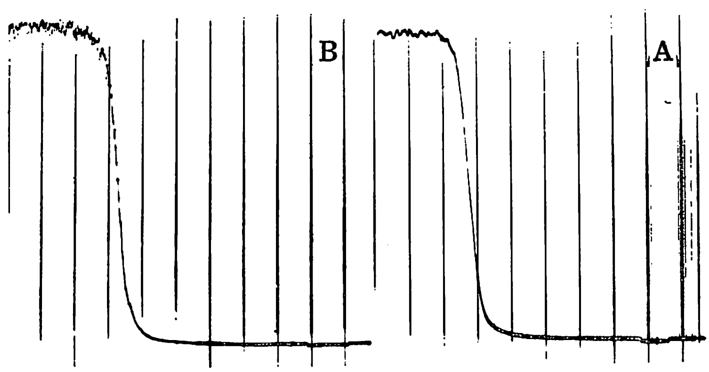


Fig. 58: Densogram of Rotatory Cross Section Rodiogram of a brass cylinder taken with the tube inclination angle of 15° (A) and that of 30° (B).

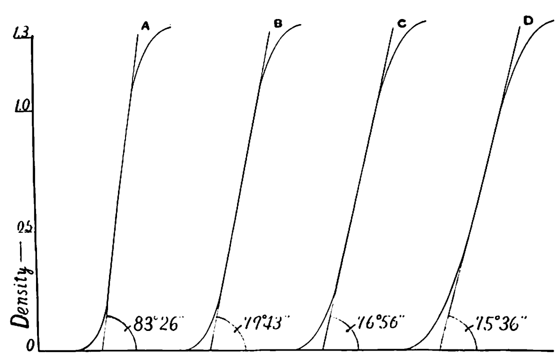


Fig. 59: Schematic representation of Fig. 58.
A: Tube inclination angle of 30°,
B: Tube inclination angle of 15°
C: Tube inclination angle of 10°
D: Tube inclination angle of 8°

On the other hand, lead plate, one edge of which was sharp, was placed vertically between the tube focus and the film at a distance of 100 cm, and several normal radiograms were taken with the plate gradually moving away from the film. It was then found that the sharpness of the X-ray image of the lead plate edge gradually became worse. Sharpness of this X-ray image of the lead edge was measured and compared with the images obtained by Rotatory Cross Section Radiography and tomography. The X-ray images taken by Rotatory Cross Section Radiography showed changes in sharpness according to the tube inclination angle as indicated in Table 7.

Table 7
Sharpness of Rotatory Cross Section Radiogram

Angle of tube inclination	F_4DB_1	D
30°	83°.26″ (87.0)	86°.20″ (93.0)
15°	79°.43″ (79.2)	85°.55″ (92.2)
10°	76°.59″ (72.5)	85°.41″ (91.3)
8°	75°.36″ (70.2)	85°.29″ (91.0)

Next, with the same apparatus and conditions for Rotatory Cross Section Radiography, tomography was made as the tube was moved in the range of 120°, 60° and 40°, and the results obtained were as shown in Table 8.

Table 8
Sharphness of Tomogram

Range of transfer of X-ray tube	Film a. int. screen	Sharpness
40°	F_4DB_1	84°.54″ (89.9 cm)
60°	„	84°.18″ (88.7 „)
120°	„	80°.13″ (80.3 „)

From the two Tables the following conclusions can be drawn.

In Rotatory Cross Section Radiography, sharpness of the image becomes poorer as the tube inclination angle becomes smaller. In respect to sharpness, the tomogram taken with tube movement of 60° is similar to that of the Rotatory Cross Section Radiogram taken with a tube inclination angle of 30°. Sharpness in Rotatory Cross Section Radiogram is superior when intensifying screens are not used and, in addition, is influenced little by the tube inclination angle.

Sharpness of Rotatory Cross Section Radiogram taken with a tube inclination angle of 15° and the distance between focus and film at

100 cm, is similar to that of a normal radiogram with the penumbrae produced when the distance between tube focus and object is 80 cm.

b). Blurring due to Intensifying Screen[20]

In Rotatory Cross Section Radiography, the blurring caused by the intensifying screens also contribute to the degradation in sharpness of image. The reason for this is that the X-rays are projected on the film surface through the layers of intensifying screens at a slant.

A small lead disc with thickness of 0.1 mm and diameter of 1.5 mm was used as a subject. A film coated on one side, or a duplitised film, or on a single coated film with a single intensifying screen or a duplitised film held between two screens were used. Cross Section Radiography was made. At the actual Rotatory Cross Section Radiography, the film was covered along one edge for 1 cm wide with a lead plate about 1 mm thick for partial interruption of X-rays.

Here, if the ground density of the Rotatory Cross Section Radiogram is $S\max$, the density of the small lead disc is So, and the density of the film under the lead plate is Sz, then the sharpness index of the X-ray image of the small lead disc will be $\dfrac{S\max - Sz}{S\max - So}$.

This formula is a modification of the *sharpness index* obtained by Rudginger and Spiegler's method.[89]

In an actual experiment, it was difficult to adjust the position of the thin lead disc exactly on the correct cross section, and the disc was moved by a microelevator attached to the rotation table at exact intervals of 0.05 mm so that the disc would approached gradually the correct cross section level.

The sharpness index of the image of the disc was small at the beginning but it became gradually increased as the disc approached the cross section. The index decreased gradually again after the maximum was reached (Fig. 60 and 61).

The fact that, despite the small sharpness index at the beginning, the index increased with the lifting of the film by a microelevator, indicates that the small disc approached the correct cross section gradually. The maximum value of the sharpness index represents the

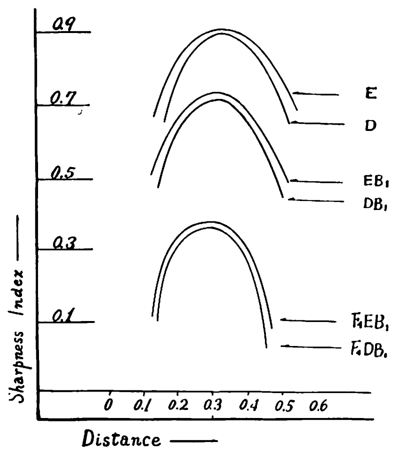


Fig. 60: Curve of sharpness index of Rotatory Cross Section Radiography taken at the tube inclination angle of 30° E: Film coated on one side, D: Duplitized film, F: Intensifying screen (front), B: Intensifying screen (back)

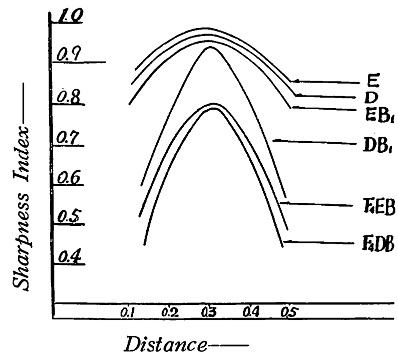


Fig. 61: Curve of sharpness index of Rotatory Cross Section Radiography taken at tube inclination angle of 15°. E: Film coated on one side, D: Duplitized film, F: Intensifying screen (front), B: Intensifying screen (back)

approximation of the hitness of the position of the disc to that of the cross section. The change in sharpness can be shown as a curve on the abscissa. Hence, the values of the acme of the respective curves was considered to represent the sharpness index in the experiments. When the values of sharpness indixes were compared, it was found that an X-ray film with one surface coated (without intensifying screen) showed the best sharpness index, followed by that of the duplitized film only. Then the sharpness index decreased with the two-sided coated film with back screen, the single coated film with double screen, and two-sided coated film with double screen, in that order.

Further it was found that Rotatory Cross Section Radiograms made with the tube inclcnation angle of 15°, when compared with the one taken at an angle of 30°, showed a considerable difference in sharpness index, especially when a duplitized film with double screen was used. Thus it becomes clear that when existing intensifying screens are used in Rotatory Cross Section Radiography, the blurring due to the screen strongly influences the X-ray image, and it is neccessary to use a screen as thin as possible.

C. *Exhibiting Power*[33)]

As previously stated, contrast and sharpness in Rotatory Cross Section Radiography are not very good. But it is more important to know how this method can detect the diseased foci. In order to actually recognize a diseased focus within the body, examinations were made to determine the grade of *exhibiting power* (*Darstellbarkeit*) in Rotatory Cross Section Radiogram. The threshold of exhibiting power for a single cavity placed in the homogenous opaque medium is best in the normal radiogram, followed by tomogram and Rotatory Cross Section Radiogram. For example, in a mass of beeswax of 8 cm in diameter, holes of different diameters (1.92 mm, 1.2 mm and 0.96 mm) were arranged on the same plane, and this was used as the subject. Employing an experimental apparatus of Rotatory Cross Section Radiography, this beeswax mass was radiographed by normal radiography, by tomography (tube transfer in the range of arc of 60°), and by Rotatory Cross Section Radiography. Using films of ground density of 1.2, the images of the hole were compared with each other. It was the purpose of this experiment to know what size of cavities would be imaged and recognized. The results showed that the cavity with diameter of 0.96 mm appeared as a clear image in normal radiogram, but in the tomogram a cavity of 1.2 mm in diameter, and in Rotatory Cross Section Radiography one with a

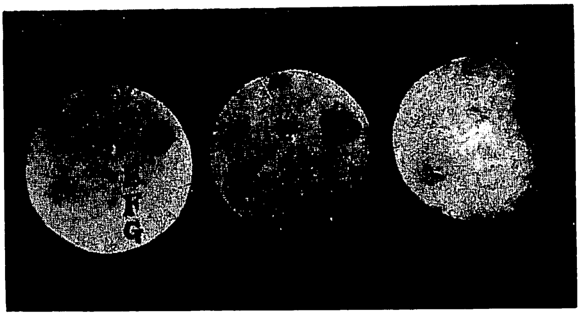


Fig. 62: Normal radiogram (left), Tomogram (center) and Rotatory Cross Section Radiogram (right) of cavities in a beeswax, showing the threshold of exhibiting power
E: Cavity of 1.92 mm in diameter,
F: Cavity of 1.2 mm in diameter
G: Cavity of 0.96 mm in diameter

diameter of 1.92 mm, could be recognised as holes (Fig. 62). Thus, in a substance like beeswax whose contrast is as poor as that of soft tissue, tomography showed slightly better contrast, and had a slighty higher threshold of exhibiting power than Rotatory Cross Section Radiography.

D. Distortion[33)]

Regarding contrast, sharpness and exibiting power of radiogram, Rotatory Cross Section Radiography is inferior to tomography, but is superior in the respect of distortion of the X-ray image. In other words, in Rotatory Cross Section Radiography there is no distortion of the X-ray image, contrary to which in tomography the image is frequently distorted.

A small beeswax model was made into a cavity having a wall thickness of 2 mm and external diameter of 20 mm.

Then Rotatory Cross Section Radiography was made through various cross sections at intervals of 2 mm. In this way the pole of the globe, when radiographed, appeared as a point. With the advancement of the cross sectioned level to the equator of the globe, the point image changed its shape to a circle and the diameter of the circle increased in size, and decreased again with further advancement of the level of cross section after passing the equator. Whereas, in tomography, only when the level of the cross section corresponded to the equator of the globe was a sharp X-ray image of a circle obtained. When the level of cross section moved towards the pole for a distance

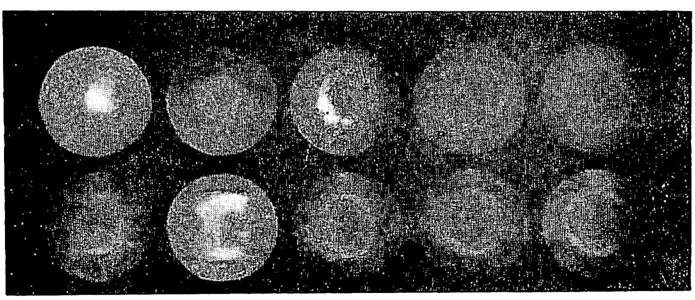


Fig. 63: Rotatory Cross Section Radiogram (top), showing no distortion of the X-ray image, and tomogram (bottom), showing distortion of the X-ray image of a beeswax cavity encircled with thin wall

equal to one half the radius, the cross section image lost its circular outline and became a double image consisting of two circles forming an oval. The pole did not appear as a point in X-ray images (Fig. 63).

Again, when a beeswax model cavity with a wall thickness of 10 mm and an external diameter of 48 mm was taken by Rotatory Cross Section Radiography at 2 mm intervals, the images showed circles the same as in the case of cavities with a thin wall. Contray to this, in tomography, a circular image was obtained only when the section was cut across the equator, and blurred cavity images were obtained in other sections. Further, even when the level of section lay outside the poles of the cavity, a dull outline of the cavity image was also obtained (Fig. 64).

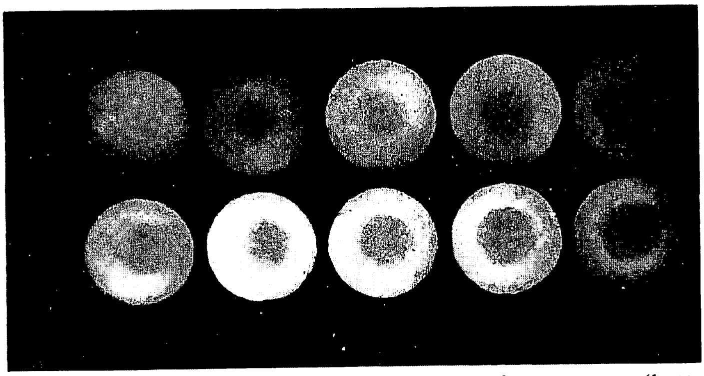


Fig. 64 Rotatory Cross Section Radiogram (top) and tomogram (bottom) of a beeswax cavity encircled with thick wall, showing no distortion (top) and distortion (bottom) of X-ray image

Next, a subject made of paraffin in the form of a cylinder with diameter 10 mm and length 40 mm, was put upright on a rotating table and the film placed horizontally, the horizontal cross section of the cylinder appeared as a circular image in the radiogram. When the cylinder was inclined at 45° the image obtained was oval. When, however, this inclined cylinder was tomographed, the image did not become oval but was spindle shaped, i. e. was distorted (Fig. 65).

From these experiments it became clear that Rotatory Cross Section Radiography produced an actual cross section figure accurately, but tomography did not.

Fig. 65: Rotatory Cross Section Radiogram (left) and tomogram (center) of a parraffin cylinder stood at a slant. Horizontale Rotatory Cross Section Radiogram (right) of the cylinder

E. Obstructive Shadow Occured Especially in Radiography of Chest[19]

In Rotatory Cross Section Radiography there is no distortion of the X-ray image, but obstructive shadows may appear. Especially in radiography of the chest in which this type of radiography can be mostly applied, line shadows are superimposed in the lung field which have no origin in the lungs (III, 3). These shadows cause perplexities in diagnosis. These line shadows correspond to the nuclear shadows or obstructive shadows in tomography.

Investigations were conducted to find in what form and frequency these appear in Rotatory Cross Section Radiography. In the writers opinion, the obstructive shadow can be classified into four types of A, B, C and D, and there are others which can be considered their transitional types.

Type A (Fig. 66) is a curved band about 3.0 cm in width which is seen to start at the junction of the rib and the body of the spine, and produce the figure of an arc convex backwards and running along the inner wall of the dorsal part of the chest. The band is densest at the beginning, gradually becoming fainter and narrower to the periphery. The margins of the band are denser than the central part, and the inner margin is much denser and clearer. This shadow makes difficult the diagnosis of lesions in the dorsal part of the lungs and also in the posterior mediastinum.

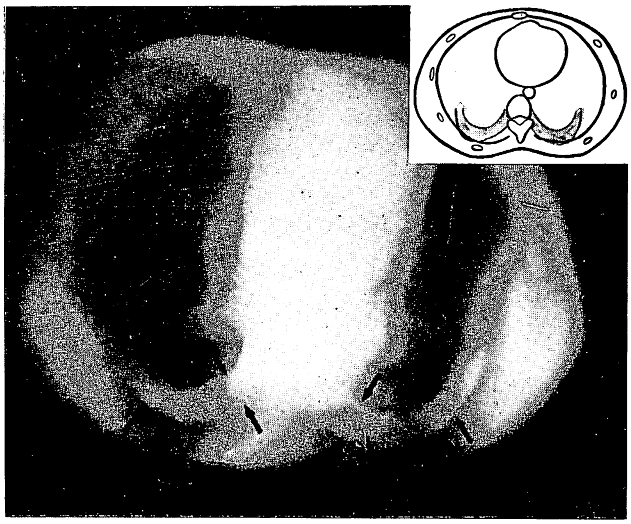


Fig. 66: Obstructive shadow of the chest. Type A
Top right: Schematic representation of type A

Type B (Fig. 67) is a somewhat narrow curved band that draws a convex arc anteriorly in the lung field, and two or three may be seen on each side of the lung field. Those appearing posteriorly are

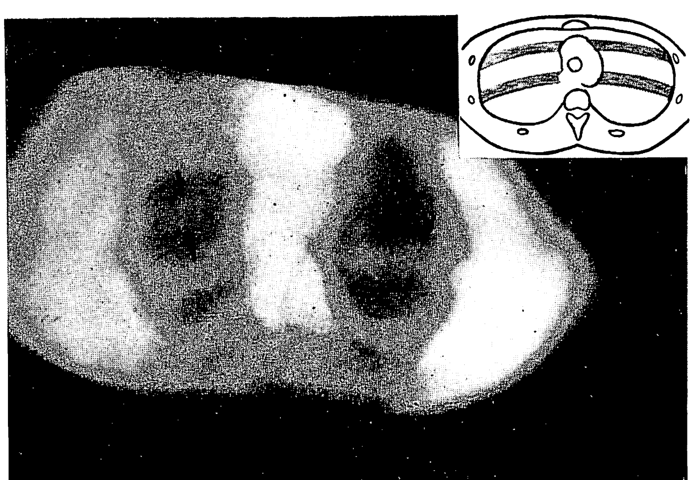


Fig. 67: Obstructive shadow of the chest. Type B
Top right: Schematic representation of type B

imaged more dense than those anteriorly. When the two ends of this band figure are faint and indistinguishable, they appear as the figure of a spindle in the lung field. In cases in which the margins of the curved band are especially dense, this shadow can be misdiagnosed as a cavity, thus the obstructive shadows render diagnosis of the lesion in the pulmonary field difficult.

Type C (Fig. 68) begins at the body of the spine and runs within the lung field postero-laterally, drawing an arc convex laterally, and extends to outside the lungs. The width and density of this curved band are uniform. This type also makes difficult diagnosis of lesions in the posterior lung field and the posterior mediastinum.

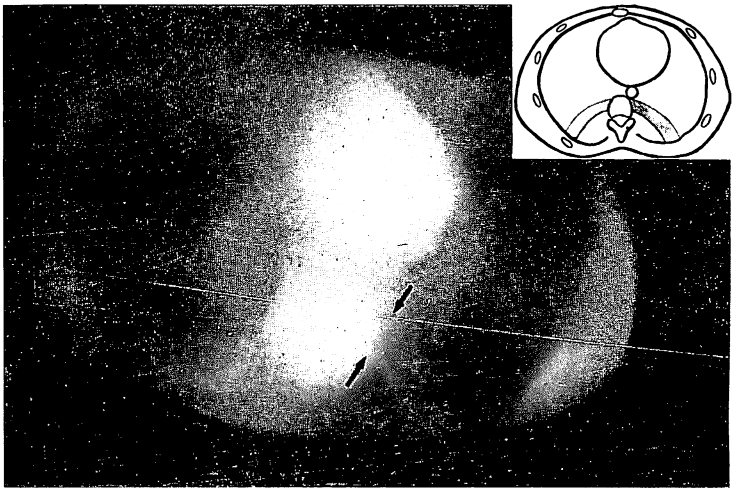


Fig. 68: Obstructive shadow of the chest. Type C.
Top right: Schematic representation of type C

Type D (Fig. 69) extends from the cross section of the ribs on the antero-lateral and/or postero-lateral aspects of the lung field. As they approach the antero-lateral and/or the posterolateral field they widen and present a belt-like appearance. The parts of the cortex and medulla of the bone cannot be differentiated here, and the whole appears uniform in density. Thus this type makes difficult diagnosis of the lung field.

The frequency of appearance of these four types of obstructive shadow on a radiogram depends principally on the tube inclination

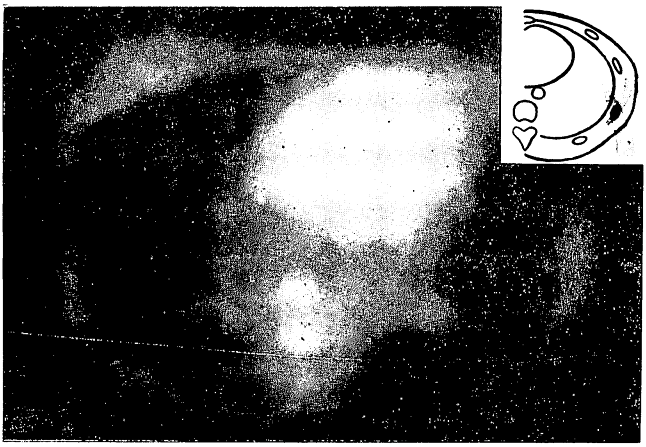


Fig. 69: Obstructive shadow of the chest. Type D
Top right: Schematic representation of type D

angle. This was made certain by the following experiment. Two hundred nineteen persons were radiographed with tube inclination angles of 30°, 25°, 20°, 15°, 10° and 8°, and the frequency of occurrence of the obstructive shadow on the Cross Section Radiograms of the lung field at the levels of the apex, sternoclavicular joint, aortic arch, hilum, midpoint between hilum and diaphragm, and diaphragm were examined (Tab. 9).

Table 9
Frequency of occurance of obstructive shadows

Tube inclination angle	Cases	Obstructive shadow	%
30°	33	33	100
25°	44	44	100
20°	42	40	96
15°	100	23	23
10°	35	0	0
8°	40	0	0

It was thus found that with tube inclination angles of 30° and 25°, obstructive shadows were noted 100%, and with a tube inclination angle of 20°, in 96% of cases. In 13% of these the obstructive shadows were very faint and did not actually interfere with the diagnosis. However, with an angle of 15°, only 5% of the obstructive shadows were clear enough to be followed, while in addition in 18% of cases the shadow could not be traced, i. e. did not interfere with diagnosis. But even then, the total number of recognized shadows accounted for 23% of cases. With an inclination angle of 10° and 8° no obstructive shadows appeared at all.

The obstructive shadows most frequently encountered are of the A and B types, and when the tube inclination angles were 30° and 25°, they always appeared. Types C and D were infrequent and appeared only in about 20% of cases.

With a tube inclination angle of 15°, type B which is most obstructive in diagnosis, appears as bands usually within the posterior chest wall. In practice such will not obstruct the establishment of a correct diagnosis.

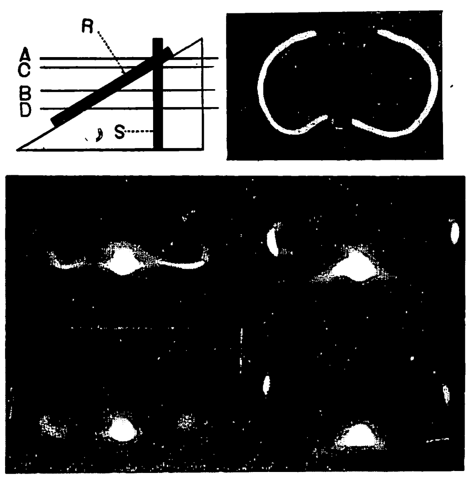


Fig. 70: Model experiment showing the occurance of obstructive shadows in Rotatory Cross Section Radiography of the chest.
Top right: Model of lead wire representing the rib
Top left: Model of the rib (R) with that of the spine (S). A, B, C and D representing the levels of the cross section
Middle left: Type A of obstructive shadow occured at the level of A
Bottom left: Type B of obstructive shadow occured at the level of B
Middle right: Type C of obstructive shadow occured at the level of C
Bottom right: Type D of obstructive shadow occured at the level of D

The mechanism underlying the appearance of these obstructive shadows, has already been mentioned in the section on theory of blurred image formation (III, 3, i-vii), and is probably due to blurring of each point in the rib into arc-like shadows which then remain as line shadows. To confirm this a model of each rib and vertebra was made of lead wire, and this was placed at an inclination angle corresponding to that actually seen in the living body about 15° at the apical region and 30° at the middle chest region (Fig. 70). Rotatory Cross Section Radiography of this model was made at intervals of 5 mm. The results showed, the same as in Cross Section Radiography of the ribs in the living body, that obstructive shadow of all four types appeared as X-ray images. From this it was surmised that these obstructive shadow were line shadow of the ribs themselves.

5. *Topographic Relation of Organs in Cross Sections of the Living Body*

At present, Rotatory Cross Section Radiography is applicable to every part of the body. Also it is used for not only horizontal cross sections but for inclined cross sections (heart, pelvic inlet, etc.). It should be pointed out here that hitherto in the living body it has not been possible to take the radiogram of the cross section. Also when cross sections of living body are compared with those taken from a cadaver, the latter shows not only atony and distortion, but it differs somewhat from the findings in the living body because of its prone or supine position.

The living human body was radiographed at the following regions, namely, cranium,[24)55)] ventricles and cisterns[25)54)] (Fig. 71), neck,[26)56)] chest,[27)29)36)] abdomen[28)37)30)] (Fig. 72), abdomen with pneumoperitoneum,[39)] abdomen with retroperitoneal insufflation with air[40)] and pelvis.[30)] (Fig. 74).

As a result it was found possible to make inspections of cross sections directly of the organs in situ. For example, in order to know the position of the stomach by means of polar co-ordinates,[37)] the pole was made to be the point of intersection of the sagittal plane with

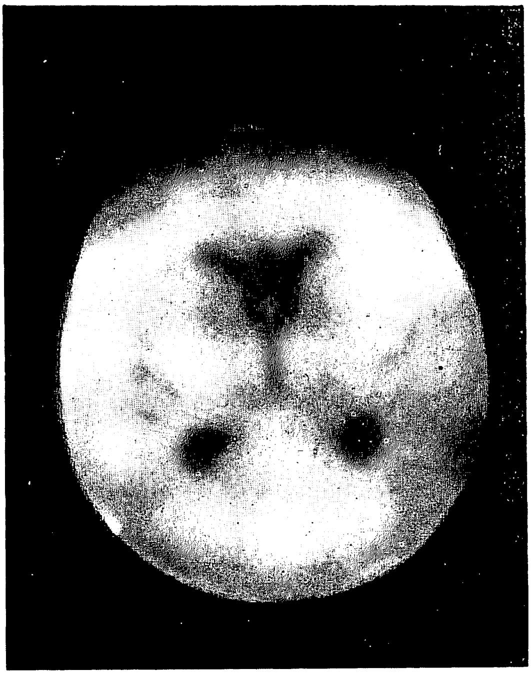


Fig. 71: Rotatory Cross Section Radiogram of the ventricle and cistern

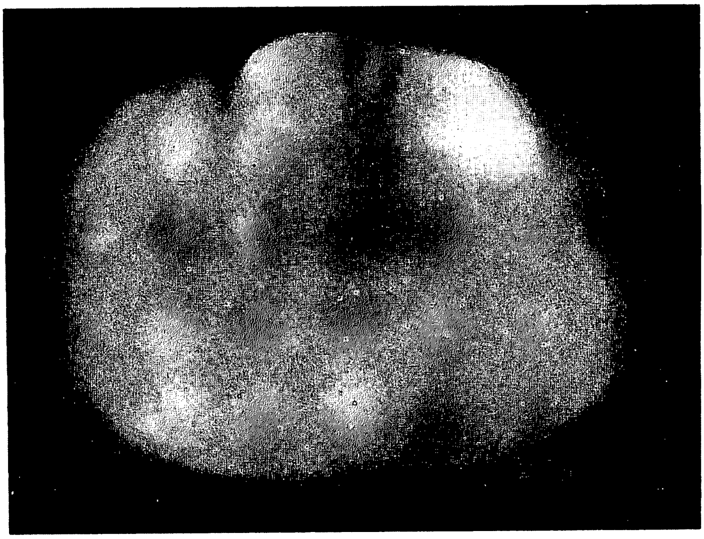


Fig. 72: Rotatory Cross Section Rodiogram of the stomach

the anterior margin of the vertebral body, and the lines directed to the left laterally from this were taken to be the initial lines, while the distances between this point (pole) and the skin surfaces were represented by precentages. Then the center of the body of the stomach, that of the lower part of the body of the stomach and that of the gas bubble were plotted in the shape of a fan, as indicated in Fig. 73. The outer aspect of the outline of the fan will contain the area including the stomach, and this is determined statistically within a margin of error of 0.05, while the inner aspect will confine the area within a margin of error of 0.1.

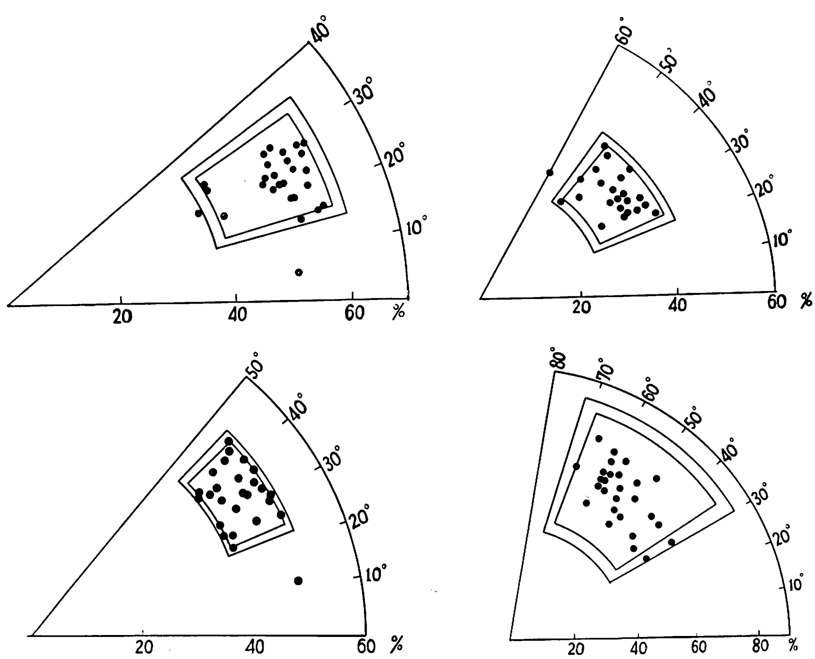


Fig. 73: Location of the stomach in the cross section
Top left: Center of the gas bubble
Top right: Cardia
Bottom left: Center of middle part of the body
Bottom right: Center of the lower part of the body

Air was introduced into the retroperitoneal space, and from an X-ray image of the kidney obtained the renal hilum was plotted[40]. The shape of the fan was similar to that of Fig. 73. in the plotting way (Fig. 74 and 75).

Fig. 74: Kidney in the cross section of the abdomen

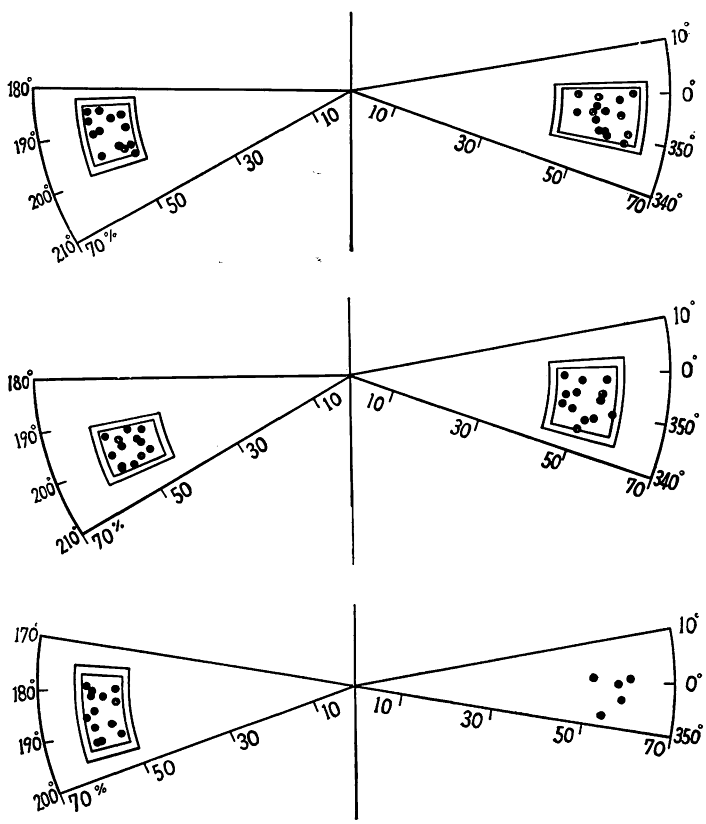


Fig. 75: Location of the kidney in the cross section of the abdomen
Top: Midpoint of the upper pole and the hilum of the kidney
Middle: Hilum of the kidney
Bottom: Midpoint of the hilum and lower pole of the kidney

When 16 healthy adults were cross section radiographed at the level of the gall bladder[28] and the contours of the gall bladder were plotted at the cross section of the upper abdomen, they are shown in Fig. 76 and 77.

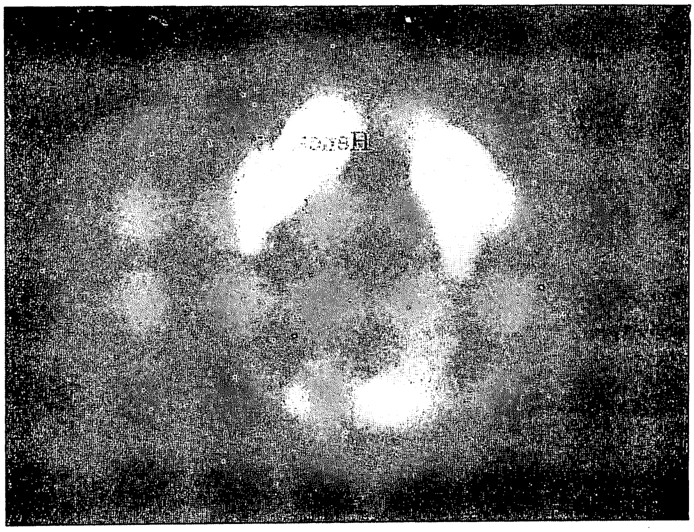


Fig. 76: Gall bladder in the cross section

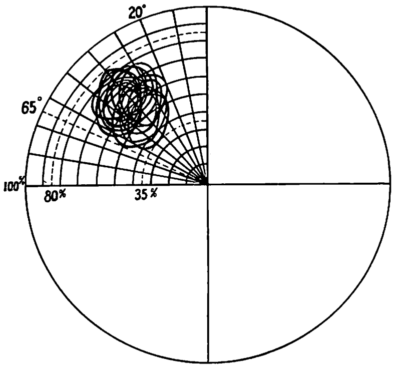


Fig. 77: Location of the gall bladder in the cross section

6. *Rotatory Cross Section Radiography Applied to Clinical Practice*

A special feature of Rotatory Cross Section Radiography is that it can, as in the case of tomography, take radiograms of layers in the body that are required.

This layer is in Rotatory Cross Section Radiography nothing but the cross section of the body. This feature has not been found in other existing radiographic methods.

Thus, it has the power of discovering diseased foci which may originally be missed due to superimposition of shadows when normal radiography is employed. Further, it can bring to light dimensions of depth in the living body which have been found difficult by existing methods of tomography. Hence, it can make clear in detail the position, size and shape of organs in the living body, and thus help in discovering diseased states. It will be considered now to what extent the above features are of help clinically. And as concrete examples the following cases are presented.

A. Chest Diseases[29)59)]

Five hundred eighty four patients, suffering from chest disease, were subjected to normal radiography, followed by Rotatory Cross Section Radiography, and eight hundred sixty seven Cross Section Radiograms, revealing some significant lesions in the chest, were obtained. The ages of patients ranged from three to seventy years.

Diagnosis of the disease was established first with the normal radiogram, and then checked with the Rotatory Cross Section Radiogram. If the latter showed additional findings not found by the former and contributed to better diagnosis, this method was evaluated as useful.

We classified these into four groups as follows;

a. Group Applied to Detection of Lesions

One hundred twenty six out of 867 radiograms were evaluated as useful for detecting lesions (Tab. 10).

There were three types of lesions in this group, namely, one hidden by an extrapulmonary shadow, intrapulmonary one surrounded by a dense shadow and one situated at the inlet of the mediastinum. The first could be discovered in an oblique or a lateral view of normal radiography. The second could be discovered as to its nature by means of tomography, too.

However, the third, localized either in or in the vicinity of the

Table 10

	Name of lesions detected	Cases
1.	Cavitation surrounded by dense consolidations	21
2.	Cavitation hidden by shadow of the clavicula, ribs or scapulae	12
3.	Intrapulmonary lesions surrounded by pleural lesions	17
4.	Lesions situated in the vicinity of or in mediastinum,	
	superior anterior	14
	posterior	11
5.	Intrapulmonary lesions hidden by the heart displaced or dilated	11
6.	Paravertebral lesions hidden by the diaphragmatic arch	5
7.	Lesions of the hilum	19
8.	Lesions hidden by the mediastinum displaced by artificial pneumothorax, thoracoplasty or old pleurisy	16

upper mediastinum or paravertebral region hidden by the diaphragmatic arch, might not be discovered by the tomographic procedure due to the occurrence of obstructive shadows. This area can be made clear only by Rotatory Cross Section Radiography.

b. Group Applied to Differential Diagnosis

Two hundred forteen out of 867 Cross Section Radiograms contributed in estiblishment of correct diagnosis (Tab. 11).

Table 11

	Name of lesions differentiated	Cases
1.	Cavitation imaged in a ring figure and suspected as superimposition of shadows	58
2.	Lesions superimposed at the area of the hilum and differentiated as:	
	lymphadenitis	17
	perihilar infiltration and intrapulmonary lesions	12
3.	Opacity with sharp border, differentiated as:	
	encapsulated pleurisy	8
	atelectasis	5
	pneumonia	7
	lobus accessorius inf.	2
4.	Cases misdiagnosed as the intrapulmonary lesions and later proved to be:	
	pleural callosum	11
	encysted pleurisy	10
	interlobare pleurisy	10
	pulm. lesion combined with pleurisy	18
	pulm. infiltration	8
5.	Enlargement of the upper mediastinum found due to:	
	anterior mediastinal pleurisy	24
	paratracheal lymphadenitis	12
	pulmonary tuberculous infiltration	3
	Thymus hypertropy	4
6.	Miscellaneous,	
	stomach hernia, cold abscess etc.	5

These results would not have been obtained by normal radiography only, because the differential diagnosis in this group becomes difficult unless the location of lesions is made clear. For this either the Rotatory Cross Section Radiography or normal radiography of an oblique or lateral view is needed. The latter, however, would fail to image lesions of the mediastinum clearly.

There were other cases in this group in which ring shadow imaged on the pulmonary field of a normal radiogram was suspected as a mere superimposition of shadows. This was differentiated as an image of cavitation when imaged as a ring shadow on both radiograms taken by normal radiography and Rotatory Cross Section Radiography.

c. Group Applied to the Determination of Extent and Position of Lesions (Tab. 12).

Table 12

	Name of lesions made clear of their location etc.	Cases
1.	Cavitation	72
2.	Tucerculous infiltration	282
	The one accompanied by the atrophy of the thorax	21
3.	Hilusinfiltration	45
4.	Pleurisy,	
	costal	27
	encysted	4
	interlobar	3
	serothoracic	6
5.	Arteriosclerosis	26
6.	Aneurysma	2
7.	Aortic valvular disease	7
8.	Mitral valvular disease	10

Five hundred and five out of 867 radiograms were found useful in determining the site, extent or position of lesions.

These lesions have already been diagnosed correctly with the normal radiogram, but the state of thoracic atrophy and deformity of the heart caused by valvular diseases are manifested more cleary sometimes by this type of radiography. Moreover a three dimensional knowledge of the lesions can never been known by normal radiographic procedure. Hence, this method was estimated as useful.

d. Group Applied to Pretherapeutic Procedure

Hundred fifty three out of 867 radiograms proved not only useful in diagnosis but also in therapy (Tab. 13).

Table 13

Name of treatment of lesions, surgical or radiological	Cases
1. Collaps therapy in determining the state of a collapsed lung after:	
thoracoplasty	44
extrapleural prombaging or pneumosewing	8
pneumothorx	37
2. Determination of the location of foreign body	6
3. Punction of the exudative pleurisy or the cavitation	16
4. X-ray treatment of lung tumors adjusted with isodose chart.	
pulmonary or broncheal tumor	25
metastatic tumor	9
mediastinal tumor	8

The collapsed lung adherent to the mediastinum in pneumothorax, or one displaced to the retrovertebral sinus in thoracoplasty was discovered easily by this method.

The location of foreign bodies was also very easily determined.

In planning irradiation of the pulmonary tumor the isodose chart for the figure of the cross section of the chest was applied. Without the Cross Section Radiogram, the reasonable irradiation would not be possible.[61]

B. *Frequency of Tuberculous Lesions in the Mediastinal Lung Field*[35)65)]

Lesions in the mediastinal lung field are difficult to visualize with the routine postero-anterior chest radiogram because of the overlying structures in the mediastinum. However, on the Rotatory Cross Section Radiogram lesions in this region can be clearly imaged in spite of the overlying structures. Using this method the mediastinal lung fields of 479 patients with tuberculosis of the lung and/or pleura were studied. The results obtained are as follows:

a. In the 479 patients studied 516 lesions were found by Rotatory Cross Section Radiography in the lung and/or pleura and of these 336 or 65 percent were in the mediastinal lung field.

b. Mediastinal shift was found in 95 instances or 18.4 per cent of mediastinal lung field lesions.

c. Rotatory Cross Section Radiography provided adequate diagnostic studies in 28 instances where the lesion was not seen on the posteroanterior radiogram and in 34 other instances including 4 with cavitation where the lesion was difficult to distinguish from the confluence of vascular shadows.

d. The relative diagnostic value of the lateral chest radiogram, tomography and Rotatory Cross Section Radiography in lesions of the mediastinal lung field was compared and discussed. Rotatory Cross Section Radiography was considered most valuable diagnostically except in lesions of the middle mediastinal lung field where tomography was found to be of equal value.

C. *Rotatory Cross Section Radiography Compared with Tomography for Examining the Tuberculous Lung Cavity*[34]

Twenty four cases where at least one cavity was clearly demonstrable by normal radiography were chosen, and each case was subjected to tomography and Rotatory Cross Section Radiography at 5 mm intervals. The rates of discovery of other cavities and determing the structure of the cavity ascertained by the two methods were compared. The number of cavities found by Rotatory Cross Section Radiography and Tomography were 66. With normal radiography only 24.2% of these cavities were discovered. Cavities found by tomography but which were not clear or entirely missed by Rotatory Cross Rection Radiography totaled 15, while cavities found by Cross Section Radiography but not by tomography totaled 8. The factors for missing of these cavities by both methods of radiography were the obstructive shadows. With regard to the images obtained of the one and same cavity by the two methods, contrast of the X-ray image in the case of tomography was better, and the inner wall of the cavity was imaged clearly and sharply. Also by tomography the presence of tuberculous bronchiectasis was noted in 75% of the cavities against only 13% in the case of Rotatory Cross Section Radiography. Thus, for discovery and confirmation of a cavity and its leading bronchiectasis, tomography was superior to Rotatory Cross

Section Radiography. But when compared with normal radiography Rotatory Cross Section Radiography was better. However, to know the cavity or diseased foci in situ without distortion of shape in the living body, the manner of spread of the lesion and its relationship to the chest wall and mediastinal cavity, Rotatory Cross Section Radiography surpassed tomography in that the results obtained were more accurate and concrete.

D. Position of Tuberculos Cavity in Lung[31)]

By Rotatory Cross Section Radiography a cross section image without distortion can be obtained.

There are few investigations on the position of tuberculous cavities in the chest. These results, however, have been obtained usually by the method of normal radiography or tomography. For such a purpose Rotatory Cross Section Radiography will present more acurate information regarding position of cavities in the chest.

When 253 cavities from 193 radiograms diagnosed as tuberculous cavities were examined by Rotatory Cross Section Radiography, the following results were obtained.

1). Shape of cavity: Round or approximately round cavities accounted for 51.1% of all the cases. Oval or irregular oval cavities accounted for 24.1% and 23.3% respectively.

2). Site of cavity: Most were seen at the levels of the sterno-clavicular joint and the aortic arch, the percentages being 37.4% and 21.9% respectively. Cavities were observed extremely rarely below the level of the middle of the cardiac border.

3). When the positions were examined in respect to cross sections of the lung, with center of the chest as the original point, the cavities were plotted radially at intervals of 10° (Fig. 78 and 79).

The pole or origin of this diagram was not selected as the point of intersection of the sagittal plane with the anterior margin of the vertebra as in the case of the stomach or the kidney, but the mid-point of the anterior and posterior chest wall in the sagittal plane.

The results indicated that at all levels cavities are found within the range of from +25° to −25° in respect of the initial line, and at other areas were rarely found.

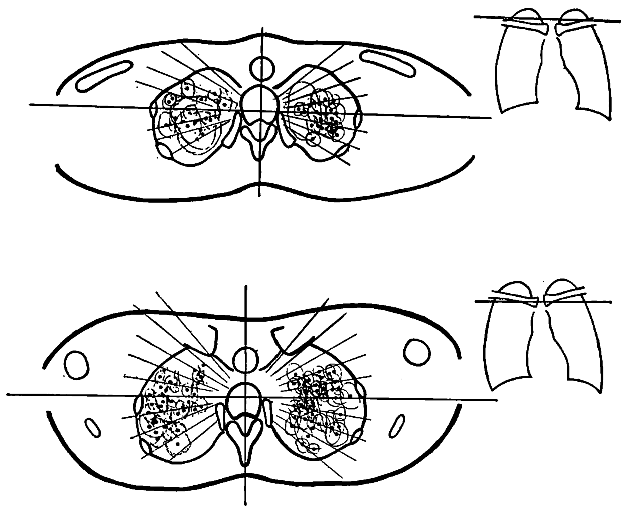


Fig. 78: Location of tuberculous cavities in the cross section of the chest

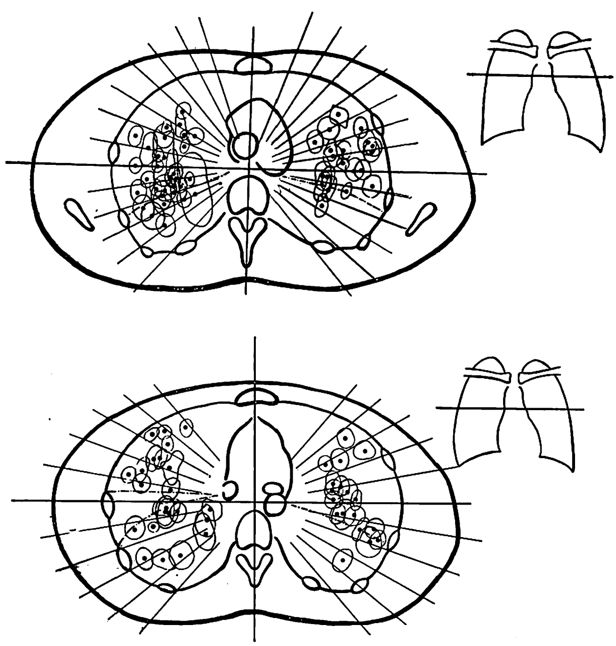


Fig. 79: Location of tuberculcus cavities in the cross section of the chest

Chapter IV

Solidography

Solidography is a type of Rotation Radiography by which the internal organs of the body are transfered in their original shapes radiographically to outside of the body.

This is an application of the principle of X-ray image formation in Rotatory Cross Section Radiography, that on the rotation-table placed further away from the tube focus, there exists a three dimensional image similar to the actual organ on the rotation-table placed nearer to the tube focus.

1. Geometrical Consideration of Solidography[22)49)52)60)]

The principle of this method was proved geometrically as follows (Fig. 80).

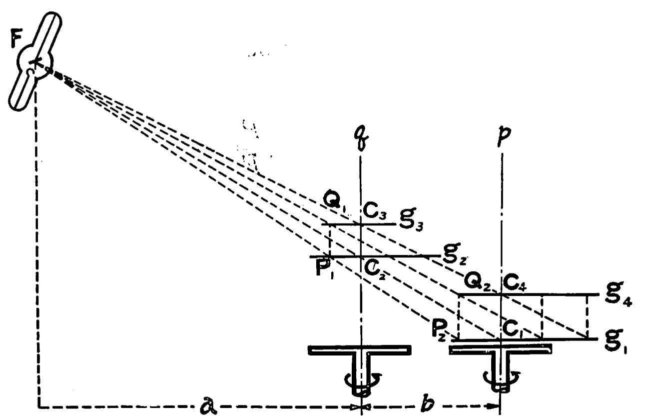


Fig. 80: Diagram of geometrical consideration of Solidography

Let the distance between the tube focus F and axis of the rotation-table q be "a" and the distance between the axis of two rotation-tables be "b" as shown in Fig. 80. Join the tube focus F and the rotation center C_1 of the film on the rotation table p. Let FC_1 intersect the axis of the rotation table q at point C_2. Through this point

C_2 draw a plane g_2 parallel to the film. Join tube focus F and any point P_1 on this plane g_2 and let the extension of this line meet the film at P_2.

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_1, may be placed on the line FP_1P_2 at one moment of the rotation, but it strays away from this line at the next moment of rotation. Therefore the point Q superimposes as one point not during whole course of rotation but only for a moment and is naturally blurred. Now we have learned that only the horizontal layer of the body corresponding with the plane g_2 is imaged on the film which is laid horizontal on the rotation-table p.

Next, let a plane g_3 be parallel to the plane g_2 and take a point Q_1 in the plane g_3 such that P_1Q_1 is parallel to the axis of the rotation table q. Join the tube focus F and the point C_3, whcih is the intersection of the plane g_3 and the axis of the rotation table q. Let a plane g_4, which contains the point C_4 (the intersection of FC_3 with the rotation axis of the rotation table p), be parallel to the plane g_3, and let extension of the line FQ_1 intersect the plane g_4 at the point Q_2.

Then $\dfrac{C_3Q_1}{C_4Q_2}=\dfrac{FC_3}{FC_4}=\dfrac{a}{a+b}=\dfrac{FC_2}{FC_1}=\dfrac{C_2P_1}{C_1P_2}$ $(\because C_1P_2//C_2P_1//C_3Q_1//C_4Q_1)$.

From this $\qquad C_4Q_2=\dfrac{a+b}{a}\,C_3Q_1$

Similarly $\qquad C_1P_2=\dfrac{a+b}{a}\,C_2P_1$

and $\qquad C_3Q_1=C_2P_1$

Hence $\qquad C_1P_2=C_4P_2$

Because points P_1, P_2, Q_1 and Q_2 are placed in a plane, Q_2P_2 is parallel to C_1C_4.

Moreover $\quad Q_2P_2//Q_1P_1 \quad (\because Q_2P_2//C_1C_4,\ P_1Q_1//C_2C_3)$

Therefore $\qquad Q_2P_2=\dfrac{a+b}{a}P_1Q_1, \qquad C_4Q_2=\dfrac{a+b}{a}C_3Q_1$

If we take many planes $g_5, g_6, \cdots, g_n$ on the rotation table q in such a manner, we will find that planes $g_5', g_6', \cdots, g_n'$ are arranged on the rotationtable p regularly according to 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 radiography of the body. From this we see that on the rotation-table p there exists an X-ray image similar to the actual body on the rotation-table q. The X-ray image is, however, enlarged $\frac{a+b}{a}$ times the original body.

2. *Principle of Solidography and Simultinous Multi Cross Section Radiography*

In Rotatory Cross Section Radiography it was found thus geometrically that the X-ray image of the subject was formed on the rotating table, placed further away from the X-ray tube. If on this table a mass of photosensitive material is placed, it will be possible to obtain photo-image of the subject as it is.

In order to prove whether the result obtained geometrically is correct or not, a model and a film block were prepared. The model consisted of a barium block in the shape of two eggs combined (Fig. 81). A film block was constructed by piling one hundred and twenty sheets of film, 3×4 cm in size and packed by light proof paper. The model was placed on the rotation table, nearer to the tube, and the film block on the rotation table further away from the tube, so that each film was laid horizontally. The rotation table was rotated through the rotation range of from $0°$ to $190°$ during the exposure. The film block was unbound and each film was developed. On each film there was imaged a corresponding cross section of the subject as shown in Fig. 81. When these sheets of films were piled up in the original order, it became clear that there resulted a three dimensional image of the body similar to the actual body. In order to demonstrate this actually, the figure of the X-ray image was cut from every film and piled up in the original order, when we obtained a film block similar to the actual body. This plastic was, however, enlarged in the ratio of $\frac{a+b}{a}$.

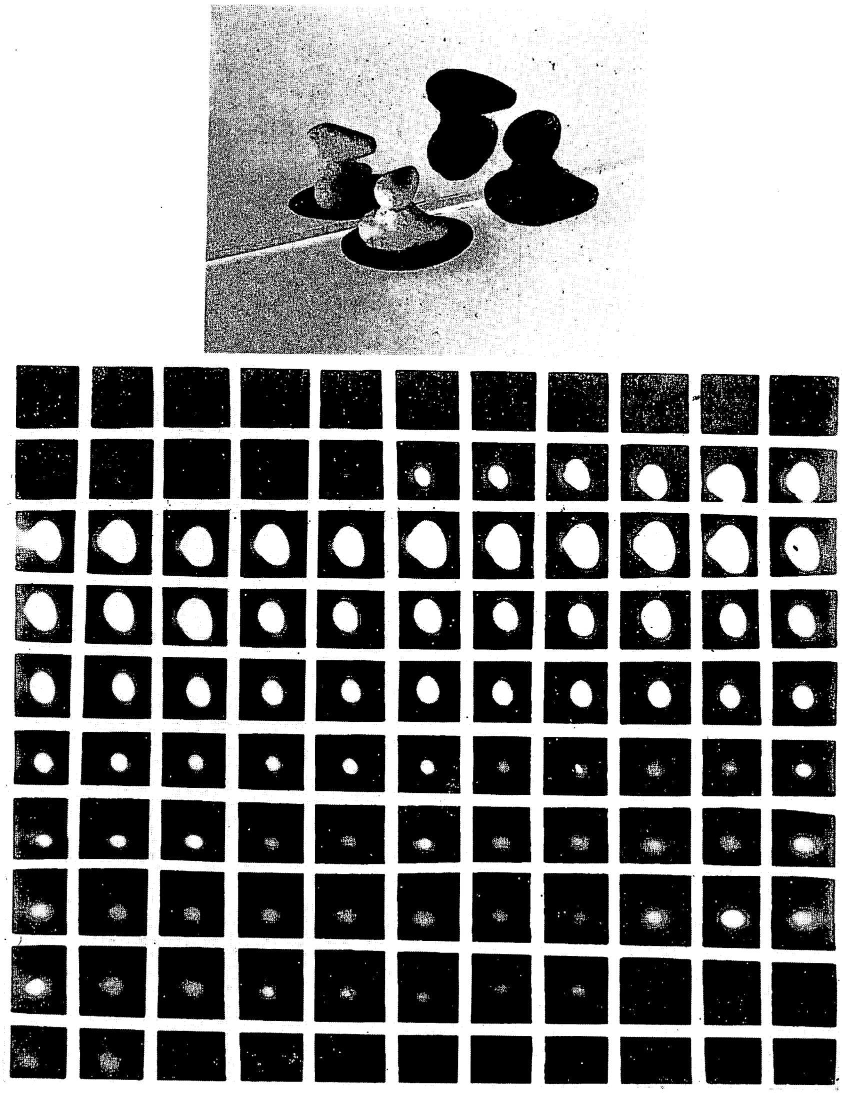


Fig. 81: Model experiment of Solidography.
Top: Model (left) and Solidogram (right) showing their backs by a mirror
Bottom: Rotatory Cross Section Radiograms at the Solidography

It can be considered that Solidography is a development of simulatanous multilayer tomgoraphy. A device has expressed in 1936 for the first time that, when, at planigraphy, a film was set at the position different from formerly, different layers of the body can be taken.[89] But in case of simultanous multilayer tomography,[90] it will be difficult to get the three dimensional image of the body, especially when applied to the chest, due to the superimposition of obstructive shadows. In the writers opinion the most suitable method to obtain a three dimensional image is by Rotatory Cross Section Radiography. There has been already devised also a method of Radioplasik,[91)92)] which, however, is different from the writer's in its principle.

With our technique available today, however, such a three dimensioned photosensitive emulsion can not be prepared for clinical use. Accordingly, some modified radiographic method similar to this had to be found.

The X-ray tube and two tables were arranged as in Rotatory Cross Section Radiography, with the tube inclination angle 15° (Fig. 82 and 83). The distance between the tube and the rotating table for

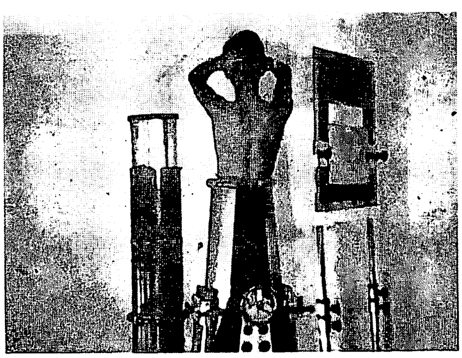


Fig. 82: Solidograph in action

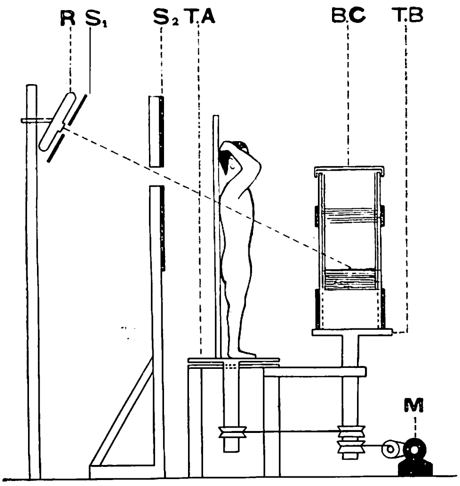


Fig. 83: Sketch of Fig. 82.
R: X-ray tube, S_1: First slit,
S_2: Second slit, TA: Rotation table,
BC: Cylinder cassette, TB: Rotation table

the subject was 145 cm, and the distance between the two tables was 50 cm. The X-ray tube used was 10 kW in capacity, and the target of the tube was cooled by running water (speed of current, 1 l/min.). The two tables were rotated synchronously in the same direction by a motor. The cassette was enclosed in a cylinder with external diameter 21 cm and height 80 cm (Fig. 84). Twenty wooden frames of height 3 cm and fitting exactly the internal diameter of the cylinder were prepared. Between the frames were placed Oriental X-ray papers of diameter 20 cm. By such means a total of 18 sheets of X-ray papers was placed in the cylinder between the frames at 3 cm intervals, each piled on top of the other, and facing its own intensifying screen.

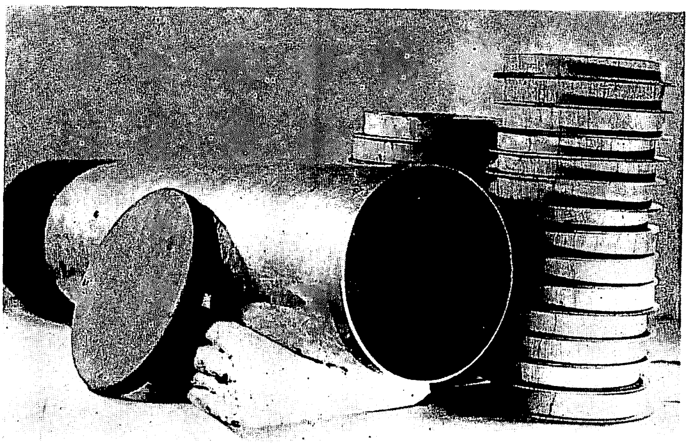


Fig. 84: Cylinder cassette

An outer box which enclosed exactly the above box and acted as a sheath, was prepared. The rotating table was rotated while being exposed to X-rays. When rotation exceeded 190°, the trap supporting the inner cylinder containing the X-ray paper was automatically freed and the cylinder fell down through 20 cm. The rotating table continued to rotate and when it made another rotation of 190°, the clasp was again freed and the cylinder fell for a further 21 cm. Thus, after the table was rotated through 570°, exposure to X-rays was stopped. The conditions of exposure were 80 kV of tube terminal and 35 mA of tube current.

By subjection to such an exposure, though the papers within the cylinder were piled on top of each other at 3 cm intervals, the slide in position of the paper between the initial arbitrary exposure and the subsequent one was 1 cm. Hence, despite radiography having been made in 3 stages of exposure, when all the papers were collected and observed the heart was seen to have been radiographed as cross sections of 1 cm intervals (Fig. 85 and 86).

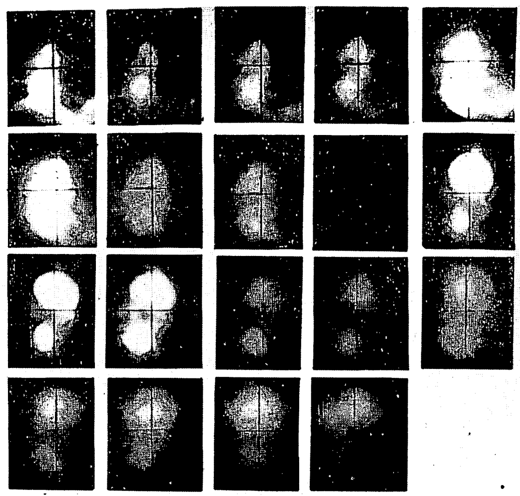


Fig. 85: Rotatory Cross Section Radiograms of the heart simultanously taken

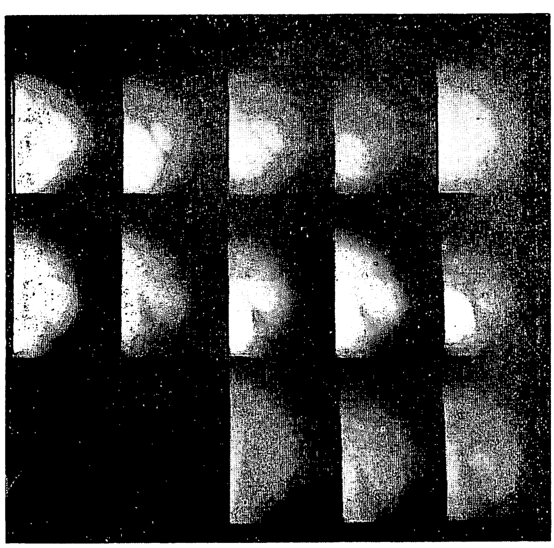


Fig. 86: Rotatory Cross Section Radiograms of the kidney simultanously taken

Simultaneous Multi Cross Section Radiogram,[46] not for molding the Solidogram, but for obtaining the X-ray images for direct diagnosis is also now used in clinical practice in our Department.

Round films with round intensifying screens of a cm in diameter are piled up horizontally with the intervals of b cm, and are put in a cylinder cassette. To get the X-ray image shaded only by the upper one pair of intensifying screens and not interfered by the other screens, there should be a relationship of $\frac{2b}{a}=\tan\alpha$, where the tube inclination angle to the film is α.

Here, tube inclination angle will not take the same value for the 1., 2. and 3. film in the same size because of their different levels in the cassette. The sensitivity of intensifying screens must be made suitable for giving similar density on each film.

In practice we are using three pairs of intensifying screens A, B and C of 19 cm in diameter. The intensification factor and the sharpness of screens A are measured 25; 0.55, B 30; 9.5 and C 30; 0.5. The sharpness was measured with 0.3 mm of slit in aperture by *Rudginger* and *Spieglers* method. The intervals between screens are made 2.1 cm from A to B ($\alpha=12°21'$) and 2.6 cm from B to C ($\alpha=15°15'$).

The inter spacer of coarsed polystylen is put in the space between screeens A, B and C to press the films and to mainten the constant distance between films. This method is convenient to take simultanously three peices of clear radiograms of mediastinum. The conditions of exposure are 82 kV in tube terminal, tube current of 40 mA and exposure time of 8 seconds.

To get the good radiograms b should be taken $\frac{a}{2}\tan\alpha$, the center of cassette box be strictly coincided to that of the rotation table, and the range of rotation of the table must be from 0° to 360° as a special case of Rotation Radiography. Otherwise, the radiogram exposed homogenously will not be obtained because of the interference of the intensifying screens placed upwards.

3. *Molding*

A specially contrived apparatus for molding the organs into a concrete figure is composed of two rotating table placed on the same plane (Fig. 87, 88). A photoelectric tube is connected by a relay apparatus to a cutter over the other table. Both tables are made to slide in the same direction forwards, backwards, left and right by means of a gear and constructed in such a way that they can rotate synchronously. On one table is placed a Rotatory Cross Section Radio-

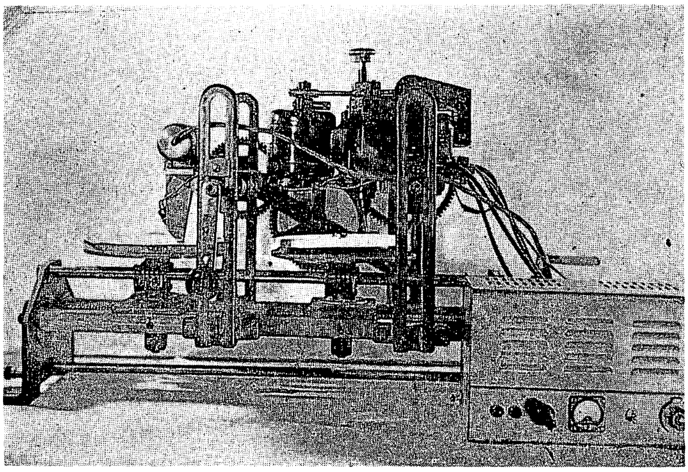


Fig. 87: Molding machine

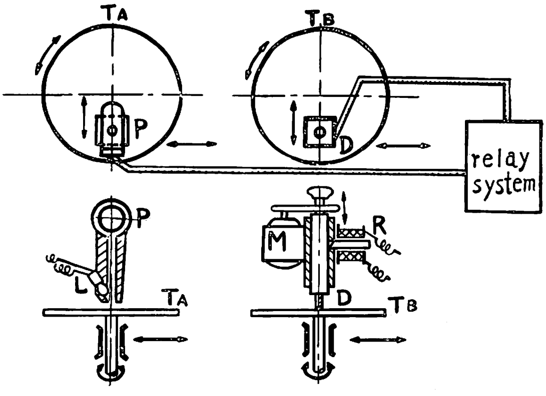


Fig. 88: Schematic representation of Fig. 87.
Top: Plan, Bottom: Elevation.
TA: Rotation table carring the Cross Section Radiogram,
TB: Rotation table carring the plaster disc,
P: Phototube, D: Cutter

gram, and on the other a plaster disc. Over the Cross Section Radiogram the photoelectric tube makes a scanning, while a cutter shaves the plaster off. The photoelectric tube and cutter work synchronously.

The movement of the cutter is so adjusted that in relation to the sliding of the photoelectric tube it moves for just the reciprocal of the enlargement ratio of the Rotatory Cross Section Radiogram. In other words, when the Cross Section Radiogram is enlarged 1.25 times, it is arranged such that the photoelectric tube moves through 1.25cm and the cutter through 1.0 m. When the 1.0 cm thick cross section images are observed individually, a solid image of the organ cannot be obtained. So, by using these radiograms an attempt was made to prepare a mold. As cuts were made before exposure on the edge of X-ray papers, these cuts were joined together to form a cross in the center of the paper, and this was employed as the standard line. Next, a paper was placed on the paper table and the plaster disc of 1 cm in thickness on the plaster table of the molding apparatus.

The photoelectric tube was switched on, and with a handle the tube was made to slide forwards or backwards. By so doing the cutter also slided in the same direction on a straight line. At the black part of the X-ray image the plaster plate was shaved off by a cutter, but at the white part of the X-ray image the photoelectric tube worked and kicked away the cutter. Thus, a plaster disc of size 1 : 1.25 of the X-ray image on the paper was obtained. On this plaster disc the standard line was marked, and the discs obtained were piled together according to their standard lines. The figure thus piled up showed one with tiers.

To make the figure with tiers approach the real one in the body, tiers were usually cut off the projecting part and the depressing part

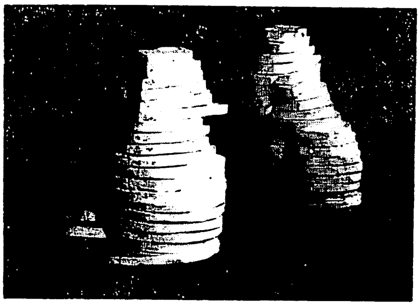


Fig. 89: Solidogram of the heart (with tiers), showing its back by a mirror

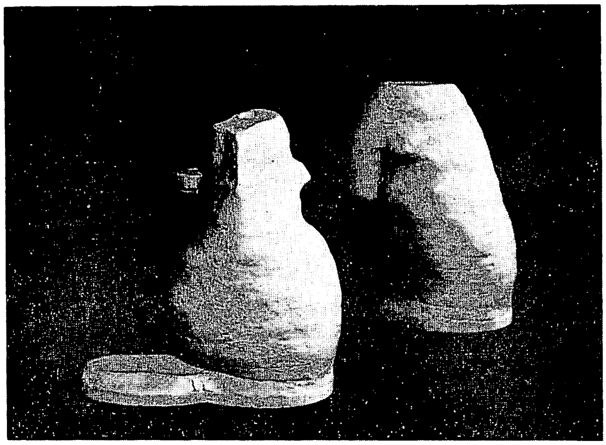


Fig. 90: Solidogram of the heart (without tiers) showing its back by a mirror

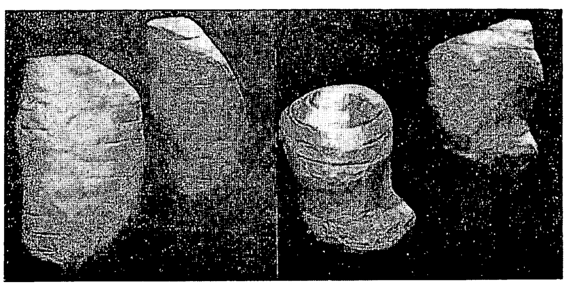


Fig. 91: Solidogram of the kidney
Left: Normal kidney Right: Ren mobile with deformity

filled, and thus the figure with smooth contours was obtained (Fig. 89, 90, 91).

Relation between a figure obtained by molding and actual figure of the organ within the body will now be discussed below[64] (Fig. 92).

When the plaster plates are piled up by fitting together the standard lines, a general appearance of the organ with tiers is obtained. However, the real organ has no tiers and the contour is smooth and continuous. The lower surfaces of the plates composing the tiers show the actual cross section in outline, but the outline of the upper surfaces is not actual.

The figure with cut tiers or with the space between tiers filled will be more near the actual one than that of the original one.

Fig. 92 shows a figure of a rational vertical section of the plaster

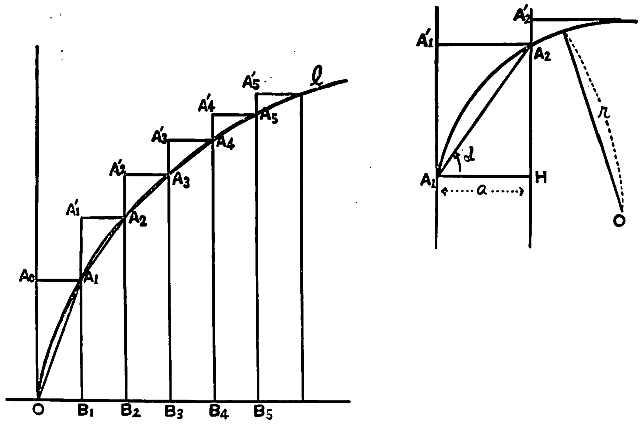


Fig. 92: Diagram showing relation between tiers and actual contour of the organ

states piled up. The quadrilaterals $A_0OB_1A_1$, $A_1'B_1B_2A_2$, $A_2'B_2B_3A_3,\cdots$ represent the plaster plates respectively.

Points $A_1, A_2, A_3,\cdots$ are located on curve l representing the real outline of the organ.

It is possible to obtain a plaster figure with a real outline from a plaster figure with tiers by the following technique. When the cross section increases in size as shown in Fig. 92, parts designated by $OA_0'A_1$, $A_1A_1'A_2$, $A_2A_2'A_3,\cdots$ are shaved off and points $A_1A_2A_3A_4A_5\cdots$ made to lie on the smooth outline of the plaster image. Thus the smooth outline obtained represents a most real curved surface. On the other hand, when the cross section decreased parts $A_5'A_5A_6$, $A_6A_6'A_7$, $A_7A_7'A_8,\cdots$ are filled in and the points will be situated on the smooth outline of the plaster figure.

Thus this outline also represents roughly a real curved surface.

When this method was applied to a patient with ren mobile,[38][64] the molded figure obtained is shown in Fig. 91. The molded figure revealed that the lower half of the kidney was bent markedly to the median. When viewed from the back, the posterior surface was not smooth but there was a cavity in the middle part of the kidney, and a projection directly below that cavity. These findings were observed also after removal of the kidney from the body.

Chapter V

Rotation Kymography

Rotation Kymography (*Rotationskymographie*)[11] is a type of Rotation Radiography by which contraction and dilatation of an internal organ can be recorded along the outline of the cross section. The principle of this method is based on a combination of the Rotation Radiography and the one slit kymography.

Usually the one slit kymography is used for analysing the state of movement whose direction is parallel to the body axis. There are two modes of one slit kymography. The one is the *one slit kymography of the slit slide type* and the other *of the film slide type*. In the usual slit kymography the lead slit or film moves along the axis of the body.

If the human body is made to rotate instead of moving the slit, what will be the result?

First, while the subject is made to rotate, the film placed directly behind the lead slit slides upwards (or downwards) synchronously with the rotation of the body, so movements of each point arranged on the outline of the cross section of the dilating and contracting organ can be recorded. Such will correspond to a type of usual roentgen kymography of the slit slide type, but as the rotation is continuous and successive in this case, it will be termed *Continuous Rotation Kymography*[11)53] (*Kontinuierliche Rotationskymographie*).

On the other hand, the rotating table carrying the subject is made to rotate discontinuously, and with each rotation the film is made to slide behind the lead slit for just the needed distance with uniform speed. With the above procedure usual roentgen kymography of the film slide type is obtained. Some definite points on the outline of the cross section of the organ during dilatation or contraction can be recorded. As in this case rotation is made discontinuously, it is termed *Discontinuous Rotation Kymography*[11)53)] (*Diskontinuierlihe Rotationskymographie*).

Actually in these types of radiography, the X-ray tube, subject, the lead plate with horizontal slit and the film are arranged in the above order. Between the subject and the X-ray tube there is placed an additional lead diaphragm which intercepts the X-rays not necessary for radiography. The subject is fixed on the rotating table and the film is rolled on the cylinder just behind the lead slit. When the cylinder rotates, a part of the film exposed slides downwards. The rotations of the rotation table and cylinder are connected with each other, and they move synchronously. At the center of the lead slit a wire is made to cross the extension line joining the tube focus and the rotation axis of the rotation table. This wire is imaged at the middle of the radiogram as the *standard line.* Here the distance between tube focus and the film is 110 cm and that between the center of the rotation table and the film is 20 cm.

Now, as the rotating table is at rest while the cylinder with the film rolled on it is allowed to rotate, an exposure is made and is cut off when the film had rotates through 12 mm. After the rotating table has been made to rotate 10°, it is brought to a stand, and an exposure is made after the film starts again to move. This procedure is repeated from 0° to 190°. By the above procedure a Discontinuous Rotation Kymogram is obtained.

In Continuous Rotation Kymography there is required rotation of the rotating table at uniform speed and continuously by means of an electric motor, and an X-ray exposure of 12 seconds is made during the operation.

Scale of goniometer shows 0° when the subject faces the film, and the X-ray tube rotates counter-clockwise when viewed from the top of the subject downwards. Exposure is made continuously while the table rotates from 0° to 190°. The radiogram thus obtained is imaged as a curved zone, and its borders are imaged wavy similar to those of the usual kymogram. The standard line runs in the middle of the radiogram.

1. *Theoretical Consideration of the X-ray Image of Continuous Rotation Kymogram*[11]

Though the Continuous Rotation Kymogram is a radiographic record of the movements of the cross section of the organ, the X-ray image obtained does not show a direct and concrete cross section image. The main image corresponds to that of Continuous Rotatogram. It must be interpreted that the margin of the curved zone represents the outline of the real cross section itself. (I, 1-13). Thus the need arises to consider whether the wavy margin of the curved zone which is supposed to represent the movements, corresponds in significance to the wavy borders on the usual kymogram. To make clear this an apparatus for model experiments of a Rotation Kymography was constructed. On the rotating table was placed a rubber balloon as a subject (Fig. 93). This balloon was made to dilate and contract with

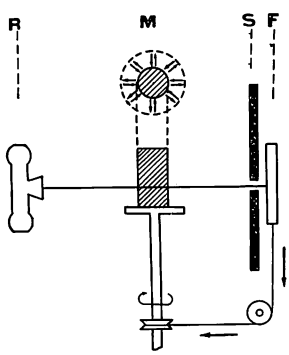


Fig. 93: Schema of the experimental apparatus for Rotation Kymography
R: X-ray tube, M: Rotation table carrying a balloon acting in contraction and dilatation, S: Slit, F: Film

an air pump. By working the pump normally, the balloon was made to perform a simple harmonic motion to the direction of the normal line to the outline of the cross section; and by working the pump with a cam attached, it was possible to make dilating and contracting movements of the balloon of any type at will. If the balloon was divided into two by a partition in the center, and the two parts were made to perform different types of dilatation and contraction, it was possible to get simultaneous or different phase movements of two parts. In company with the results of these experiments, theoretical considerations were also made.

A. Point on the Wall of Balloon in Dilatation and Contraction

As a simple case the movement of a point is considered first.

a). A Point with Simple Harmonic Motion

On the wall of a balloon translucent to X-rays, a lead point was pasted, and the balloon was made to dilate and contract with a simple harmonic motion at the cross section, and while rotating the rotation table on which the balloon was placed, Continuous Rotation Kymography was taken. The result as shown in Fig. 94 was obtained. If in Fig. 94, an arbitrary point of the movement was taken and de-

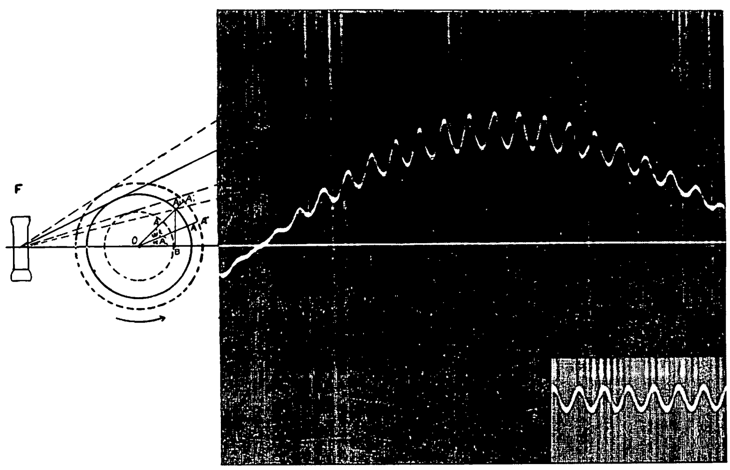


Fig. 94: Continuous Rotation Kymogram of one point
F: Tube focus, O: Rotation center, A: a point acting in a simple harmonic motion.
Bottom right: Usual one slit kymogram of film slide type

signated A, and if this point did not make a dilation or contraction but rotated around the rotation center with an angular velocity ω, the value of y at an optional moment t is represented by

$$y=r\sin(\alpha+\omega t)\frac{a+b}{a+r\cos(\alpha+\omega t)},$$ where α is the initial angle at the rotation. The above is the same as (I, 1, i).

If now this point was supposed to be performing a simple harmonic motion with amplitude l in the direction of the radius, the distance between this point and the point 0 is represented by $r+p$ at an optional moment t. If the point is moving with an angular velocity ω' in simple harmonic motion, then, $p=l\cos(\beta+\omega' t)$, where β is initial angle at the rotation.

If this value is substitued for the above mentioned y, then the value of y will be

$$y=\{r+l\cos(\beta+\omega' t)\}\sin(\alpha+\omega t)\frac{a+b}{a+r\cos(\alpha+\omega t)} \cdots\cdots\cdots\text{V. 1, i}$$

When in this formula $\frac{b}{a}$ approached zero, and $b>r+1>0$, then

$$y=(r+p)\sin(\alpha+\omega t)\cdots\cdots\cdots\text{V. 1, ii}$$

Actually, when Rotation Kymography is applied to clinical use, it was possible to make $\frac{b}{a}=0.2$. In such a case it may be considered that the latter formula can be used instead of the former long formula.

b). N Number of Points Acting in Simple Harmonic Motion

The outline of the cross section of the body can be considered to be an oval closed curve made up of numberless points arranged linearly. Fifteen lead points were pasted at equal distances from each other along the outline of the cross section of the balloon, and then Continuous Rotation Kymography was made while this balloon was made to contract and dilate. The result shown in Fig. 95 was obtained. It will be seen that curves formed by each point compose a curved band.

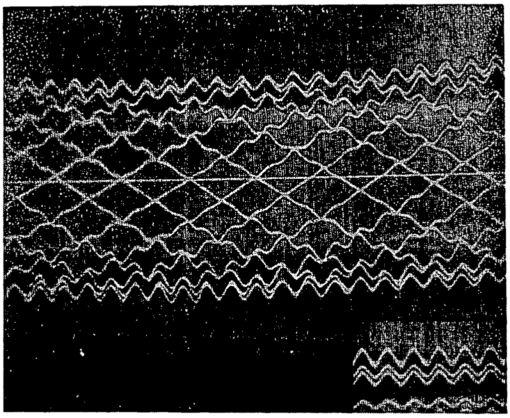


Fig. 95: Continuous Rotation Kymogram of n number of points

In other words, contraction and dilatation of a cross section can be taken to be enveloped lines drawn on the kymogram by each of the numberless points composing the outline of the cross section.······V. 2

B. Cross Section of the Balloon showing Dilatation and Contraction

a). Outline of the Cross Section being a Circle and Its Center Corresponding to the Rotating Center

i) Movement acting Simple Harmonic Motion

Continuous Rotation Kymogram of such a case was shown in Fig. 96, where the X-ray image showed a straight zone parallel to the standard line, but the margins of the zone were wave shaped (Fig. 96).

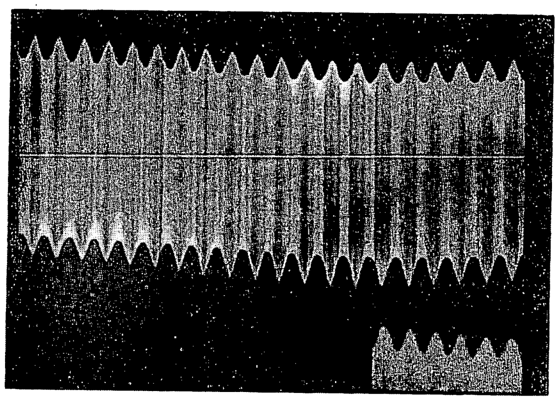


Fig. 96: Continuous Rotation Kymogram of a plane acting in dilatation and contraction in simple harmonic motion

If the circle is not in action in the formula $y=r\sin(\alpha+\Delta\alpha+\omega t)$, an envelope of y becomes a straight line $y=\pm r$, when the value of $\Delta\alpha$ is variable, and this straight line is parallel to the standard line. However, the various points arranged on the circle were perfoming movements represented by the formula $y=r+1\sin(\beta+\omega t)$, so on the margin of the straight zone there resulted in the X-ray image a wave, namely a sine curve, due to simple harmonic motion of the point. In this case the straight line joining the peaks of the waves and that joining the bottoms of the waves (base line) are parallel to the standard line, and the base line of each wave was divided into a and b, if a line was drawn perpendicularly from the peak of the wave to the base line. If a straight line is drawn parallel to the base line, it is divided by this line into m and n by this perpendicular line. If the length of the line joining two successive peaks is represented by e, and that of the line joining the adjacent bottoms of the waves by f, then there exists a relationships of $a=b$, $m=n$, and $e=f$. (Fig. 97) .... V. 3, i

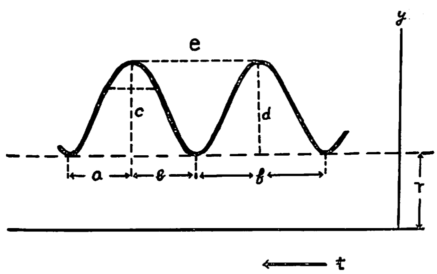


Fig. 97: Schematic representation of the wave of kymogram of Fig. 96

ii) Movement not in Simple Harmonic Motion (Fig. 98 and 99)

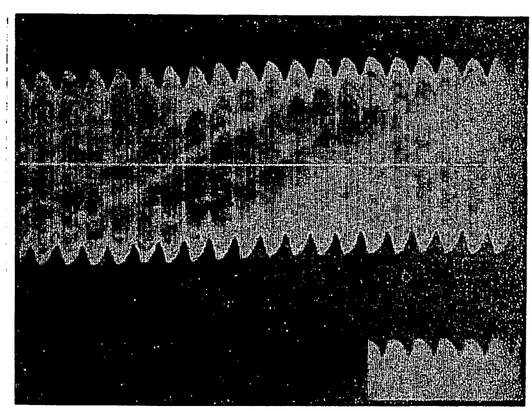


Fig. 98: Continuous Rotation Kymogram of a plane acting in dilatation and contraction not in simple harmonic motion

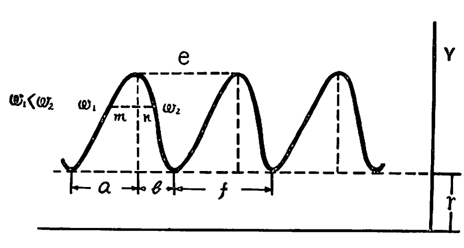


Fig. 99: Schematic representation of the wave of Fig. 98

Instead of contraction and dilatation of a simple harmonic motion, the balloon dilated with an angular velocity ω_1 to reach a maximum amplitude, and contracted with an angular velocity of ω_2 where $\omega_1 < \omega_2$.

Then, there exists in the wavy margin of the curved zone a relationship where $a > b$, $m > n$, $e = f$.……………………………………V. 4, i

b). Outline of the Cross Section forming an Irregular Closed Curve

Actually it was usual for the outline of the cross section to be an irregularly convex closed curve placed in the arbitrary position. In such a case the base line joining the bottoms of the waves on the Continuous Rotation Kymogram was not parallel to the standard line. Even in such cases, however, if the balloon was placed as near as possible to the rotation center of the rotating table, the curvature of the margin of the curved zone of the cross section was not small but large enough to be observed, and it was regarded as approximately a straight line. When the base line of the wave and the standard line were not parallel, then even if the cross section of the organ contracted and dilated with simple harmonic motion, the wavy image of the kymogram did not appear as a sine curve. Nevertheless, there was a relationship of $a = b$, $e = f$, $m = n$. ……………V. 3, ii (Fig. 100). In other words even in the case of B, b, where the line joining the bases of the wavy border of the kymogram showed an inclination of α to the standard line, abscissa, the equation for (V. 3. i), was applicable.

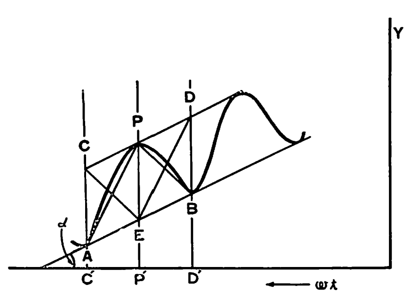


Fig. 100: Schema of the wave of a Continuous Rotation Kymogram

C. Cross Section of the Balloon, divided into two Parts, showing Dilatalion and Contraction

a) Two Parts moving with Different Amplitudes of the Same Phases

When, as shwon in Fig. 101, the two parts of the cross section of the balloon divided by a partition *AB* into part *A* and *B*, were contracting and dilating with different amplitudes but with the same phase movements, the kymogram was analyzed to be the superimposition of two kymograms of the two moving parts. There appeared

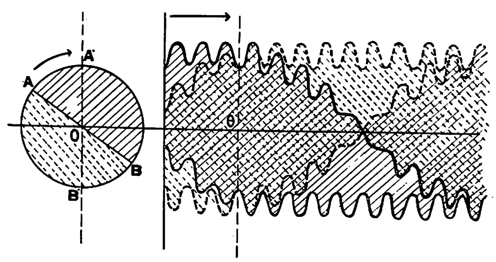


Fig. 101: Schema of superimposition of two Continuous Rotation Kymograms of plane of AA'B and that of AB'B

two wavy borders, one leaving the standard line and the other approaching it, and they were superimposed. If the amplitude of the group *B* waves was greater than that of group *A*, there occurred no complete coincidence by superimposition of the two waves.

The movement at the transitional boundary of two parts are imaged as the superimposition of waves A_0 and B_0.

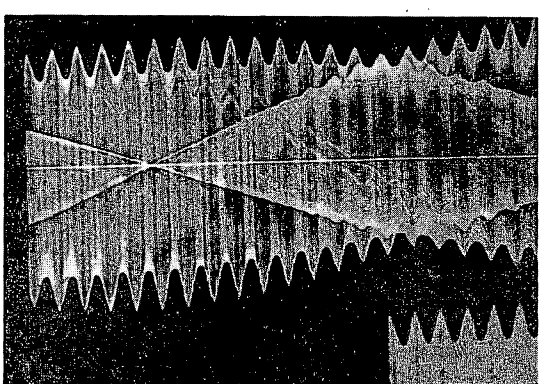


Fig. 102: Continuous Rotation Kymogram of the plane

When wave A_1 was superimposed by wave B_{-1} the form of usual type of wave A_1 was deformed by the cutting away of the top of the wave by crossing with the wave B_{-1}, and the form assumed that as shown in Fig. 103. bottom. In other words, there resulted a special wave type (double wave) and its amplitude was different from existing ones. (Fig. 103) When the bottom of the wave A_0 corresponded to that of the wave B_0 at the point M, there occurred no double wave. Even in such a special case, however, the amplitude of the wave differed at the border of the curved zone.……………………………V. 5. i.

As stated above, when two movements of different amplitudes were in the same phase at the transitional boundary of the two parts, there was produced usually a double wave, except for only special cases. Nevertheless the distances between the bottoms of the waves on the kymogram were always equal.

Thus, throughout Fig. 103 and 104, there was a relationship where $k=l=m=n$. ……………………………………………………………V. 5. ii

Further, the double waves, if imaged, were imaged separately, at equal distance between adjoining peaks or bottoms of the wave, and such was characteristic of a state where the phases of movements were the same between the two parts. ……………………………V.5. iii

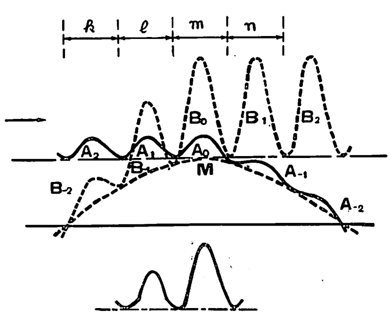


Fig. 103: Sketch of Fig. 102. Schema showing the superimposition of two waves representing the simple harmonic movements of different amplitude in the same phase

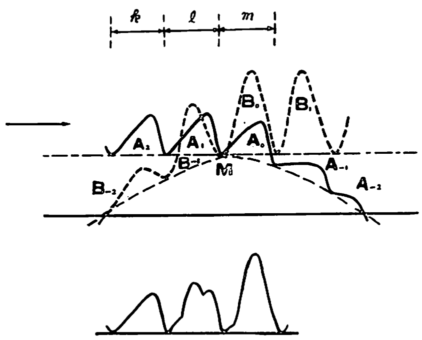


Fig. 104: Schema showing the superimposition of two waves representing the not simple harmonic movements of different amplitude in the same phase

b). Two Parts moving with Different Amplitudes and Different Phases

The phases of contraction or dilatation of groups A and B of waves were taken to differ by angle α, that is, the phase lag being α, as shown in Fig. 105. When waves from A_2 to A_0 and waves from B_2

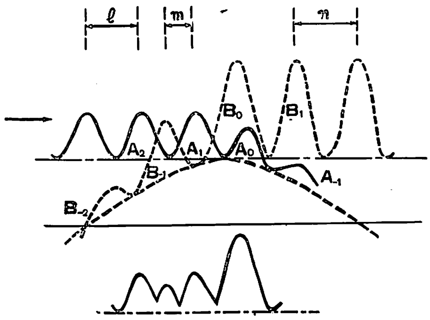


Fig. 105: Schema showing the superimposition of two waves representing the movement of different amplitude in the different phase

to B_1 were superimposed at the transitional part, they produced double waves. However, the double waves differed from that in the former case (V. 5), in that the double waves were not separated individually but formed a single double wave with many peaks and a broad base. It indicated in Fig. 106 an actual kymogram where $\alpha = \frac{\pi}{2}$.
The double wave was seen to have many peaks at the transitional

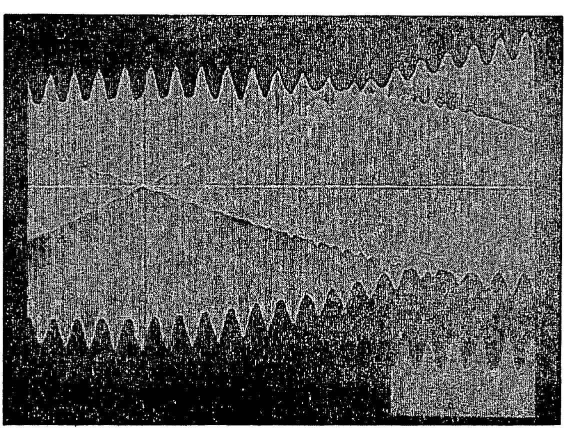


Fig. 106: Continuous Rotation Kymogram representing Fig. 105

part and a broad base of the wave. ....V. 6. i

If now the distances between the peaks of the waves of groups A and B that were not superimposed were taken to be l and n, and those of groups A and B that were superimposed to be m, then $n=l$ and $l \neq m$, and the phase lag α is indicated by $\alpha=\frac{m}{l}\pi$. ......V. 6. ii

When the type of movement differed in contraction and dilatation between two parts of the balloon, there appeared a difference in wave type in the transitional part. In such a case the formation of double waves showed, as already stated, the only difference as the former noted in the type of wave produced, because the shape of the wave did not appear as the sine curves. The double wave produced also possessed many peaks and a wide bottom.

2. *Reading of Continuous Rotation Kymogram*

The nature of the wave on the Continuous Rotation Kymogram has thus been made clear. From this consideration, it will become possible to know the state of the cross section and its movement. As stated above, Continuous Rotation Kymography has two features, that is, the nature of Continuous Rotatography and that of one slit kymography. Usually the X-ray image on the Continuous Rotatogram is represented as a curved zone itself. For determing the state of the cross section of a moving organ from this curved zone, the laws for Rotation Radiography and method of interpreation of Rotation Sighting Radiogram are applicable. From this X-ray image the state of movements of the organ can be interpreted, too.

The heights of the wave at the margins of the curved zone represent the amplitude of the movement. If now the peaks of the waves of the wavy margin and the bottoms of the waves are joined, two pairs of curves will be obtained which can be considered to be the Continuous Rotatograms of the outline of the cross section of an organ that is performing contraction and dilatation. Therefore, the amplitude of movement is interpreted from the reading of the Continuous Rotation Kymography (V. 1).

The type of wave revelas the type of movement. When the type of wave is analyzed by taking the coordinates of time (ordinate) and amplitude (abscissa), the actual state of movement can be interpreted. For example, if the type of the wave is imaged as a sine curve, as stated in V. 3, it can be concluded that the concerned organ is contracting and dilating in simple harmonic motion.

If it is saw-teethed in the shape of wave, as shown in Fig. 107, contraction and dilation are occurreing not with harmonic but with some other kind of movement interpreted by the coordinate mentioned above (V. 4). If the base line of the wave is inclined α to the standard line as shown in Fig. 108, the foot of the perpendicular line drawn from the peak of the wave to the base line, i. e. drawn from P to

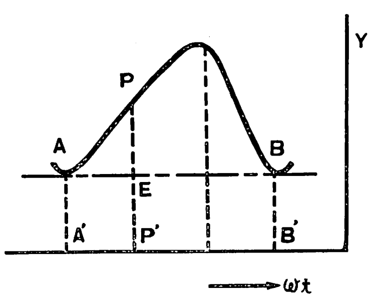


Fig. 107: Schema for reading the Continuous Rotation Kymogram

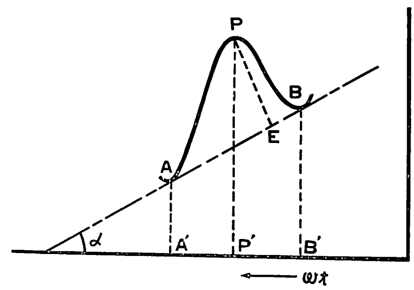


Fig. 108: Schema for reading the Continuous Rotation Kymogram

AB is E, then the distance PE can be considered to be the amplitude of the movement. By so doing, an analysis can be made as in the case of the base line drawn parallel to the standard line. (Fig. 108)

Again when a double wave is recognized in a Continuous Rotation Kymogram, it may be considered to be the superimposition of two different movements at the transitional part of the organ.

If the double waves are separated from each other, and if the phases of the movements in two parts are the same, there will be a relationship of $k=l=m=n$ in the distances between the bottoms of the waves, as stated in (V. 5).

If as stated in (V.6). the double waves are not separated and $l \neq m$, then the phases of the movements in two parts will be different, and the phase can be known from the equation $\alpha=\frac{m}{l}\pi$. And in order to understand the entire nature of the movements in two parts respectively, there would be observed two different types of waves which are imaged close to the concerned double wave. When these two waves are not superimposed, these waves reveal clearly the movements respectively. From an analysis of the shape and peculiarities of these waves, understanding of the movement of the organ will become thus possible.

3. *Reading of Discontinuous Rotation Kymogram and Method of Sketching Cross Section of the Heart*

A Discontinuous Rotation Kymogram is formed by 19 narrow kymograms. At the center of each kymogram there is imaged the standard line and all standard lines of the kymograms are arranged on a straight line in the kymogram. The individually striped kymograms can be regarded to be similar to the usual kymogram of film slide type, so that their readings can be made by the methods of reading for existing kymogram. Successive readings of each striped kymogram will mean an observation of the movement of definite points on the outline of the cross section of the organ.

From Discontinuous Rotation Kymogram, a cross section can be concretely sketched on paper. For this, the peaks and bottoms of the wavy margins of the striped kymogram are joined respectively. These will represent the borders of a heart that contracts and dilates. Thus, the sketch of two contours of a cross section showing contraction and dilatation is prepared according to the operation of Discontinuous Rotatography (Fig. 114). The cross section figure can also be reproduced photographically by Discontinuous Cross Section Radiography (Indirect Method).

4. *Rotation Kymography of the Heart in the Normal Person*[12]

Rotation Kymograms of 30 cases with no pathological findings in the normal radiograms of the chest, and no special findings in ECGs, were observed. The part radiographed was the cross section (horizontal) of the heart across the midpoint of the right border of the heart. (Fig. 109, 110) In reading the kymogram special attention

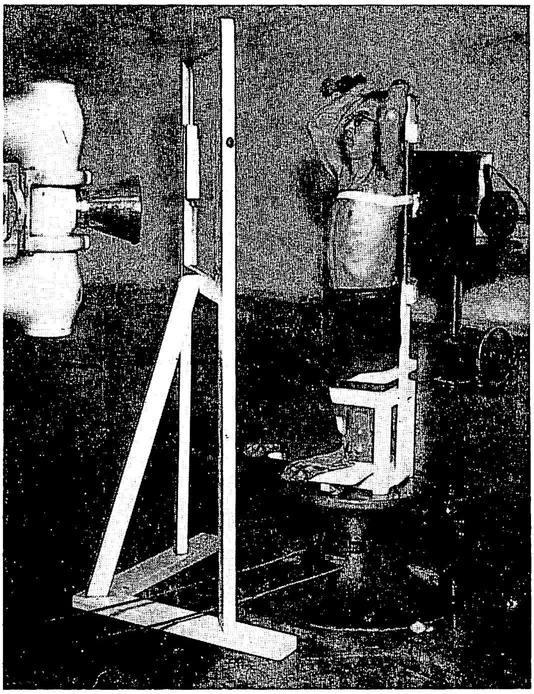


Fig. 109: Rotation Kymograph in action

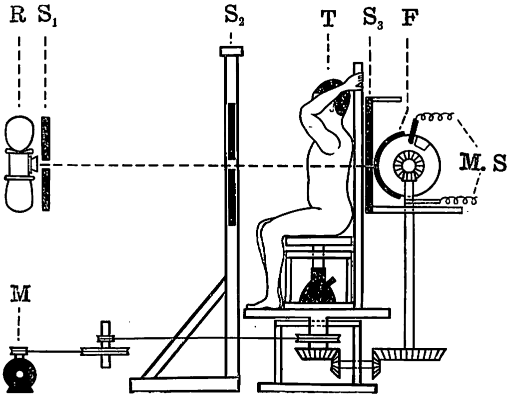


Fig. 110: Schematic representation of Fig. 109
R: X-ray tube, T: Rotation table, S_1: First slit, S_2: Second slit, S_3: Main slit, F: Film, M: Electric motor

was paid to make clear the state of motion at the boundary area between the ventricles and atriums, the type and amplitude of the movement along the outline of the cross section (Fig. 111, 112, 113). The findings are indicated below.

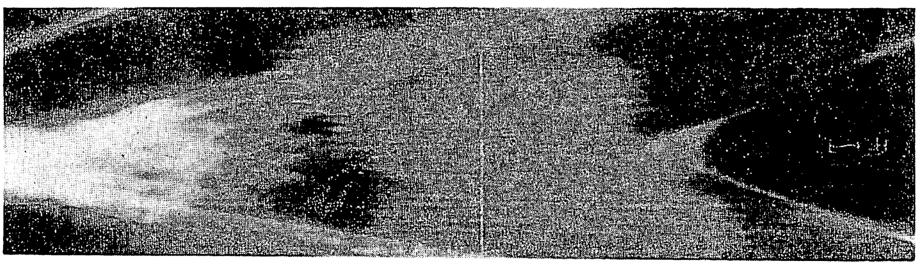


Fig. 111: Continuous Rotation Kymogram

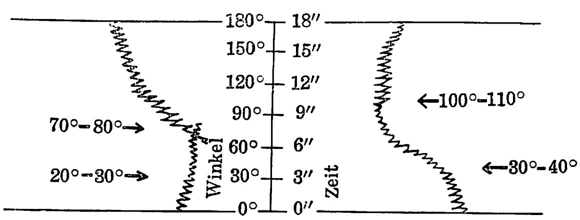


Fig. 112: Schematic representation of Fig. 111

A. Boundary Area between Chambers

In these Rotation Kymograms, a double wave was found, two groups of different types of waves in shape or amplitude appeared discontinuously around a certain point and the distances between the peaks of the wave adjacent to the double wave became different. Thus, as stated in the section on theory of Rotation Kymography, such a part can be considered to be the boundary area between ventricle and atrium. The results obtained by such an interpretation is shown in where in Tab. 14 the left side of the curved zone of the Rotation Kymogram of the heart, in 70% of all cases the boundary points between the atria were noted at rotation angles from 20° to 40°, and in 90% of those between the atrium and ventricle were seen at rotation angles from 70° to 100°. The boundary between atrium and ventricle was recognized in 96.6% of cases, while it was impossible

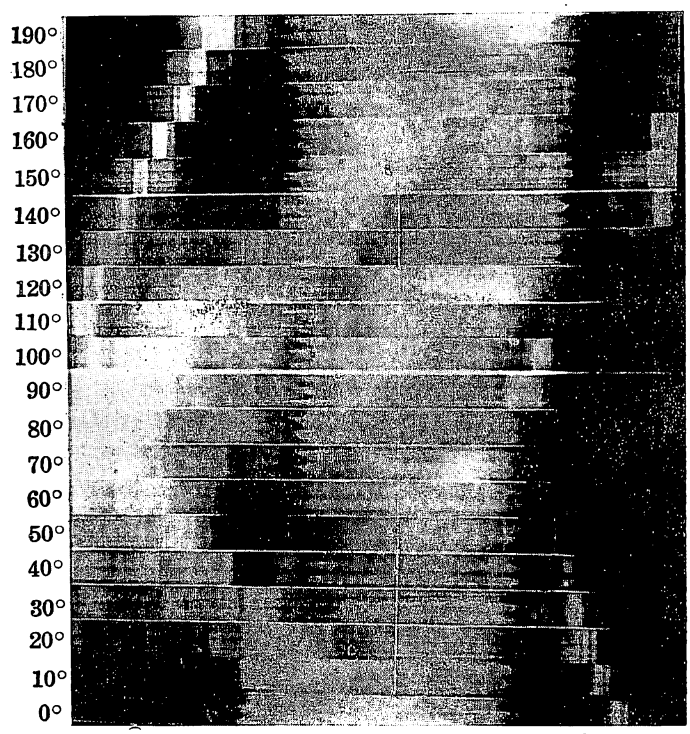


Fig. 113: Discontinuous Rotation Kymogram

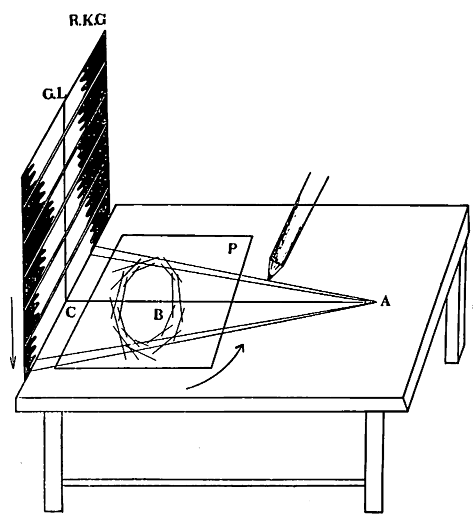


Fig. 114: Schema of method of drawing the outline of the cross sections of the heart from Discontinuous Rotation Kymogram

RKG : Rotation kymogram,
GL : Standard line
P : Paper
A : Point representing the X-ray tube focus
B : Point representing the rotation center
C : Point representing the slit

in the remaining 3.4%. On the left side of the curved zone 54% of the boundaries between the atria were seen at rotation angles of 30° to 50°, and in 36% of cases this boundary could not be recognized. The ventricular boundary was determinable in 70% of cases, and of these 53.3% were at rotation angles of 120° to 140°. Actually there were seen cases where the waves of the kymogrm were superimposed on the X-ray image of the vertebral column etc., and clear differentiation of the shadows could not be made. These are indicated in the Table as not clear.

B. Amplitude

In Rotation Kymogram, the amplitude of the wave on the kymogram will differ as the rotation angle of the body develops. The relationship between rotation angle and amplitude of the wave on a Discontinuous Rotation Kymogram is shown in Tab. 15. It will be seen that the waves on the right side do not show marked changes in amplitude with rotation angles of from 0° to 40°. Eeyond this range

Table 14

Boundary of the atrium and ventricle in the Rotation Kymogram

<table>
<tr><th rowspan="2">Rotation angle</th><th colspan="2">Right side</th><th rowspan="2">Rotation angle</th><th colspan="2">Left side</th></tr>
<tr><th colspan="2">Boundary between the atria</th><th colspan="2">Boundary between the ventricles</th></tr>
<tr><td>20°- 30°</td><td>15 cases (50%)</td><td rowspan="2">21 cases (70%)
not clear
9 cases (30%)</td><td>30°- 40°</td><td>5 cases (17.0%)</td><td rowspan="2">16 cases (54%)
not clear
14 cases (36%)</td></tr>
<tr><td>30°- 40°</td><td>6 cases (20%)</td><td>40°- 50°</td><td>11 cases (37.0%)</td></tr>
<tr><td></td><td colspan="2">Boundary between left atrium and ventricle</td><td></td><td colspan="2">Boundary between right atrium and ventricle</td></tr>
<tr><td>60°- 70°</td><td>1 case (3.3%)</td><td rowspan="5">29 cases (96.6%)

not clear
1 cases (3.4%)</td><td>110°-120°</td><td>3 cases (10.0%)</td><td rowspan="5">21 cases (70%)

not clear
9 cases (30%)</td></tr>
<tr><td>70°- 80°</td><td>9 cases (30.0%)</td><td>120°-130°</td><td>7 cases (23.3%)</td></tr>
<tr><td>80°- 90°</td><td>9 cases (30.0%)</td><td>130°-140°</td><td>9 cases (30.0%)</td></tr>
<tr><td>90°-100°</td><td>9 cases (30.0%)</td><td>140°-150°</td><td>2 cases (6.7%)</td></tr>
<tr><td>100°-110°</td><td>1 cases (3.3%)</td><td></td><td></td></tr>
</table>

there is a tendency to increase in amplitude, and from 80° onwards the increase becomes suddenly marked, and a maximum is attained at 120°. When the rotation angle becomes greater than this there occurs a secondary decrease up to 190°. The waves on the left side show a tendency to decrease in amplitude from 0° to 80°, and at 80° there is a sudden marked decrease with the minimum at 90°. Beyond 100° an increase begins to appear which reaches a maximum at 130°. After this there are seen no great changes in amplitude up to 160°,

Table 15

Relationship between rotation angle and amplitude

	Amplitude of the waves on the left side			Amplitude of the waves on the right side		
Rotation angle	Case number	Arithmetical mean	Standard deviation	Case number	Arithmetical mean	Standaad deviation
0°	30	7.16	±1.47	29	3.76	±1.75
10°	30	6.86	±1.31	25	3.50	±1.01
20°	29	6.41	±1.23	21	3.43	±1.17
30°	29	6.24	±1.58	19	3.66	±0.92
40°	29	6.01	±1.51	23	3.33	±0.85
50°	28	5.57	±1.35	23	3.65	±1.16
60°	21	5.40	±1.33	24	3.84	±1.22
70°	15	4.56	±1.87	27	3.72	±2.01
80°	6	3.67	±1.33	27	4.96	±2.07
90°	2	2.10	±0.31	27	7.34	±3.28
100°	6	3.45	±0.95	28	8.81	±2.17
110°	10	4.15	±0.67	28	9.75	±2.17
120°	19	4.61	±1.74	29	9.86	±2.06
130°	28	5.44	±2.13	28	9.03	±1.83
140°	30	5.45	±1.73	30	9.26	±1.61
150°	30	5.45	±1.84	30	8.65	±1.71
160°	30	4.59	±1.43	30	7.98	±1.74
170°	28	4.24	±1.07	30	7.62	±1.47
180°	26	3.81	±1.10	30	7.68	±1.42
190°	23	3.67	±1.05	29	7.02	±1.56

Table 16

Amplitude of the atrium and ventricle in Rotation Kymogram

	Right atrium	Left atrium	Left ventricle	Right ventricle
Amplitude (average)	4.17±1.06	3.97±0.91	7.87±1.05	4.75±1.27

but after 170° there occurs a secondary decrease up to 190°. In Table 15, it will be found that there is indicated no uniformity in the number of cases to be mentioned, but this is because depending upon the rotation angle the waves were not clearly recognizable and such cases were omitted, and measurements were made only of those where the waves were clearly recognized.

In order to compare the amplitudes of the atrium and ventricles along the outline of the cross section, the averages of the amplitude of Discontinuous Rotation Kymograms taken at every 10° of rotation angle were calculated, and these are indicated in the Tables 15 and 16. It will be seen that in the cross section, the amplitude of movement of the left ventricle is greatest, followed by those of the right ventricle, right atrium and left atrium in this order.

C. Wave Type

In Rotation Kymogram of the heart the types of wave appearing along the border will differ depending on the part of the heart, direction of X-rays and individual variation. However, from observations of the normal heart by Discontinuous and Continuous Rotation Kymograms, as well as from a classification by existing kymograms, we classified the wave types of a Rotation Kymogram into eleven basic types (Fig. 115). The ratio of appearance of these basic types according to rotation angles are indicated in Table 17. Of these various types of wave appearing in Rotation Kymograms, the curved and straight hooked types are seen most, and they appear throughout the whole range of rotation of from 0° to 190°, followed by the

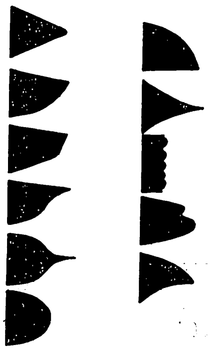


Fig. 115: Wave types of Rotation Kymogram

Left: From top to bottom: Straight hooked type, Curved hooked type, Blade type, Pointed hooked type, Pointed circular type, Circular arc type

Right: From top to bottom: Vessel type, Pointed hill type, Glimmering type, Double type, Dilating leg and concave type

Table 17 Ratio of appearance of the basic type of waves and the rotation angle in Rotation Kymograms

Left Border	Dilating leg and concave type													15.4	10.5	23.3	23.5	20.9	4.8		
	Double type						5.2	6.4						7.7	10.5	9.6	9.6	13.3			
	Glimmering type														5.5			4.8	4.8		
	Pointed hill type																				
	Vessel type																				
	Circular arc type							12.8	22.3	50.0	50.0	20.0			10.5	4.8		4.8	4.8	5.5	
	Pointed circular type													23.1	21.0	9.6	4.8	4.8			
	Pointed hooked type								11.1			20.0	12.5							5.5	5.5
	Blade type	38.1	38.1	50.0	68.4	57.9	52.8	43.3	37.3			20.0	50.0	7.7	10.5	19.2	23.5	13.3	23.8	30.9	30.9
	Curved hooked type	57.1	57.1	45.0	31.6	26.3	31.5	37.5	33.3	50.0	50.0	40.0	25.0	38.4	31.5	33.5	33.5	28.5	52.2	52.6	63.6
	Straight hooked type	4.8	4.8	5.0		15.8	10.5							7.7			4.8	9.6	4.8	5.5	
	Rotation angle	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	190°
Right Border	Dilating leg and concave type		5.0																		
	Double type	5.0	10.0	18.2	26.8	18.8	11.6	5.5	5.2	5.2											
	Glimmering type																				
	Pointed hill type																				
	Vessel type	5.0	5.0		13.3	11.6	5.8			5.2	4.8							4.8			
	Circular arc type	10.0	5.0	11.6					5.2	5.2								4.8	4.8	9.6	9.6
	Pointed circular type								5.2	5.2	9.6	14.8	19.0	23.8	19.0	9.6	9.6	16.4	4.8		
	Pointed hooked type			11.6	13.3	11.6	17.4	22.0	10.4	20.8	47.6	62.0	62.0	47.6	38.1	38.4	24.0	9.6			
	Blade type	30.0	35.0	29.3	33.3	29.0	47.8	45.0	48.0	37.6	14.8			4.8	9.6	9.6	19.2	16.4	38.4	38.4	42.4
	Curved hooked type	50.0	40.0	29.3	13.3	29.0	17.4	27.5	26.0	20.8	23.2	23.2	19.0	23.8	33.3	42.4	42.4	48.0	52.0	52.0	48.0
	Straight hooked type																4.8				

apical hooked, apical round, double, and dilating leg and concave types are seen randomly. In Rotation Kymogram, the waves appear in the right border throughout the entire range of rotation, but those appearing in the left border become difficult to discern as the rotation angle becomes 90° due to the superimposition of shadows of the heart and sternum. The rates of differentiation of the waves in relation to rotation angle are shown in Tab. 18. It will be seen that at rotation angles of 0° to 50°, and 130° to 190°, 90% of the waves

Table 18
Rates of differentiation of the waves in relation to rotation angle in the Rotatory Kymogram

Rotation Angle (degree)	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
Rate of differentiation %	100	100	96	96	96	91	77	43	19	7	24	38	62	91	94	96	96	100	100	100

could be discriminated, but beyond 60° discrimination became suddenly difficult, and at 90° only 7% (minimum) could be discriminated. Beyond this, with increase in the rotation angle the rates of wave discrimination became better again.

5. *Clinical Applications of Rotation Kymography*

As Rotation Kymography has been applied to the diagnosis of heart diseases, a case of mitral stenosis will be described here as an example, with special mention made of the border of the atrium and ventricle division, amplitude, type of pulsation, coefficient of pulsating area, and wave type of the cross section of the heart where in the normal radiogram of the chest there was seen dilatation of the left atrium and pulmonary conus, and dilatation of the right atrium. The part photographed was a horizontal cross section of the heart at the most bulging part of the right atrium border of the heart (Fig. 116, 117 and 118).

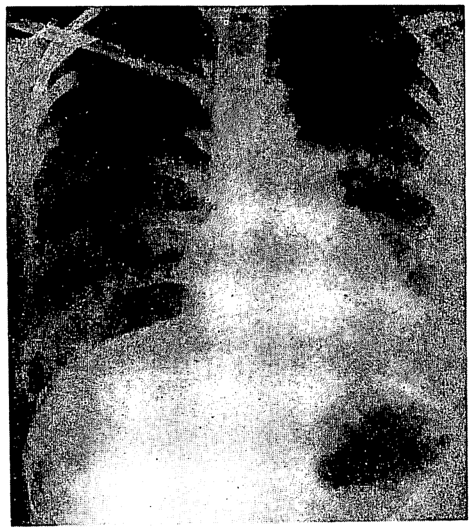


Fig. 116: Normal radiogram of the heart in mitral stenosis

Fig. 117: Continuous Rotation Kymogram of the heart in mitral stenosis

A. Atrium Ventricle Boundary

The positions of the atrium ventricle boundaries in the cross section, as indicated in Tab. 19, showed that the boundary between the right atrium and left atrium lay within rotation angles of 10° to 30°, that of the left atrium and left ventricle within the range from 70° to 100°, that of the left ventricle and right ventricle within 20° to 30°, and that of the right ventricle and right atrium within 140° to 160°. When these were compared with those of normal cases, it was noted that the boundary of the left atrium and right atrium appeared at rotation angles shallower than in the case of normal, while no abnormalities were seen in the boundary of the left atrium and left

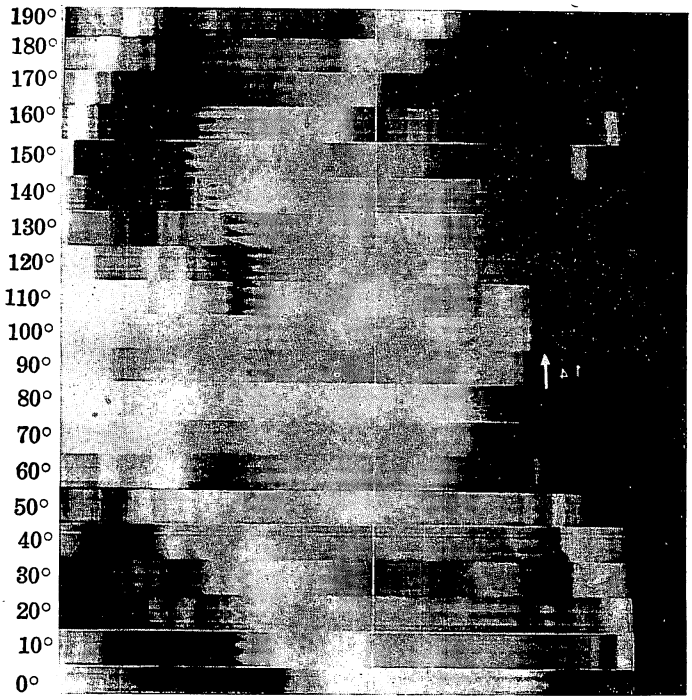


Fig. 118: Discontinuous Rotation Kymogram of the heart in mitral stenosis

ventricle. It was thus clear that there was a bulging in the left atrium. Again, the boundary of the left ventricle and right ventricle was seen to be present at a shallower rotation angle; contrary to this the boundary of the right ventricle and right atrium was seen with a large rotation angle. From these findings it became clear that there was a dilatation of the right ventricle as a whole. Then dilatations of the right ventricle and atrium were recognized concretely as projections in the image of the heart directed externally, in Continuous Rotation Kymography.

B. Amplitude

In order to compare the respective amplitudes of the atrium and ventricle along the outline of the cross section, the averages of their amplitudes were taken for each rotation angle of 10°. The results indicated in Tab. 19 show that they were 4.4 ± 1.7 mm for the right

Table 19

	Mitralstenosis		Normal control		Judgement
Atrium- ventricle division	Right atrium-left atrium	10°— 30°	Right atrium-left atrium	20°— 40°	Bulging of left ventricle
	Left atrium-left ventricle	70°—100°	Left atrium-left ventricle	70°—100°	
	Left ventricle-right ventricle	20°— 30°	Left ventricle-right ventricle	30°— 50°	Bulging of right ventricle
	Right ventricle-right atrium	140°—160°	Right ventricle-right atrium	130°—140°	
Amplitude	Right atrium	4.4 ± 1.7	Right atrium	4.17 ± 1.06	Right atrim +
	Right ventricle	6.2 ± 0.9	Right ventricle	4.75 ± 1.27	Right ventricle ++
	Left atrium	3.6 ± 0.57	Left atrium	3.97 ± 0.91	Left atrium —
	Left ventricle	8.1 ± 1.45	Left ventricle	7.87 ± 1.05	Left ventrucle +
Coefficient of pulsating area	8.83 ± 0.55		9.34 ± 1.14		Decreasing of coefficient
Pulsating type	All cases	type A	type A	16.7%	
			type B	73.3%	
			Intermediate type	10.0%	

atrium, 6.2±0.9 mm for the right ventricle, 3.6±0.57 mm for the left atrium, and 8.1±1.45 mm for the right ventricle. Thus it was found that the values for the right atrium and left ventricle were slightly greater than normal, for the left atrium slightly smaller, and that for the right markedly increased.

C. Coefficient of Pulsating Area

In Continuous Rotation Kymography, when the points corresponding to the peaks of the waves and bottoms of the waves were successively joined together, two figures, large and small, was obtained from the internal and external margins of the heart shadow, corresponding to the contraction and dilatation of the heart. If it was considered then that to be differences existed in heart shadow produced by dilatation and contraction, and the value obtained by boundary of this area by that of the contracting shadow to be the coefficient of pulsating area, the value obtained was 8.84±2.65, as indicated in Tab. 19. This, when compared with 9.34±1.14 of a normal heart, was seen to be smaller. In other words, the amplitude in this particular case was in general increased, but the cardiac function was found to be lowered as the coefficient of pulsating area indicated.

D. Type of Pulsation

In this case the type of pulsation was type A where the amplitude becomes larger with increase in rotation angle. This deserved attention as in the normal heart 73.3% showed decrease in size of amplitude with increase in rotation angle, and was of the type B.

E. Wave Type

No wave type specific to this case was noted, except that in the right atrium and left atrium double type and curved hooked types, were mainly seen, besides a pointed hill type. In the right ventricle close to the left ventricle were noted and straight hooked types, but as the rotation angle approached 90°, a circular arc type and type with indefinite amplitudes were recognized. In the left ventricle curved hooked, pointed hooked and pointed circular types were most numerously noted, followed by the pointed hill and circular arc types.

By application of Rotation Kymography in diseased hearts it became possible to obtain various findings in the movement of cross section, hitherto not available. In other words, not only along the longitudinal direction but also along the horizontal plane the dilatation of the atria and ventricles was possible to be known. In addition it was possible to know numerically by the increase and descrease in amplitudes the states of disease of the atria and ventricles. Also by adoption of tne coefficient of pusating area it became possible to express numerically the functional state of the diseased heart. That the type of pulsation in the diseased heart might change into type A deserved attention. No specific wave types were noted, but it was ascertained that the pointed hill, circular arc and types found to be characteristic of diseased hearts by plane kymography, were also most numerously seen in this Rotation Kymography.

Summary

None of the usual methods of X-ray examination can present the actual state of the body interior as satisfactorily as is possible to determine with the naked eye during autopsy because they can make only two-dimensional images whereas the autopsy possesse three dimensional image capacity.

The fault in the present radiography the general rule that both the tube and the subject must keep absolutely still or be allowed movement within a limited range, and hence radiography has been operated only statically up to the present time.

To improve the technique of radiography, there has been devised an original method whereby the X-ray tube is movable, i. e., the tube can rotate freely around the subject. This new method is termed " Rotation Radiography " because, during operation, the X-ray tube and the film are both rotated in the same direction from 0° to 190° around a certain point within the subject to be examined. Identical results were obtained when the tube and film were kept at rest and the subject on the rotating table was made to turn in the opposite direction from the foregoing.

The aim of Rotation Radiography is to make clear the dimension of depth of the subject which is lacking in the usual radiogram, and thus to discover the diseased foci and to help in diagnostic discrimination between diseases.

In Rotation Radiography, even though the X-ray tube be rotated around the subject, the mode of rotation is varied. There are various kinds of combinations between the modes of rotation of the tube and those of rotation or transfer of the film. As many modes of rotation and rotation combinations as possible were devised.

According to the kind of rotation employed, the results of radiography will differ and as a consequence the aims of Rotation Radiography must also differ. Thus, based on its aims, Rotation Radiography has been classified into four types: (1) Rotation Sighting

Radiography; (2) Cross Section Radiography; (3) Solidography and (4) Rotation Kymography When compared with existing methods of radiography they correpond to (1) normal radiography, (2) tomography, (3) stereography and (4) roentgen kymography, respectively. Rotation Radiography, however, has made available findings not heretofore possible.

All these types of Rotation Radiography were not devised simultaneously. They were developed one-by-one as outgrowths.

In 1946 the theory of Rotation Sighting Radiography was introduced by the present author. From the Rotation Sighting Radiography there were soon developed two radiographic methods, one Continuous Rotatography (1946) and the other Discontinuous Rotatography (1947), revealing a cross section of the subject. From these two methods a further five were successively devised for taking cross section images, viz., Direct Cross Ssction, Continuous Cross Section (Original Method), Rotatory Cross Section, Direct Cross Section (Direct Crossgraphy, Improved Method) and Discontinuous Cross Section (Discontinuous Crossgraphy, Indirect Method). Continuous Rotatography preceded Rotation Kymography and Rotatory Cross Section Radiography proceded Solidography.

During the progress of these investigations it was found possible to unify the several types of Rotation Radiography and take radiograms with one single apparatus, because common to all types was the characteristic enabling the X-ray tube to be rotated around the still subject. For this, a Universal Rotatograph of horizontal type was manufactured and now this type of Rotatograph is also in clinical use.

The two principal features of Rotation Radiography lie in rotation accuracy and range of rotation from 0° to 190°. When accurate rotation is made it is found that certain laws must control the tube focus, the subject, rotation center, and X-ray image. These laws are the basis of Rotation Radiography.

When a point rotates around the rotatory center, a curvedl ine y representing the point will be imaged so as to mingle with the standard line (locus image of the rotation center on the radiogram) as follows:

$$y = r \sin\theta \frac{a+b}{a+r\cos\theta}$$

where r is point - rotation center distance; a is focal spot - rotation center distance; b is rotation center - film distance, and θ is rotation angle.

Thirteen laws similar to this formula were obtained when various kinds of subjects were used as models in the experiments.

As for the range of rotation, it was proved geometrically that every organ in the body can be inspected from all directions when the rotation angle is from 0° to 190° and thus every organ is delineable.

Rotation Sighting Radiography is a type of Rotation Radiography. In this type of radiography, every time rotation is stopped it is made to stop at an angle previously determined, that is, at the discontinuous rotation angle which was adjusted to a desired degree according to the size and outline of the organs to be examined. The subject is then successively exposed to X-rays.

Thus Rotation Sighting Radiogram consists of a series of radiograms taken from different directions successively. Each one of the Rotation Sighting Radiograms is, little more than a composite of normal radiograms, differing from the normal, however, only in that they are joined together by their standard line and are arranged according to discontinuous rotation angle. Characteristic decipherment of Rotation Sighting Radiograms will thus become possible under the laws governing Rotation Radiography.

At present, however, the main purpose of Rotation Sighting Radiography is detecting lesions separate from superposition of shadows through successive serial radiography and keeping a check on the results with margin of error controlled by the discontinuous rotation angle previously determined.

The margin of error against missing the lesions to be imaged can be represented by

$$h=\frac{a}{2}\tan\frac{\varphi}{2}$$

where a is anatomical data and φ is discontinuous rotation angle.

When this method was actually applied to radiography of renal pelvis, in the X-ray image the number of isolated calyces was increased by 65.3% when compared with results of existing methods of normal radiography and furthermore the shape and state of the calyces could be exactly determined.

When the photoroentgenographic technique was applied to this Rotation Sighting Radiography for examination of the chest, diseased foci were revealed by 2.9% more than by normal methods and that contributed to a differental diagnosis by 15.6% more in total than by normal photoroentgenography. Of 1,258 cases, the benefit from this method of roentgenography amounted to 96.7%.

The size of sella turcica was measured accurately, when applied these method, because it was possible to image the overlap of both anterior and posterior clinoid processes. The state of sella was clearly seen when both sides of processes were imaged separately.

For taking radiogram of optic canal, this method proved to be entirely suitable because the en facé image of sharp ring image without deformity of the canal was obtained, and complete differentiation between the optic canal and ethomoid cells became possible.

Cross Section Radiography is a type of Rotation Radiography which, in the cross-section, clarifies of the state by radiography. Seven types were devised. Cross Section Radiography is the common name for these seven types. Each has the following features.

Discontinuous Rotatography

Rotation Sighting Radiograms are made by successive images on one film whereby there results a radiogram with gradations similar to those of kymography. With this Rotatogram, the cross section of the body is drawn on a paper by systematically arranged procedure. The cross section figure obtained is life size, but the procedure of drawing is indirect and laborious. Further, it can not be disregarded that there is a possibility of thinking subjectively when drawing the cross section.

Continuous Rotatography

Continuous Rotatography corresponds to Discontinuous Rotatography made at a discontinuous rotation angle of 0°, that is, it becomes continuous. In this type of radiography both sharpness and contrast ars good. The procedure of radiography is simple and direct, but it needs skill to decipher the radiogram because of lack of concreteness in the X-ray image.

Continuous Cross Section Radiography (Original Method)

This is a device for drawing the cross section photographically from Continuous Rotatogram. The procedure is indirect but it is possible to exclude the subjectivity in drawing. The image obtained, however, is somewhat less sharp, but of actual size.

Direct Cross Section Radiography (Original Method)

This is a type of radiography for obtaining the concrete figure of a cross section without resorting to indirect procedure of reproduction. This method is time consuming and the subject is exposed to comparatively large doses of X-rays, although the radiogram obtained is of good contrast. The defect is that the X-ray image is not sharp, and not life size but is somewhat enlarged.

Rotatory Cross Section Radiography

This type of Cross Section Radiography is similar in technique to Axial Transverse Stratigraphy (Vallebona) and to Transversale Schichtaufnahme (Gebauer and Wachsmann)

The technique consists of rotating two rotation tables, one for subject and one for film, synchronously during exposure.

The procedure is direct but the X-ray image obtained is not life size. By this radiographic method, not only horizontal cross section, but also inclined or curved images can be obtained.

Rotatory Cross Section Radiography is simple to operate, and the subject to be examined is exposed to only small doses of X-rays so that it is being used widely in clinical practice.

Direct Cross Section Radiography (Improved Method)

For an improved method of Direct Cross Section Radiography, a device was made by which the film is exposed to divergent X-rays while it faces the X-rays perpendicularly. Sharpness and contrast of X-ray images become better than those of the Rotatory Cross Section Radiography. The procedure is direct, but the X-ray image is enlarged but not life size. This method is time consuming and thus restricted to clinical use.

Discontinuous Cross Section Radiography (Indirect Method)

In this method a device is used to reproduce the cross section of the indirect method at the Continuous Cross Section Radiography. With any Continuous Rotatogram previously taken, an X-ray film is made to face perpendicularly to X-rays and the rays made to diverge, as is done in the original method of Continuous Cross Section Radiography. Sharpness and contrast of the cross section image obtained by this method are better than by the original one. This method may be applicable to clinical use.

The most advanced forms of Cross Section Radiography can be accepted as the last three types, i. e., Discontinuous Cross Section, Rotatory Cross Section, and Direct Cross Section Radiography

At present, of these three the most convenient for clinical practice may possibly be Rotatory Cross Section Radiography. For this reason more details will be gone into now. Details of the general aspect of Rotatory Cross Section Radiography have already been published widely. Therefore the data here are restricted to results obtained in our investigations which results can be regarded as important.

The apparatus and technique of Rotatory Cross Section Radiography used in Japan can be considered characteristic of this country, because it differs from those used in other countries in that it did not evolve from tomography but developed step-by-step from Rotatography. First, apparatus and technique are briefly outlined, as follows:

The tube inclination angle (angle between the central X-ray and the film surface laid horizontally) is small, about 15° ; a normal radiographic unit is attached to the Rotatograph ; additiontal accessaries for radiography of inclined or curved cross section are attached; variable focal spot tube is used; range of tube rotation is from 0° to 190° and over; high voltage radiographic technique is used. A trial Rotatograph of horizontal type was successfully produced.

In order to examine the quality of X-ray images, the mechanism of occurance of the obstructive shadow in Rotatory Cross Section Radiography was geometrically considered, and laws were obtained.

The first investigations were made to ascertain what factors had the most influence on contrast, sharpness and exhibiting power of minute subject in Cross Section Radiography.

Contrast in Rotatory Cross Section Radiogram which is taken at tube inclination angle of 15° is inferior to that of a tomogram made at a rotation angle of 60°.

Sharpness becomes poorer as the tube inclination angle becomes smaller and as the intensifying screens become thicker.

Regarding the exhibition power of this method to a small subject, Rotatory Cross Section Radiography is not so good as tomography.

One good feature, however, of this roentgenographic method is that there is no distortion of the X-ray image.

Some obstructive shadows of ribs, termed line shadow, do occur especially when the chest is imaged. The obstructive shadows in this case are classified into four types, A, B, C and D. When the tube inclination angle is made small, that is from 30° to 8° respectively, the obstructive shadows grow fainter and do not confuse diagnosis. In other words, the smaller the angle, the fainter the shadows. With a tube inclination angle of 15°, only 15% of the obstructive shadows can be distinguished in radiograms of the chest. When the high voltage technique is adopted, the obstructive shadows also become faint.

It can thus be concluded from the foregoing that a tube inclination angle of 15° is suitable for Rotatory Cross Section Radiography, because obstructive shadows can be eliminated, even though contrast and sharpness must suffer.

At present, Rotatory Cross Section Radiography is applicable for use in imaging any part of the body. Rotatory Cross Section Radiography was taken of 98 healthy adults and the topographical relation of the stomach, kidney, and gall bladder to the body in the cross section, was plotted in the diagram by using a polar coordinate system.

The merits of this method as applied to chest diseases were listed one-by-one. As to its ability to detect lesions, the Rotatory Cross Section Radiography may be somewhat inferior to tomography due to image fuzziness, but is supperior in that it does show the actual location and real shape of lesions in the cross section. It was learned that the diagnosis of lesions in the mediastinum was established better by means of detecting the presence of lesion and ascertainning their location. Moreover, this method has the advantage of being applicable to pretherapeutic use.

Solidography is a type of Rotation Radiography by which internal body organs are in image transfered radiographically in their original shapes outside the body. This is an application of the principle of X-ray image formation in Rotatory Cross Section Radiography that there exists on the rotation table placed farthest away from the tube focus, a three dimensional image similar in shape to the actual body placed on the rotation table nearest to the tube focus. Though the X-ray image is similar in size to the actual body, it is enlarged in ratio of $\frac{a}{b}$, where a is focus film distance and b the focus body distance.

The principle of this method was proved not only geometrically but also experimentally. A film block composed of 120 sheets of film piled up one on top of the other and exposed by this method. On each film there was an image corresponding to the cross section of the subject. The figure of the X-ray image was cut out of every film and again piled up in the original order; then a film block quite similar to the actual body was obtained.

In place of the film block, however, a cassetter of multilayer films is used clinically. A total of 18 sheets of X-ray paper is enclosed at intervals of 3 cm in the cassette. The cassette was divided into three sections and each section exposed at every rotation of 190°. By a special technique of operation, there is a difference of 1 cm between the position of the film in the first section of the cassette and the position of the two subsequent exposures. Hence the subject is seen radiographically as cross sections at 1 cm intervals. By the similar technique Simultaneous Multi Cross Section Radiograpay is also applicable.

A specially contrived apparatus for molding the organs into a concrete figure is composed of two rotating tables placed on the same plane. A photo tube over one table is connected by a relay apparatus to a cutter over the other table. On one table is placed the Cross Section Radiogram, and on the other a plaster disc. The X-ray image on the Cross Section Radiogram is traced by a photo tube and the plaster disc is cut by a cutter which acts synchronously with the photo tube. The discs cut are piled up together according to their standard line. The general appearance showed that the molded organ is in tiers. The real organ, however, has no tiers, its contour being smooth and continuous. Therefore, the figure-cut tiers are nearer to the actual figure than is the molded original figure. This was proved geometrically also.

The heart, which is not observed stereoscopically because of homogenous shadows, was molded and observed three dimensionally. The molding of the figure serves to give real facts about the diseased heart in configuration of deformity.

The kidney is also molded by this method after insuflation into the retroperitoneal cavity.

Rotation Kymography is a type of Rotation Radiography by which contraction and dilatation of an internal organ can be recorded along the outline of the cross section.

There are two types of Rotation Kymography, Continuous and Discontinuous, in which there are arranged, in this order, an X-ray tube, subject on rotatory table, a lead plate with horizontal slit and film. The rotation of the rotation table and the transfer of the film are connected by gearing.

In Continuous Rotation Kymography, exposures are made continuously while the table is rotated from 0° to 190°.

The radiogram thus obtained is an image of a curved zone and the margin of the curved zone is wavy and similar to that of the usual kymogram. The standard line is imaged in the middle of the radiogram. This method corresponds to the slit slide type of usual roentgen kymography, because the wavy margin of the curved zone represents the movement of all points ranging along the outline of the cross section.

In Discontinuous Rotation Kymography, an exposure is made while the film is transfered over a certain short distance, but the rotation table is at rest. Next, after the rotating table is made to rotate at 10°, the subject is brought to a stop and an exposure is made after the film has started to move again. The procedure is repeated through 0° to 190°. This method corresponds to the usual roentgen kymography of the film slide type because only definite points along the outline of cross section are recorded in their movement.

In order to decipher the Rotation Kymogram, the laws governing the Continuous Rotation Kymogram were considered.

If a point is distant from a center r and is rotated around the rotation center at an angle velocity ω, and if the point acted in simple harmonic motion with amplitude l, then the locus of the point in the X-ray image can be represented.

$$y=r\sin(\alpha+\omega t)\frac{a+b}{a+r\cos(\alpha+\omega t)}$$. If $b>r+1>0$, and $\frac{a}{b}\rightarrow 0$,

$$y=(r+p)\sin(\alpha+\omega t),$$

where $p=1\cos(\beta+\omega t)$.

From geometrical consideration and model experiment seven laws governing Continuous Rotation Kymography were obtained.

By means of the thirteen laws governing Continuous Rotatography and the seven laws governing Kymography a way was studied as to how to get the position, shape, and size as well as the mode of the movement of the organ in the cross section.

Interpretation of Discontinuous Rotation Kymogram is similar to that of usual kymogram of film slide type. In Discontinuous Rotation Kymography when the technique of Rotation Radiography is used, it is possible to get a sketch of the figure in cross section of the body.

Rotation Kymograms of the heart in thirty adults having no heart abnormality were observed.

Thus it was made clear that the position of the boundary between ventricle and auricle or between both ventricles was not fixed, but it was shown that there were variations, for instance variations in rotation of the heart.

The amplitude was greates in the left ventricle, followed by that in the right ventricle, right atrium and left atrium, in this order.

The waves in the margin of the curved zone of the heart were classified into eleven types.

By application of Rotation Kymography to investigate diseased hearts, it has become possible in the cross section to know the various modes of movement hitherto not available.

Zusammenfassung

Keine der üblichen Methoden der Röntgenuntersuchung vermag den wahren Zustand des Innern des Körpers so genügend darzustellen, wie er bei der Autopsie mit blossem Auge festgestellt werden kann, weil sie nur zwei-dimensionale Bilder liefern können, während die Autopsie den drei-dimensionalen Bild besitzt.

Der Grund liegt nun wohl darin, das die bisherige Röntgenaufnahmetechnik gewöhnlich nur statisch ausgeführt worden ist, indem man dabei die Röntgenröhre sowie den Gegenstand in absoluter Stille zu halten oder den beiden nur in sehr beschränktem Masse die Bewegungsfreiheit zu erlauben pflegt.

Um die Technik der Röntgenaufnahme zu verbessern, hat der Verfasser eine originelle Methode erfunden, eine Röntgenröhre, die sich frei um den Gegenstand herum drehen kann, zu gebrauchen.

Diese neue Methode heisst „Rotationsröntgenographie oder Rotatographie", da bei der Aufnahme sowohl die Röntgenröhre als auch der Film in dieselbe Richtung gedreht worden, und zwar mit einem Winkel von 0° bis 190° Grad um einen bestimmten Punkt innerhalb des zu untersuchenden Gegenstandes herum. Dieselbigen Resultate sind freilich erfolgt, als man die Röhre und den Film in der Ruhelage hielt, während der Gegenstand auf einer sich drehenden Tafel in der entgegengesetzten Richtung gedreht wurde.

Der Zweck der Rotatographie ist der, dass die Dimension der „Tiefe" des Gegenstandes ins klare gesetzt wird, was bei der üblichen Röntgenaufnahme nicht erzielt werden kann, und dass man also leichter die krankhaften Herde zu finden vermag und auch die Differentialdiagnostik zwischen den Krankheiten demnach erleichtert wird.

Bei der Rotation aber, während sich die Röntgenröhre immer um den Gegenstand herumdreht, kann die Weise der Rotation selbst recht verschieden sein. Mancherlei Arten von Kombinationen sind möglich zwischen den Rotationsarten der Röhre einerseits und denselbigen des

Films oder seiner Ortsveränderung andererseits, und soviel Arten der Rotation und auch ihrer Kombinationen als möglich sind nun erforscht worden. Es müssen die Resultate der Röntgenaufnahme, und dementsprechend der Zweck der Rotatographie zugleich, je verschieden sein, nachdem diese oder jene Rotationsweise dabei verwendet wird.

Die Rotatographie ist also auf ihren Zweck hin in vier folgende Typen eingeteilt: 1) Rotationstreffenaufnahme, 2) Quersehnittsaufnahme, 3) Solidographie und 4) Rotationskymographie. Mit den bestehenden Methoden der Röntgenographie verglichen, entsprechen sie bzw. 1) der einfachen Aufnahme, 2) der Tomographie, 3) der Stereographie und 4) der Kymographie. Durch diese Rotaographie sind nun Entdeckungen, wie sie bisher unzugänglich waren, nutzbar gemacht worden.

Alle diese Typen von der Rotatographie aber haben sich nicht zu gleicher Zeit erfinden lassen, sondern erst allmählich, einer nach dem andern, entwickelt.

In 1946 wurde zuerst die Theorie der Rotationstreffenaufnahme vom jetzigen Verfasser eingeführt. Von dieser aus entwickelten sich dann zwei andere Methoden der Aufnahme, d. h. die Kontinuierliche und die Diskontinuierliche Rotatographie, den Querschnittsbild des Körpers enthüllend. Und nach diesen zwei wurden noch fünf weitere Methoden für die Aufnahme vom Querschnittsbild des Körpers erfunden, d. h. 1) Direkte Querschnittsaufnahme, 2) Kontinuierliche Querschnittsaufnahme (Originalmethode), 3) Rotationsquerschnittsaufnahme, d. h. Transversale Schichtaufnahme, 4) Direkte Querschnittsaufnahme (Verbesserte Methode) und 5) Diskontinuierliche Querschnittsaufnahme (Indirekte Methode). Es folgte nun der Kontinuierlichen Rotatographie die Rotationskymographie und der Rotationsquerschnittsaufnahme die Solidographie.

Im Laufe dieser Forschungen aber hat es sich auch als ausführbar erwiesen, einige dieser Typen der Rotatographie so zu vereinigen, dass man vielerlei Röntgenogramme mit einem und demselben Apparate aufnehmen kann; denn eines war nun allen diesen Typen gemein, dass die Röntgenröhre immer um einen stillstehenden Gegenstand herum-gedreht wurde. Ein Universaler Rotatograph von horizontalem Typus ist also hergestellt worden und schon ist dieser Typus Rotatograph allgemein in klinischem Gebrauch.

Das Charakteristische an dieser Rotatographie liegt wohl in der Exaktheit der Rotation einerseits und in ihrer Weite von 0 bis 190 Grad andererseits. Wenn man eine genaue Rotation erzielt hat, dann stellt es sich heraus, dass zwischen dem Fokus von der Röhre, dem Gegenstand, dem Rotationszentrum und dem Röntgenbilde gewisse Verhältnisse bestehen müssen, die ja die Grund der Rotatographie bilden sollen.

Wenn sich ein Punkt um den Rotationszentrum dreht, wird eine den Punkt repräsentiereden Kurve y dergestalt gemalt werden, dass sie die Grundlinie (Röntgenbild des Rotationszentrum auf dem Röntgenogramme) durchschneidet. Die Gleichung ist folgende:

$$y = r \sin \theta \frac{a+b}{a+r \cos \theta}$$

r stellt hier die Entfernung des Rotationszentrums von jenem Punkte, a dann diejenige von dem Fokus, b diejenige von dem Film und θ den Rotationswinkel dar.

Dreizehn ähnliche Formeln wie diese sind weiter gewonnen worden, nachdem man mit vielerlei Gegenständen experimentiert hat.

Was die Rotationsweite anbetrifft, so wird nun geometrisch bestätigt, dass jedes der Organen im Körper aus allen Richtungen untersucht werden kann, wenn sich der Rotationswinkel gerade von 0 bis 190 Grad erstreckt und demnach sämtliches Organ schon darstellbar ist.

Die *Rotationsteffenaufnahme* ist ein Typus der Rotatographie. Bei diesem Typus der Aufnahme wird nämlich die Rotation zu jeder beliebigen Zeit unterbrochen, so dass sie an jedem vorherbestimmten Winkel genau angehalten wird, nämlich an dem diskontinuierlichen Rotationswinkel, der sich zum voraus einem ausgewählten Grad, der Grösse des zu untersuchenden Organs gemäss angepasst worden ist. Und dann kommt der Gegenstand fortwährend die Röntgenstrahlen ausgesetzt zu werden.

Das Rotationstreffenaufnahme besteht also aus einer Reihe der Röntgenogramme, die aus verschiedenen Richtungen hintereinander aufgenommen worden sind. Jedes von solchen Rotationstreffenaufnahme ist also im Grunde nichts anderes als ein einfaches Röntgenogramm; Jenes unterscheidet sich dann von diesem nur darin, dass bei dem ersteren alle Bilder zusammen eigentlich durch die Grundlinie geknüpft und gerade dem diskontinuierlichen Rotationswinkel angeordnet sind. Die charakteristische Entzifferung des Rotatogramms wird also nur gemäss den Gesetzen, die die Rotatographie herrschen, ermöglicht werden.

Zwei Hauptzüge der Rotationstreffenaufnahme aber will man für jetzt darin sehen, dass man a) aus der Übereinanderlegung der Schattenbilder durch die serienweise aufeinanderfolgende Aufnahme krankhefte Herde entdecken und b) die Resultate mit der durch den vorherbestimmten diskontinuierlichen Rotationswinkel kontrollierten Fehlergrenze nachprüfen kann.

Die Fehlergrenze in bezug auf die Verfehlung der darzustellenden Herde kann repräsentiert werden durch:

$$h = \frac{a}{2} \tan \frac{\varphi}{2}$$

wo a die anatomischen Daten, und φ der diskontinuierliche Rotationswinkel ist.

Als diese Methode praktisch angewendet wurde auf die Aufnahme des Nierenbeckens, so konnten die Röntgenbilder der einzelnen Nierenbecher an ihrer Zahl um 65.3% zunehmen, im Vergleich mit den Resultaten von den bisherigen Methoden der einfachen Aufnahme, und die Figur sowie der Stand der Nierenbecher konnten exakt festgestellt werden.

Als man aber die Indirekteaufnahmetechnik auf diese Rotationstreffenaufnahme der Brust angewendet hat (Indirekte Rotationsaufnahme), da wurden nun um 2,9% mehr Herde entdeckt, als es bisher durch die einfache Indirekte Aufnahme möglich war, und dadurch wurde auch zur Differentialdiagnostik im ganzen um 15.6% mehr beigesteuert als durch die einfache Indirekte Aufnahme. Die

Proportion der Fälle, denen diese neue Methode gerade wirkungsvoll war, zu den gesamten 1258 Fällen, betrug sich sogar 96.7% hoch.

Auch die Grösse des Türkensattels wurde nun genau ermittelt, da die Überlagerung des vorderen und des hinteren „processus clinoideus" bildlich erklärt werden konnte. Man sah den Stand des Türkensattels klar, indem beide Seiten des processus je gesondert abgebildet wurden.

Es erwies sich diese Methode auch dazu völlig geeignet, den optischen Kanal aufzunehmen, da hier das en facé Bild des Kanals scharf umrissen und ohne Deformierung gewonnen und damit auch die vollständige Unterscheidung zwischen diesem optischen Kanal und die ethmoidalen Zellen ermöglicht wurde.

Die *Querschnittsaufnahme* (oder Kreuzaufnahme) ist ein Typus der Rotatographie, wobei man mit dem Querschnitt des Körpers durch die Röntgenographie ins klare kommt. Es sind ihrer sieben Typen entworfen worden, und die Querschnittsaufnahme ist eine diesen sieben Typen gemeinsame Benennung. Sie haben aber jeder für sich folgende Eigentümlichkeiten.

Diskontinuierliche Rotatographie:

Die Rotationstreffenaufnahme wird auf einen Film nacheinander vollzogen, woraus ein Röntgenogramm, das die denjenigen der Kymographie ähnlichen Stufen bekommt, folgt. Bei diesem Rotatogramme wird der Querschnitt des Körpers auf einem Blatt gemalt, oben auf die systematisch geordnete Verfahrungsweise. Die so gewonnene Querschnittsfigure ist in natürlicher Grösse, das Verfahren des Malens aber ist indirekt und mühselig. Ausserdem kann man auch das nicht ausser acht lassen, dass hier beim Malen des Querschnittes eine Möglichkeit subjektives Vorstellens eintritt.

Kontinuierliche Rotatographie:

Die Kontinuierliche Rotatographie ist solche, die der Diskontinuierlichen Rotatographie, mit dem diskontinuierlichen Rotationswinkel von θ Grad Null, also kontinuierlich ausgeführt, entspricht. Bei diesem Typus der Aufnahme sind sowohl die Schärfe als der Kontrast gut. Das Verfahren der Aufnahme ist einfach und direkt, aber es bedarf der Gewandtheit, des Röntgenogramm zu entziffern, da es hier im Röntgenbilde an der Anschaulichkeit mangelt.

Kontinuierliche Querschnittsaufnahme (Originalmethode):

Dies ist eine Erfindung, dass der Querschnitt photographisch von dem kontinuireliche Rotatogramme aus dargestellt werden soll. Das Verfahren ist indirekt, aber hier ist es möglich, die Subjektivität beim Malen auszuschliessen. Das gowonnene Bild ist zwar etwas weniger scharf, aber in natürlicher Grösse.

Direkte Querschnittsaufnahme (Originalmethode)

Dies ist ein Typus der Aufnahme, der die konkrete Figur des Querschnittes geben soll, ohne dass man zum indirekten Verfahren der Reproduktion greifen müsste. Diese Methode ist zeitraubend, auch wird der Gegenstand einer ziemlich grossen Menge Röntgendosis ausgesetzt, obgleich ein Röntgenogramm von gutem Kontrast gewonnen wird. Dass das Röntgenbild hier nicht von guter Schärfe ist, ist ihr Defekt. Es ist nicht in natürlicher Grösse, sondern wird vergrössert.

Rotationsquerschnittsaufnahme (Transversale Schichtaufnahme)

Dieser Typus von Querschnittsaufnahme ist in Technik ähnlich der „Axial transverse stratigraphy (Vallebona)“ und der „Transversalen Schichtaufnahme (Gebauer u. Wachsmann)“.

Die Technik besteht nämlich darin, dass zwei Rotationstafeln, eine für den Gegenstand und die andere für den Film, gleichzeitig umgedreht werden. Das Verfahren ist direkt, das gewonnene Röntgenbild ist aber nicht in natürlicher Grösse. Durch diese Methode der Aufnahme wird nicht nur der horizontale Querschnitt, sondern auch das geneigte oder gebogene Bild gewonnen.

Diese Rotationsquerschnittsaufnahme ist einfach auszuführen, auch wird der zu untersuchende Gegenstand nur einer kleinen Menge von Röntgendosis ausgesetzt. Diese Methode findet also in der klinischen Praxis ausgedehnten Gebrauch.

Direkte-Querschnittsaufnahme (Verbesserte Methode):

Als eine verbesserte Methode der Direkten Querschnittsaufnahme erfand man eine Vorrichtung, wodurch der Film an divergierende Röntsgenstrahlen belichtet wired, indem er gegenüber ihnen senkrecht steht: Schärfe und Kontrast der Röntgenbilder werden besser als die der Rotationquerschnittsaufnahme. Das Verfahren ist unmittelbar, aber das Röntgenbild ist über die Lebensgrösse vergrössert. Diese Methode braucht längere Zeit und wird also nur in beschränktem Masse klinisch gebraucht.

Diskontinuierliche Querschnittsaufnahme (Indirekte Methode):

Bei dieser Methode gebraucht man eine Vorrichtung, die den Querschnitt bei der Kontinuierlichen Querschnittsaufnahme durch die indirekte Methode reproduziert. Mit jedem Kontinuierlichen Rotatogramme, das früher aufgenommen ist, ist ein Röntgenfilm gegenüber Röntgenstrahlen senkrecht gestellt, um die Strahlen zu divergieren, wie es bei der Originalmethode von der Kontinuierlichen Querschnittsaufnahme ausgeführt ist. Schärfe und Kontrast des Querschnittsbildes, durch diese Methode erfolgt, werden besser als die durch die Originalmethode. Diese Methode wirde auf klinischen Gebrauch anwendbar sein. Für jetzt können als die fortgeschrittensten Formen der Querschnittsaufnahme die letzten drei Typen gelten, d. h. Diskontinuierliche Querschnittsaufnahme, Rotationsquerschnittsaufnahme und Direkte Querschnittsaufnahme.

Von diesen drei Typen aber, für jetzt, wird die Rotationsquerschnittsaufnahme für klinische Praxis der zweckdienlichste sein. Aus diesem Grunde sind nun weitere Einzelheiten davon zu beschreiben.

Die Einzelheitsbeschreibungen der allgemeinen Lage der Rotationsquerschnittsaufnahme sind schon weit und breit herausgegeben worden. Daher sind die hier angegebenen Data auf die Resultate beschränkt, die erfolgt wurden in unseren Untersuchungen und die für wichtig gehaltenwerden können.

Der Apparat und die Technik der Rotationsquerschnittsaufnahme, die man in Japan gebraucht, können als charakteristisch für dieses Land gelten; denn sie unterscheiden sich von denjenigen der anderen Länder dadurch, dass sie sich nicht aus der Tomographie, sondern aus der Rotatographie Schritt für Schritt entwickelten. Sie sind zuerst folgenderweise zu skizzieren:

Der Röherenneigungswinkel (der Winkel zwischen dem zentralen

Röntgenstrahlen und der horizontal gelegten Filmoberfläche) ist klein, ungefähr 15 Grad; die einfache Aufnahme apparat wird an den Rotatograph angeheftet; weitere Zutat für Aufnahme des geneigten oder gekrümmten Querschnittes wird angeheftet; die Röhre von veränderlichbarem Fokus wird gebraucht: die Weite der Rotation ist von 0 bis 190 Grad und darüber; die Hartstrahltechnik für die Aufnahme wird gebraucht, und ein Universale-Rotatograph von horizontalem Typus entsteht.

Um die Qualität des Röntgenbildes zu untersuchen, ist der Mechanismus des Vorgangs des Störschattens in der Rotationsquerschnittsaufnahme geometrisch betrachtet, worauf Gesetze erfolgt sind.

Man hat die erste Untersuchung gemacht, um zu erfahren, welche Faktoren auf Kontrast, Schärfe und Darstellbarkeit des winzigen Gegenstandes im Querschnittsröntgenogramm den grössten Einfluss hätten.

Der Kontrast im Querschnittsröntgenogramm, das mit dem Röhrenneigungswinkel von 15 Grad aufgenommen wurde, war geringer als der in einem Tomogramm, das mit einem Rotationswinkel von 60 Grad aufgenommen wurde. Und je kleiner der Röhrenneigungswinkel und je dichter die Verstärkungsdeppelfolie sind, um so ärmer ist die Schärfe.

Was die Schwelle der Darstellbarkeit von einem kleinen Gegenstand betrifft, so ist die Rotationsquerschnittaufnahme nicht so gut als die Tomographie.

Ein guter Zug dieser röntgenographischen Methode aber besteht darin, dass hier keine Deformation des Röntgenbildes entsteht.

Einige Störschatten, genannt Linieschatten, entstehen da besonders, wo die Brust dargestellt wird. Die Störschatten in diesem Falle liessen sich in vier Typen klassifisieren, d. h. A, B, C und D. Wenn der Röhrenneigungswinkel kleiner gemacht wird, d. h. von 30 bis 25, 20, 15, 10 und 8 Grad bzw., werden die Störschatten matter und bringen also die Diagnose in keine Verwirrung. Anders ausgedrückt, je kleiner der Winkel, desto matter sind die Schatten. Mit einem Röhrenneigungswinkel von 15 Grad konnten nur 15% Störschatten im

Röntgenogramme der Brust erkannt werden. Auch wenn die Hartstrahltechnik angenommen wurde, wurde des Störschatten matt.

Auf dem oben Erwähnten kann man schliessen, dass der Röhrenneigungswinkel von 15 Grad zur Rotationsquerschnittsaufnahme geeignet ist, da man Störschatten eliminieren kann, wenn man auch für Kontrast und Schärfe büssen muss.

Für jetzt ist die Rotatiosquerschnittsaufnahme für Darstellung zu jedem Teil des Körpers anwendbar. Sie wurde von 98 gesunden Erwachsenen aufgenommen, und die topographischen Beziehungen des Magens, der Niere und der Gallenblase zum Körper im Querschnitt wurden im Diagramme dargestellt, indem man eine Polarkoordinate gebraucht hatte.

Die Verdienste dieser Methode, wenn sie auf Brustkrankheiten angewendet wurde, trug man eines nach dem andern in die Liste ein. Was ihr Vermögen, krankhafte Veränderungen zu entdecken, betrifft, so mag die Rotationsquerschnittsaufnahme von der Tomographie an der Schärfe des Bildes einigermassen übertroffen sein; doch ist die erstere der letzteren daran überlegen, dass sie die wahre Lage und Gestalt der krankhaften Veränderungen im Querschnitt zur Schau stellt. Es stellte sich heraus, dass die Diagnose der Veränderungen im Mediastinum dadurch festgesetzt wurde, sie zu entdecken und ihre Lage zu ermitteln. Uberdies hat diese Methode daran Uberlegenheit, auf pretherapeutischen Gebrauch anwendbar zu sein.

Die *Solidographie* ist ein Typus der Rotatographie, wodurch innere Körperorganen in ihren eigentlichen Gestalten ausserhalb des Körpers röntgenographisch übertragen werden. Das ist eine Anwendung des Prinzips der Röntgenbildformation in der Rotationsquerschnittsaufnahme, dass auf der vom Röhrenfokus am fernsten erhaltenen Rotationstafel ein drei-dimensionales Bild entsteht, welches dem wahren Körper ähnlich ist, der auf der Rotationstafel dem Röhrenfokus am nächsten gestellt ist.

Obwohl das Röntgenbild an der Grösse dem wahren Körper ähnlich ist, so ist es doch im Verhältnis von $\frac{b}{a}$ vergrössert, wo b die

Entfernung des Fokus vom Film und a dieselbe vom Körper ist.

Das Prinzip dieser Methode wurde nicht nur geometrisch, sondern auch experimental geprüft. Hundert und zwanzig Blätter Filme, die einen Filmblock bildeten, wurden übereinandergelegt und durch diese Methode belichtet. Auf jedem Film war ein Bild, das dem Querschnitt des Gegenstandes entsprach. Die Figur des Röntgenbildes wurde von jedem Film abgeschnitten und wieder in anfänglicher Ordnung übereinandergelegt, dann wurde ein dem wahren Körper ganz ähnlicher Filmblock erlangt.

Man gebrauchte aber anstatt des Filmblocks eine Kassette des vielschichtigen Filmes zur Klinik. Da wurden 18 Blätter Röntgenpapier alle zusammen in Zwischenräumen von 3 cm in die Kassette eingeschlossen. Die Kassette wurde in drei Teile abgeteilt, und jeder Teil bei jeder Rotation von 190 Grad belichtet. Bei der Anwendung einer speziellen Technik der Operation besteht eine Differenz von 1 cm zwischen der Stelle des Filmes im ersten Teil der Kassette und derjenigen der zwei nachfolgenden Belichtungen. Daher wurde der Gegenstand als Querschnitte in 1 cm Zwischenräumen angesehen. Durch ähnliche Technik ist auch die Gleichzeitige Multiquerschnittsaufnahme ausgeführt.

Ein spezieller Apparat, der erfunden ist, um die Organen in eine konkrete Figur zu bilden, besteht aus zwei Rotationstafeln, die auf derselben Fläche gestellt sind. Ein Relais-apparat verbindet eine Photoröhre über der einen Tafel mit einem Schneider über der anderen. Auf der einen Tafel ist das Querschnittsröntgenogramm gestellt, und auf der anderen eine Scheibe aus Pflaster. Das Röntgenbild auf dem Querschnittsröntgenogramme wird durch die Photoröhre dargestellt, und die Pflasterscheibe wird durch den Schneider abgeschnitten, der mit der Photoröhre gleichzeitig wirkt.

Die abgeschnittenen Scheiben werden zusammen nach ihrer Grundlinie übereinandergelegt. Die allgemeine Erscheinung der gebildeten Organen sind lagenweise. Das wirkliche Organ aber hat keine Lagen, und sein Umriss ist glatt und ununterbrochen. Also ist die Figur, von der die Lagen abgeschnitten sind, der wahren Figur näher als die gebildete anfängliche. Das ist geometrisch als richtig bewiesen.

Das Herz, das wegen homogener Schatten stereoskopisch nicht zu beobachten ist, wird dreidimensional gebildet und beobachtet. Die Bildung der Figur diente dazu, Wirklichkeiten über das kranke Herz is seiner Missgestalt zu zeigen. Die Niere wurde auch durch die Solidographie nach dem Einblasen in die retroperitoneale Höhle gebildent.

Die *Rotationskymographie* ist ein Typus der Rotatographie, wobei systolische und diastolische Bewegungen eines inneren Organs dem Umriss des Querschnitts entlang zu verzeichnen sind.

Es gibt zwei Arten der Rotationskymographie, d. h. Kontinuierliche und Diskontinuierliche Rotationskymographie.

In diesen zwei Typen richtete man eine Röntgenröhre, den Gegenstand auf der Rotationstafel, eine bleierne Platte mit horizontaler Spalte und Film in dieser Ordnung ein. Die Rotation der Rotationstafel und die Übertragung des Films wurden vom Getriebe verbunden.

Bei der Kontinuierlichen Rotationskymographie wurde die Belichtung kontinuierlich gemacht, während sich die Tafel von 0 bis 190 Grad drehte. Das Röntgenogramm, nach diesem Verfahren erlangt, war ein Bild der gekrümmten Zone, und deren Band war wellenweise und dem üblichen Kymogramme ähnlich. Die Grundlinie lief entlang dem Mitte des Röntgenogrammes. Das entsprach dem Typus von gleitendem Schlitz in der üblichen Röntgenkymographie, da der sellige Rand der gekrümmten Zone die Bewegung aller Punkte darstellte, die entlang dem Umriss des Querschnitte hinfuhr.

Bei der Diskontinuierlichen Rotationskymographie wurde eine Belichtung gemacht, indem der Film über einem gewissen kleinen Abstand übertragen wurde, während die Rotationstafel stillstand. Und dann, nachdem die Rotationstafel sich mit 10 Grad gedreht hatte, wurde der Gegenstand zum Stillstand gebracht, und eine Belichtung wurde gemacht, nachdem sich der Film wieder zu bewegen begonnen hatte. Das Verfahren wurde von 0 bis 190 Grad hindurch wiederholt. Das entsprach der üblichen Röntgenkymographie vom Typus des gleitenden Films, da nur bestimmte Punkte am Umriss des Querschnitts in ihere Bewegung dargestellt wurden.

Um das Rotationskymogramm zu entziffern, wurden die über das Kontinuierliche Rotationskymogramm herrschenden Gesetze in Betracht gezogen.

Wenn ein Punkt von einem Rotationszentrum r entfernt war, und sich darum mit einer Winkelgeschwindigkeit ω drehte, und wenn er mit der Schwingungsweite l in Pedelbewegung wirkte, dann war sein geometrischer Ort im Röntgenbilde folgenderweise darzustellen:

$$y = r \sin(\alpha + \omega t) \frac{a+b}{a + r\cos(\alpha + \omega t)}$$

Wenn sich b/a dem Null nähert in der Bedingung $b > r + 1 > 0$, dann:

$$y = (r+p)\sin(\alpha + \omega t), \quad \text{wo} \quad p = l\cos(\beta + \omega t).$$

Durch geometrische Betrachtung und Experiment waren sieben Gesetze erfolgt, die über die Kontinuierliche Rotationskymographie herrschen.

Und durch dreizehn über die Rotatographie herrschende und sieben über die Kymographie herrschende Gesetze wurde der Weg dazu erdacht, nicht nur die Stellung, Form und Grösse des Querschnitts des Körpers, sondern auch die Art der Körperbewegung zu betrachten.

Die Übersetzung des Diskontinuierlichen Rotationskymogramms ist derjenigen des üblichen Kymogramms vom Typus des gleitenden Films ähnlich. In der Diskontinuierlichen Rotationskymographie, wo man die Technik der Diskontinuierlichen Rotatographie gebraucht, ist möglich, eine Skizze der Figur im Querschnitt des Körpers zu ermitteln.

Rotationskymogramme der Herzen dreissig Erwachsener, die keine Abnormitäten haben, wurden beobachtet.

Da wurde deutlich gemacht, dass die Stellung der Grenze zwischen der Kammer und der Vorhof oder zwischen beiden Kammern nicht befestigt ist; und die Variationen des Herzens, z. B. seine Rotation, wurden gezeigt. Die Schwingungsweite war in der linken Kammer am grössten, dann folgte dieselbe in der rechten Kammer, in der rechten und in der linken Vorkammer. Der Typus der Wellen von dem Rande der gekrümmten Zone liess sich in elf Typen klassifizieren.

Durch die Anwendung des Rotationskymogramms auf kranke Herzen wurde es also möglich, verschiedene Arten der Bewegungen des Querschnitt zu ermitteln, die bisher nicht verfügbar waren.

References

1) Takahashi, S.: Discontinuons Rotatography, (Studies on Rotation Radiography. 1st Report). Nippon Acta Radiologica, not published.
2) Takahashi, S.: Theoretical study on the Continuous Rotatography (Studies on Rotation Radiography. 2nd Report), Nippon Acta Radiol. 9, 5, 1950. (Japanese)
3) Takahashi, S. and Imaoka, M.: Theoretical study on the Rotation Sighting Radiography, (Studies on Rotation Radiography. 3rd. Report), Nippon Acta Radiol. 10, 2, 1950, (Japanese)
4) Takahashi, S. and Kubota, Y.: Continuous Cross Section Radiography, Original Method, (Studies on Rotation Radiography. 4th Report) Nippon Acta Radiologica. 12, 6, 1952. (Japanese)
5) Imaoka, M.: Application of the Discontinuous Rotatography to determining of the location of the foreign body, (Studies on Rotation Radiography. 5th report), Nippon Acta Radiol., 10, 7, 1950. (Japanese).
6) Imaoka, M.: Cross section of the digestive tractus in the living human body (Studies on Rotation Radiography. 6th report) Nippon Acta Radiol., 10, 8, 1950, (Japanese)
7) Takahashi, S.: Rotatory Photoroentgenography (Studies on Rotation Radiography. 7th report) Hirosaki Med. J., 1, 1, 1950. (Japanese)
8) Imaoka, M.: Clinical evaluation of Rotatory Photoroentgenography appleied to chest diseases (Studies on Rotation Radiography, 8th report) Nippon Acta Radiol., 12, 5, 1952, (Japanese)
9) Mishina, H.: Rotation Sighting Radiography of the renal pelvis in healthy persons (Studies on Rotation Radiography. 9th report) Nippon Acta Radiol., 12, 3, 1952 (Japanses).
10) Mishina, H.: Rotation Sighting Radiography of the optic canal (Studies on Rotation Radiography. 10th report), Nippon Acta Radiol., 14, 9, 1954 (Japanese)
11) Takahashi, S.: Rotation Kymography, Nippon Acta Radiol., 9, 1, 1948.
Shinozaki, T.: Theoreticals of Rotation Kymography (Studies on Rotation Radiography. 11th report) Nippon Acta Radiol., 15, 2, 1955 (Japanese)
12) Shinozaki, T.: Rotation Kymography of normal adults (Studies on Rotation Radiography, 12th report) Nippon Acta Radiol., 15, 2, 1955 (Japanese)
13) Takahashi, S., Imaoka, M. and Shinozaki, T.: Rotatory Cross Section Radiography, Hirosaki Med. J., 1, 3, 1949
Rotatory Cross Section Radiography (Studies on Rotation Radiography, 13th report) Nippon Acta Radiol., 10, 1, 1950 (Japanese)
14) Takahashi, S., Imaoka, M. and Shinozaki, T.: Rotaory Cross Section Radiography of the living human body (Studies on Rotation Radiography. 14th report) Nippon Acta Radiol., 12, 11, 1950 (Japanese)
15) Takahashi, S. and Yoshida, M.: Direct Cross Section Radiography (Studies on Rotation Radiography, 15th report) Nippon Acta Radiol., 12, 11, 1953 (Japanese)
16) Mishina, H.: Rotation Sighting Radiography of sella turcica (Studies on Rotation Radiography, 16th report) Nippon Acta Radiol. 12, 11, 1953 (Japanese)
17) Mishina, H.: Clinical application of Rotation Sighting Radiography for taking sella turcica (Studies on Rotation Radiography, 17th report) Nippon Acta Radiol. 13, 3, 1953 (Japanese)
18) Takahashi, S.: Theoretical study on blurring and line image in Rotatory Cross

Section Radiography (Studies on Rotation Radiography, 18th report) Nippon Acta Radiol. 12, 2, 1952 (Japanese)

19) Takahashi, S., Matsuda, T. and Nikaido, T.: Obstructive shadow superimposed to the pulmonary field on the Rotatory Cross Section Radiogram (Studies on Rotation Radiography, 19th report) Nippon Acta Radiol. 12, 7, 1952 (Japanese)

20) Takahashi, S., Mishina, H. and Takisawa, T.: Sharpness of X-ray shadow image of Rotatory Cross Section Radiograms taken with intensifing screens (Studies on Rotation Radiography, 20th report) Nippon Acta Radiol. 12, 10, 1953 (Japanese)

21) Takahashi, S. and Yoshida, M.: Discontinuous Cross Section Radiography (Indirect method) (Studies on Rotation Radiography, 21st report) Nippon Acta Radiol. 13, 7, 1953 (Japanese)

22) Takahashi, S. and Shinozaki, T.: Solidography (Studies on Rotation Radiography, 22nd report) Nippon Acta Radiol. 13, 8, 1953 (Japanese)

23) Mishina, H. and Komiyama, K.: Experimental study on sharpness of the X-ray image of Rotatory Cross Section Radiography (Studies on Rotation Radiography, 23rd report) Nippon Acta Radiol. 13, 10, 1954 (Japanese)

24) Takahashi, S.: Cross section of the head in the adult healthy human body. (Studies on Rotation Radiography, 24th report) Nippon Acta Radiol. 11, 8, 1951 (Japanese)

25) Takahashi, S., Obara, J. and Anzai, S.: Cross section of the ventricles and subarachnoid cisterns. (Studies on Rotation Radiography, 25th report) Nippon Acta Radiol. 11, 9, 1952 (Japanese)

26) Takahashi, S. and Obara, J.: Cross section of the neck in adult healthy persons (Studies on Rotation Radiography, 26th report) Nippon Acta Radiol. 11, 10, 1952 (Japanese)

27) Matsuda, T.: Rotatory Cross Section Radiography of the chest (Studies on Rotation Radiography, 27th report) Nippon Acta Radiol. 12, 2, 1952 (Japanese)

28) Imaoka, M.: Rotatory Cross Section Radiography of the gall bladder (Studies on Rotation Radiography, 28th report) Nippon Acta Radiol. 12, 8, 1952 (Japanese)

29) Matsuda, T.: Clinical evaluation of the Rotatory Cross Section Radiography applied to chest diseases. (Studies on Rotation Radiography, 29th report) Nippon Acta Radiol. 12, 10, 1951 (Japanese)

30) Kubota, Y., Sato, Y. and Yoshida, M.: Rotatory Cross Section Radiography of pelvis (Studies on Rotation Radiography, 30th report) Hirosaki Med. J., 4, 1, 1953 (Japanese)

31) Matsuda, T.: Positon of tuberculous cavitation in the cross section of the chest (Studies on Rotation Radiography, 31st report) Nippon Acta Radiol. 13, 8, 1953 (Japanese)

32) Mishina, H. and Komiyama, K.: Experimental study on contrast of X-ray image of Rotatory Cross Section Radiography (Studies on Rotation Radiography, 32nd report) Nippon Acta Radiol. 13, 10, 1954 (Japanese)

33) Mishina, H., Kubota, Y. and Yoshida, M.: Resolving power and exhibiting power of Rotatory Cross Section Radiography (Studies on Rotation Radiography, 33rd report) Nippon Acta Radiol. 13, 11, 1954 (Japanese)

34) Matsuda, T. and Sato, Y.: Tomography and Rotatory Cross Section Radiography applied to radiography of tuberculous cavitation (Studies on Rotation Radiography, 34th report) Nippon Acta Radiol. 13, 11, 1954 (Japanese)

35) Kitabatake, T.: Cross Section of the mediastinal area of the lung field in tuberculosis (Studies on Rotation Radiography, 35th report) Nippon Acta Radiol. 13, 11, 1954 (Japanese)
36) Sato, Y.: Study on deformity of thorax and displacement of mediastinum after thoracoplasty (Studies on Rotation Radiography, 36th report) Iryo, 7, 11, 1953 (Japanese)
37) Matsuda, T.: Rotatory Cross Section Radiography of the stomach and duodenum. (Studies on Rotation Radiography, 37th report) Nippon Acta Radiol. 14, 3, 1954 (Japanese)
38) Kitabatake, T. and Ikari, H.: Solidography of kidney (Studies on Rotation Radiography, 38th report) Nippon Acta Urol. 45, 8, 1954 (Japanese)
39) Sato, Y.: Rotatory Cross Section Radiography of artifical pneumoperitoneum (Studies on Rotation Radiography, 39th report) Iryo, 8, 8, 1954 (Japanese)
40) Matsuda, T and Yaguchi, H.: Rotatory Cross Section Radiography of the upper abdomen insufflated air extraperitoneally (Studies on Rotation Radiography, 40th report) Nippon Acta Urol. 45, 10, 1954 (Japanese)
41) Yoshida, M.: Enlargement Radiography by means of Direct Cross Section Radiography (Studies on Rotation Radiography, 41st report) Nippon Acta Radiol. 14, 6, 1955 (Japanese)
42) Ikari, T.: Rotation Sighting Radiography applied to diseases of renal pelvis (Studies on Rotation Radiography, 42nd report) (in press) (Japanese)
43) Kubota, Y.: Contrast and Sharpness of Discontinuous Cross Section Radiogram (Studies on Rotation Radiography, 43rd report) (in press) (Japanese)
44) Matsuda, T., Kubota, Y. and Yoshida, M.: Highvoltage radiography applied to Rotatory Cross Section Radiography (Studies on Rotation Radiography, 44th report) Nippon Acto Radiol., 16, 11, 1957 (Japanese)
45) Matsuda, T.: Indirect Rotatory Cross Section Radiography (Studies on Rotation Radiography, 45th report) (in press) (Japanese)
46) Takahashi, S. and Matsuda, T.: Simultaneous Multi Cross Section Radiography (Studies on Rotation Radiography, 46th report) (in press) (Japanese)
47) Takahashi, S.: Cross Section Radiography, an improved method of Rotatography. Tohoku J. Exp. Med., 51. Nos. 1 and 2, 1949
48) Takahashi, S.: A Method to take radiograms of the transsection of the body at any inclination and curvature, Tohoku, J. Exp. Med., 52, Nos. 1 and 2, 1950
49) Takahashi, S. and Nikaido, T.: A Method to take a radiogram of the body in three dimensions (Prel. report), Tohoku J. Exp. Med., 52, Nos. 1 and 2, 1950
50) Takahashi, S.: Study of the technique of the radiographic delineation of the cross section of the body (Study on Rotatography and Crossgraphy) Tohoku J. Exp. Med., 54, 3, 1951
51) Takahashi, S., Imaoka, M. and Shinozaki, T.: Rotatory Crossgraphy (Rotatory Cross Section Radiography) (Study on the Rotatography, 4th report) Tohoku J. Exp. Med., 54, 1, 1941
52) Takahashi, S. and Nikaido, T.: "Solidography" A method to take a radiogram of the body in three dimensions (Study on the Rotatography) Tohoku J. Exp. Med., 54, 2, 1951
53) Takahashi, S. and Shinozaki, T.: Über zwei Methoden der Kymographie des Herzens in seinem horizontalen Querschnitt (Studien über Rotatographie, 5. Bericht) Fortschr, Roentgenstr. 75, 1, 1951
54) Takahashi, S., Anzai, S. and Obara, J.: Rotatory Crossgraphy (Rotatory Cross

Section Radiography) of ventricles and subarachnoid cisterns (Studies on Rotatography, 6th report) Tohoku J. Exp. Med., 56, Nos. 1 and 2, 1952
55) Takahashi, S. and Obara, J.: Rotatory Crossgraphy (Rotatory Cross Section Radiography) of head (Study on Rotatography, 7th report) Tohoku J. Exp. Med., 56, 4, 1952
56) Takahashi, S. and Obara, J.: Rotatory Crossgraphy (Rotatory Cross Section Radiography) of the neck. (Study on Rotatography, 8th report) Tohoku J. Exp. Med., 57, 1, 1952
57) Takahashi, S.: Theory of blurring of X-ray image and occurrence of obstructive shadow in Rotatory Cross Section Radiography. (Studies on Rotatography, 9th report) Tohoku J. Exp. Med., 58, 1, 1953
58) Takahashi, S. and Kubota, Y.: Ein Versuch der Kontinuierlichen Kreuzaufnahme. Eine Methode, die Querschnittsfläche aufzunehmen, ohne das Prinzip der Tomographie anzuwenden (Studien über Rotatographie, 10. Bericht) Fortschr. Roentgenstr. 77, 6, 1952
59) Takahashi, S. and Matsuda, T.: Clinical evaluation of Rotatory Cross Section Radiography (Rotatory Crossgraphy) applied to chest diseases (Studies on Rotatography, 11th report) Tohoku J. Exp. Med., 58, 2, 1953
60) Takahashi, S. and Shinozaki, T.: Solidography of the heart, Acta Radiologica, 41, 5, 1954
61) Takahashi, S. und Kitabatake, T.: Über Einen Versuch zum ständigen Kontrollieren des Krankheitsherdes bei der Rotationsbestrahlung mit Hilfe des Prinzips der Transversalen Schichtaufnahme (Studien über Rotatographie. 14. Bericht) Nagoya J. Med. Sci., 17, 6, 1954
62) Amisano, P.: La stratigrafia assiale transversa nell'età pediatrica, Estratto dal Policlinico Infantile Supplemento al fascicolo di Hennais 1947
63) Takahashi, S., Kubota, Y. and Yoshida, M.: Über die Vergrösserung des Querschnittbildes des Körpers mittels Roentgenstrahlen. Fortschr. Roentgenstr., 80, 3, 1954
64) Kitabatake, T.: Solidography of kidney. Nagoya J. Med. Sci., 18, 4, 1955
65) Kitabatake, T.: Frequency of tuberculous lesions in the mediastinal lung field, Nagoya J. Med. Sci. 18, 1, 1955
66) Takahashi, S.: Rotation Radiography. Read at 5. Meeting of Japanes Radiol. Society, Nov. 17, 1946., Nippon Acta Radiol., 6, 2–3, 1947 (Japanese)
67) Yamaguchi, T.: Our method of taking the radiogram of the optic canal. Tohoku J. Exp. Med. 54, 3, 1951
68) Donovan, G. E.: Colar Roentgenography. Lancet 260, 1951
69) Takahashi, S.: Chromatoroentgenography. Tohoku J. Exp. Med., 56, 1–2, 1952
70) Burger, G. C. E., Combee, B. and van der Tunk, J. H.: X-ray fluoroscopy with enlarged Image. Philips Technical Review, 8, 11, 1946
71) Takahashi, S.: A fixed Anode Tube with a very fine Focus and its Application to Enlargement Radiography, Tohoku J. Exp. Med. 62, 3, 1955
72) Grossmann, G.: Theoretisches über Tomographie. Fortschr. Roentgenstr. 51, 1935
73) Stumpf, P.: Zehn Vorlesung über Kymographie 25, Georg Thieme. Leipzig. 1937
74) Vallebona, A.: I nuovi orizzonti della Stratigrafia nei vari campi della medicina, Estratto da L'informatore medico, sez. Clin. Scient. 2, 4, 1948
75) Vallebona, A.: La stratigraphie axiale transversale an point de vue pratique, J. Radiol. et'dElectr. 31, 7–8, 1950
76) Vallebona, A.: Axiale transverse Laminagraphy. Radiology, 55, 2, 1950
77) Vallebona, A.: Transversal Axial Stratography. Estratto da Scientia Medica

Italica 1, 1, 1950
78) Gebauer, A.: Körperschnittaufnahmen in transversalen Ebenen. Fortschr. Roentgenstr. 71, 5, 1949
79) Gebauer. A. und Wachsmann, F.: Geometrische Betrachtungen und technische Fragen zur Herstellung transversaler Körperschnittaufnahmen, Röntgenblätter, 2, 5, 1949
80) Gebauer, A.: Diagnostische Vorteile und Indikationsstellung der Körperschichtaufnahmee in transversalen Ebenen gegenüber denen in vertikalen. Fortschr. Roentgenstr. 75, 1, 1951
81) Gebauer, A.: Das transversale Schichtbild des normalen Thorax, ein Beitrag zur topographischen Anatomie am lebenden Menschen. Fortschr. Roentgenstr. 74, 1, 1951
82) Fleischer, H., Gebauer, A. and Wachsmann, F.: Verwendung transversaler Schichtaufnahmen bei der Festlegung des Bestrahlungsplanes intrathorakaler Tumoren. Fortschr. Roentgenstr. 76, 1, 1952
83) Watson, W.: Differential Radiography, Radiography, 5, 1939
84) Janker, R.: Ein Universal-Schichtaufnahmegerät, Fortschr. Roentgenstr., 73, 3, 1950
85) Shimazaki, T.: Study on Rotatory Cross Section Radiography. 12, 5, 1952
Akaboshi, I.: Private letter to the author.
86) Vieten, H.: Grundlagen und Möglichkeiten der Roentgendarstellung von Querschnitten langgestreckter Körper mittels kreisförmigen Verwischung der nicht abzubildenden Objektteile, Fortschr. Roentgenstr. 73, 2, 1950
87) Vieten, H.: Untersuchungen über die darstellbare Schicht bei Anfertigung von Körperschichtaufnahmen mittels gegenläufiger Parallelverschiebung von Röhre und Bildschicht., Roentgenpraxis, 17, 1, 1948
88) Rudinger, G. und Spiegler, G.: Zum Wesen der Folienunschärfe., Fortschr. Roentgenstr. 57, 1938
89) Ziedses des Plantes, B. G.: Planigraphie, Fortschr. Roentgenstr. 51, 1, 1935
90) de Abreau, M.: Theory and Technique of simultaneous Tomography, Amer. J. Roentg. 60, 5, 1948
91) Palmieri, G. G.: Über meine Method der plastischen Darstellung des Herzens am Lebenden (Radioplastik). Acta radiologica. 10, 1929
92) Schatzki, R.: Plastischen Grössen und langwahre Darstellung des Herzens. Fortschr. Roentgenstr. 37, 6, 1928
93) Vallebona, A. et al: La Stratigrafia assiale transversa. G. Sambolino e Figli, Genova, 1947
94) Vallebona, A.: Trattato di Stratigrafia. Casa Editrice Dottor Francesco Valiardi, Milano, 1952
95) Macarini, N. and Oliva, L.: La pneumostratipancreatografia. Edizioni Minerva Medica, Genoa, 1955
96) Bonte, G., Trinez, G. and Brenot, M.: La tomographie axiale transversale. G. Doin et cie, Paris, 1955
97) Gebauer, A. and Schanen, A.: Das Transversale Schichtverfahren., Georg Thieme Verlag, Stuttgart, 1955
98) Griesbach, R. and Kemper, F.: Roentgenschichtverfahren. Georg Thieme Verlag, Stuttgart, 1955
99) Takahashi, S.: Tomography and Rotatory Cross Section Radiography, Igakushoin Tokyo, 1954 (Japanese)

Index