

PELVIMETRY BY X-RAYS.

With details of a new technique,
and a review of the measurements
of sixty cases in which labour
has been unassisted.

by Clark Nicholson M.B.

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THE WHITE HOUSE,
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I hereby declare that this thesis, entitled "Pelvimetry by X-Rays: with details of a new technique, and a review of the measurements of sixty cases in which labour has been unassisted", has been composed by me, and that the work described therein has been done by me.

24th May 1934

I. PELVIMETRY BY X-RAYS.

Introductory.

Pelvimetry by X-Rays makes but slow progress towards acceptance as a diagnostic method of precision. Although it has been practised, with some degree of accuracy, for more than twenty years, it has not yet become generally recognised even as a useful method of confirming a diagnosis of disproportion in pregnancy: still less is it, as it might well be, a routine procedure in the case of primiparae attending at ante-natal clinics. Nay more, there is, as yet, no criterion of measurement which may be used to assist a judgement as to whether any particular pelvis, whose measurements have been determined by X-Rays, is large enough to permit of normal childbirth, or whether interference with the natural process is indicated. There is no rule which decides, definitely, when any pelvis of normal shape is small enough to be classed as generally contracted, or how short must be the true conjugate diameter before a pelvis is to be classed as flat. There is not even a general agreement with regard to the degree of accuracy in measurement at which it is desirable to aim.

Introductory (contd).

It is not clear whether this state of affairs is due to the failure of the radiologists to agree on a standard technique, or to the unwillingness of the obstetricians to submit their patients to a tedious examination whose results they distrust, or merely to an over-specialisation which keeps the radiologist and the obstetrician apart. It is nevertheless true that the general practitioner, who is, after all, the responsible authority in at least 90% of childbirths, would welcome a method that would give him more confidence than external pelvimetry has ever done or can ever do. For there seems to be no doubt that ante-natal pelvimetry by X-Rays can give early warning of a possible difficulty due to disproportion, and can also encourage the obstetrician to refrain from surgical interference where it is not necessary.

Fitzgibbon (1) puts the position thus, "At present the number of women treated by induction of labour and Caesarian section is greater than the number of women who suffered from dystocia before the perfection and universal adoption of these methods of treatment, but the number of craniotomies, difficult deliveries, and disastrous results of delivery with the forceps is not diminished. This suggests that the application of operative interference for the purpose of avoiding dystocia is not wholly confined to cases calling for such treatment, while it is undoubtedly not applied to many cases in which it would be of benefit."

The Nature of the Problem.

As methods of pelvimetry by X-Rays are more or less isolated solutions of a geometrical problem, the subject does not lend itself to historical treatment, but is better dealt with as a classification of the methods of solution.

The Nature of the Problem (contd).

The problem is a problem in solid geometry, involving as it does the relationship of pairs of points in three dimensions: that relationship is to be determined from the shadows cast by them on a plane surface (the film) by a point source of radiation (the tube), whose height above the film is known. If, of course, the tube were at a sufficient height from both pelvis and film the shadow would approximate to a true projection, and from this measurements could be made directly. This method was actually tried in the early days of radiology, but the distance required in order that the error may be reduced to the region of 1% is at least 10 meters, which, apart from other practical difficulties, would necessitate tediously long exposures. With the tube at the heights usually employed in radiography the shadow is an enlarged projection, but, of course, the enlargement is not uniform, but varies with the height above the film of the objects which cast the shadows. If this height could be known for any pair of points, their distance apart could, without much difficulty, be calculated from the film: but the height of points on the bones which form the true pelvis cannot be measured directly. It is, then, this height above the film, this third dimension, which constitutes the real difficulty of pelvimetry by X-Rays: and a solution has been sought on two entirely different lines:- (A) by reference to surface anatomy, (B) by stereometric methods.

Methods making use of Surface Anatomy.

The brim of the pelvis lies, approximately, in a plane surface which is perpendicular to the sagittal section of the body, and which makes an angle of between 50 and 60 degrees with the horizontal when the subject is erect. This plane, as Baudelocque first pointed out, passes through the upper margin of the symphysis pubis and the spine of

Methods making use of Surface Anatomy (contd).
 the 5th lumbar vertebra, both of which points can be determined with more or less accuracy from the surface. This simple surface anatomy forms the basis for two methods, (1) the Frame Method, and (2) the Parallel Method, as we may call them. A further method making use of surface anatomy may be called the Transverse Method.

The Frame Method.

This was devised by Fabre (2) of France. He used a metal frame which could be bolted in a rigid rectangle round the patient, one side of the frame across the back at the level of the 5th lumbar vertebra, one across the front at the level of the upper margin of the symphysis pubis, and these were joined by the two lateral members. The inner border of the frame was serrated, the serrations being at intervals of 1 centimeter. With the frame in position the patient was placed in a prone posture over the film with the tube vertically above, and the exposure made. The metal frame throws a strong shadow on the developed film, and if opposite pairs of the serrations are joined the film is divided up into a number of distorted squares: each square is, however, the distortion of a true square centimeter, and the distortion is the same as that undergone by the shadow of the brim of the pelvis. By this means a scale is provided on the film itself and the diameters may be read off directly. Among other practical disadvantages of this method, very large films are required, and attempts have been made to use a flexible band similarly marked which could be strapped round the patient in the plane of the brim.

Thoms (3), in place of the frame, introduced a lead plate perforated in square centimeters. He places his patient in a reclining posture over

The Frame Method (contd).

the film, and measures carefully the height of the symphysis pubis and the 5th lumbar spine: he makes his exposure: the patient is then removed and the lead plate is placed in the plane which the brim of the pelvis had occupied: a flash exposure is made, which prints on the film a scale exactly the same as that achieved by Fabre's frame. Again the diameters may be read direct from the film.

A great difficulty in methods which use the antero-posterior view of the pelvis is that the sacral promontory is not a point easy to determine, and, indeed, it must be estimated by hints and suggestions from other points on the contour, or even by guesswork. For that reason Fabre uses the prone posture which brings the sacral promontory much nearer to the film: and Thoms, who originally used the recumbent posture now uses a reclining posture.

The Parallel Method.

If the patient is so arranged above the film that the plane of the brim of the pelvis is parallel to the plane of the film, the shadow of the brim is a proportional enlargement of the actual bony aperture. Moreover the degree of enlargement is governed by the height of the brim above the film, and any diameter may be calculated from the formula:-

$$x = \frac{a(t - h)}{t}$$

where x, is the required diameter: a, the length of its shadow: t, the height of the tube above the film: and h, the height of the brim above the film. This is true for any position of the tube so long as its height is not altered. The geometry involved in this proposition is given in Appendix 1.

The Parallel Method (contd).

This is the basis of the technique of the majority of radiologists who have published their methods. The required position is obtained by the use of the points of Baudelocque: the patient is seated over the film and is tilted back into a reclining position until the symphysis pubis and the 5th lumbar spine are equidistant from the film, and that distance is very carefully measured: the exposure is then made.

The work on the film should require no great elaboration. As the enlargement is strictly proportional it is an easy matter to draw a series of scales corresponding to different heights of the pelvis: any diameter may then be plotted out on the film with a pair of dividers and the length read off on the appropriate scale. This technique, which is the one which would naturally be used in a drawing office, is apparently used by but one radiologist, Walton, (4) in America. Rowden (5) makes a series of scales by exposing a lead strip marked in quarters of an inch at varying heights above the film corresponding to different heights of the pelvis: copies of these scales he attaches to his films.

American radiologists who use the parallel method are mostly wedded to Thoms' lead plate technique, although this can only save a few moments of time in making the measurements at the expense of confusing their films with an unnecessary and perfectly regular grid of black spots. Jarcho (6), Stude and Scherman (7), Jacobs (8), and Moore and Skinner (9) have all published papers on different aspects of the subject and all use the lead plate. It is a sad commentary on the mathematical ability of radiologists that Moore (9) was so astonished to find that the grid was quite regular that he consulted a professor of mathematics, Skinner,

The Parallel Method (contd)..

who was able to assure him that his eyesight was not at fault: he then took most of the black spots off his films.

The visual reproduction of the path of the rays by means of threads, a technique associated in this country with the name of Mackenzie-Davidson, seems to have a special appeal for radiologists, although it is a method full of opportunities for error. Courtney Gage (10) uses this technique to produce a true projection of the pelvic brim on his film, which he then measures direct. Indeed a good deal of ingenuity has been wasted on methods of making this simple calculation longer and less accurate.

One disadvantage peculiar to the posture of the patient required by this method is that the rays especially those which show the sacral promontory have to traverse a very considerable depth of tissue: this depth, too, increases rapidly in the later months of pregnancy until, at term, the rays have to traverse the whole of the uterus in its long axis. It therefore becomes increasingly difficult to produce a satisfactory skiagram: nevertheless good films can be secured even within a few days of term.

The Transverse Method.

This method is of fairly recent introduction, and is designed to give accurate measurements of the antero-posterior diameters of the pelvis, especially of the conjugate diameter. As the conjugate lies normally in the sagittal plane of the body, its height above the film can be easily and exactly estimated by halving the intertrochanteric measurement. The position used is either that with the patient lying on her side over the film, an uncomfortable posture, neither easy to produce nor to maintain: or with the patient lying recumbent with the film

The Transverse Method (contd).

vertical at her side. In either of these positions the conjugate must be approximately parallel to the plane of the film, so that the formula already quoted applies in this case also.

To this method Hooton (11) adds a similar method for measuring the transverse diameter. This diameter, he says, lies at a depth of two thirds of the total depth of the body at that level, so that, with an exposure made antero-posteriorly, its height above the film can be easily estimated. As it must be parallel to the plane of the film the same formula again applies.

Errors in these Methods.

There are two sources of error in these methods which are difficult to avoid. The first concerns the level of the brim: the brim is, of course, only approximately in a plane surface, and the transverse diameter is probably always 5mm. lower in level than the conjugate: moreover the upper margin of the symphysis pubis from which the level of the brim is calculated is not the point which is best distinguished in the film, which is, rather, the deepest point of the symphysis, from which the obstetrical conjugate is measured: here again there is an error of about 5mm. These difficulties have been recognised by many observers, and various corrections have been suggested, but have not come into general use.

The other source of error concerns the accuracy of Baudelocque's plane, and it is quite possible that an error of 5 degrees or more may be made by its use. Jacobs (8) was so impressed by the possibility of this error that he devised a rather complicated technique in order to avoid it. He places his patient in the recumbent position, and with the aid of a clinometer

Errors in these Methods (contd).

and a vaginal examination of the diagonal conjugate he estimates the exact inclination of the pelvic brim to the horizontal: he then repeats this inclination on a stand supporting his film, which he brings up against the buttocks of his patient.

It should be noted that both of these errors are more likely to occur in cases where the pelvis is abnormal, and where accuracy is more than ever necessary. A mathematical examination of the percentage error due to these two difficulties, (given in detail in Appendix 2), shows that each may produce an error of between 1% and 2%, so that the combined error would be at least 3%. This is by no means a negligible error, but, on the other hand, it does not seem sufficiently great to justify the condemnation of the methods if no better is available.

Objections to these Methods.

There are two objections to these methods of a very different nature. In the first place they do not provide measurements in any other level of the pelvis but the brim, and, indeed, cannot be made to do so. Now it is by no means certain that difficulties in labour due to disproportion occur only, or even mainly, at the brim: and no method can be complete unless it can give measurements at other levels.

The other objection is that these methods require the exposure of the patient to a detailed examination of the person that is definitely offensive to many women. This may be, indeed is, unreasonable, but it is the type of objection that leads so many women to make use of the midwife for ante-natal supervision, and until the medical profession resumes complete control of ante-natal work there will be no progress in obstetrics.

Stereometric Methods.

It is a commonplace that it is by the use of two view points, the two eyes, that we are able to estimate with some accuracy the relative positions of objects in three dimensions. It is equally true that if two views of an object from different points, (the relationship of these points to the object and to each other being known), are compared it is mathematically possible to reconstruct the object in three dimensions. This theory is, of course, extensively used in survey work. There have been many attempts to apply the theory to pelvimetry by X-Rays, but they have never had much success, or rather have not come into general use. The reason is not far to seek: it lies in the very elaborate mathematics or the equally elaborate mechanisms which have been devised to elucidate the results.

An obvious difficulty of this method is that it is necessary to recognise with very great accuracy the shadows of the same point on two separate skiagrams: for some points this may be very difficult indeed. It will be useful to classify these methods according to their approach to this particular problem into (1) methods using the stereoscopic viewing box, and (2) other stereometric methods.

Methods using the Stereoscope.

The technique of these methods differs only in detail, and that here outlined is the technique published by Johnson (12) in America. The patient is placed in position over the film, and one exposure is made: the film is removed and another inserted: the tube is moved for a predetermined distance parallel to the film, and the second exposure is made. On one of the developed films the points from which it is desired to make measurements are marked out. The films are then put in the stereoscopic

Methods using the Stereoscope (contd).
viewing box: a pencil is moved about on the clear film until it coincides with one of the points on the marked film, and a mark is made: the other points are marked in the same way. The films are then removed and transferred to a special table where they are set up in the same relative position as when they were taken. The table is provided with a cross-thread apparatus which reproduces visually the paths of the two rays which caused the two shadows of one point: the crossing of these indicates the position in space of that point, and an adjustable pointer is brought to that crossing and clamped there: this procedure is repeated for the opposite point: the distance between the pointers is then measured. Thus the various diameters are measured by their reconstruction in three dimensions. It will be seen that this is a lengthy not to say laborious procedure requiring cumbersome and expensive apparatus, in which, too, the human factor is given a full chance to commit its inevitable errors. Moreover the stereoscope itself is not above suspicion. It is true that a perfect stereoscopic view is obtained if the following conditions are observed:- (1) the stereoscopic shift must be exactly equal to the distance between the eyes of the radiologist, (2) the mirrors of the stereoscope must fulfil the same condition, (3) the distance from the eye to the film in the stereoscope must be the same as the tube-film distance. Theoretically the eyes should have no difficulty in recognising similar points, but stereoscopic vision depends to such an extent on the muscle sense of the extrinsic muscles of the eyes that it is not impossible to persuade the eyes that points on the pictures are the same point when, in fact, they are not.

Other Stereometric Methods.

Earlier workers have experimented with stereometric methods, without making use of the stereoscope, but the geometry of the method does not seem to have been thoroughly worked out, and they all use the cross-thread method for eliciting the results. Portes and Blanche (13) give some account of the geometry and point out that with a horizontal shift of the tube the shadow is moved parallel to the movement of the tube. They themselves have preferred to move the tube vertically between the two positions. With this technique the two shadows of the same point are in the same line with the foot of the normal ray of the tube, which permits of their accurate recognition. They use the cross-thread method for eliciting their results. The geometry of this technique is discussed in Appendix 3, where it is shown that the results may be obtained by formulae which are not too complicated, but the margin of error is too high for accurate work.

Some Criticisms of these Methods.

It will be seen that stereometry has these two very great advantages over other methods. It requires no examination of the patient by the radiologist, and it can be made to furnish measurements at other levels of the pelvic canal than the brim.

The technique of the cross threads has already been commented upon unfavourably. It is hard to imagine a piece of mechanism more liable to gross error even with extreme care in its use: the crossing of two threads, however fine, at an acute angle is not even on nodding terms with Euclid's definition of a point.

II. DETAILS OF A NEW TECHNIQUE.

Theory of the Method.

The technique I am about to describe is a stereometric method using a horizontal shift of the tube, but the points are recognised and the measurements made by a mathematical process which is much simpler than might at first sight seem possible. It depends on the correlation of two skiagrams in the same position relative to each other as when they were exposed. This may be done in one of three ways:-

(1) The two skiagrams may be taken on the same film. This is the ideal method, as it avoids a source of error which must be present when two separate films are brought together. It is, however limited to cases in which clear skiagrams, with good contrast and definition, can be taken: it is thus limited to the non-pregnant woman or to women in the first six months of pregnancy.

(2) Separate films may be taken, and combined on a viewing box with a strong light. This method has a similar disadvantage to the last.

(3) Separate films may be taken, and tracings made from them on the same tracing

Theory of the Method (contd).

paper. This method I use in the later months of pregnancy.

It is, in addition, necessary to have marked on each skiagram the projection of the tube, (or foot of the normal ray), in the position which it occupied when the exposure was made. When these conditions are satisfied the following three propositions are true:-

(1) The line joining the two shadows of the same point is parallel to the line joining the projections of the tube, ie to the line of the stereoscopic shift.

(2) If each of two shadows is joined to the projection of the tube in that position which produced it, these lines intersect in the projection of that point which caused the shadows.

(3) The height of the object causing the shadows may be calculated by multiplying the tube-film distance by the distance between the shadows, and dividing by the distance between the shadows plus the amount of the stereoscopic shift.

These statements sound neither simple nor easy when thus written at length, but a reference to the figure should make the meaning clear.

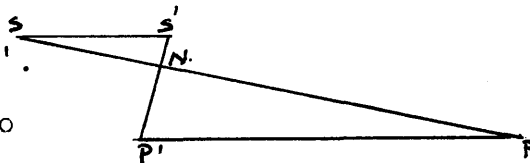
P, and P', are the projections of the tube, S, and S', are the shadows of an object, then

- (1) SS' is parallel to PP'.
- (2) N, is the projection of the object which caused S, and S'.
- (3) The height of that object above the film h, is equal to

$$t \times \frac{s}{s + p}$$

where t, is the tube-film distance,
s, is the distance between the shadows, and
p, is the amount of the stereoscopic shift.

The geometrical proof of these propositions is given in Appendix 4.



Theory of the Method (contd).

It will be seen that it is thus possible to make an orthogonal or true projection of any diameter of the pelvis on the film itself, and from this to measure the length of the diameter. Hodges and Ledoux (14) have recognised the last two of these propositions, but have missed the first. They use the stereoscope to determine the shadows of the same point, and complete the work on the film without the cross-threads: they published their paper before they had made any actual measurements. The first proposition, however, permits of a much more accurate determination of the shadows of the same point than can be achieved by means of the stereoscope.

Further Theoretical Considerations.

In making a practical application of this theory, the first requisite is a view, or views, of the pelvis in which the terminal points of the obstetrical diameters can be clearly and easily recognised. There are four such views which may be used, and each of them has certain advantages.

(1) The Antero-posterior View. (Plate I).

This is by far the easiest view to take, as it requires no special apparatus, and shows excellent detail even when the Potter-Bucky diaphragm is not used: moreover advancing pregnancy does not make it more difficult to any great extent. At the brim, the transverse diameter is, of course, very clear: but the posterior terminal points of the conjugate and diagonal diameters, (the promontory of the sacrum and the sacro-iliac synchondroses where they meet the ilio-pectineal line), are never obvious, and in the plate cannot be located, so that these diameters cannot be measured. With regard to the outlet, the terminal points of the transverse diameter cannot be determined, but that diameter may be deduced from a measurement between the postero-lateral margins of the obturator foramina, which is a close approximation.

Further Theoretical Considerations (contd).

(2) The Transverse View.

This is much the most difficult view to secure: it requires very careful adjustment of the patient to ensure that the heads of the femora are in line, and, in addition, it requires long exposures with very penetrating rays. I have not been able to secure a good film for purposes of illustration. With this view the antero-posterior diameter in all the planes of the pelvis is easily determined.

(3) The View with the Brim of the Pelvis parallel to the Film. (Plate II).

This view requires some special apparatus, or else considerable care in putting the patient in position, but it is not difficult to secure films from which accurate measurements may be made. All the points of the brim are clear with the possible exception of the sacral promontory: when this projects into the cavity of the pelvis it throws a very poor shadow because the bone here is very cancellous. The ilio-pectineal eminences, too, are not visible, and it is necessary to measure the diagonals from the points where the line of the acetabulum cuts the ilio-pectineal line. Deeper in the pelvis, the spines of the ischia are always prominent features of the film, and that diameter can be readily measured: its value in obstetrics is doubtful. At the outlet no points can be determined with sufficient exactitude to justify measurement from them.

(4) The View with the Outlet of the Pelvis parallel to the Film. (Plate III).

This is not a well known view of the pelvis, but it is as easy to take as the last both as regards the position of the patient and the length of exposure. It permits of measurement of the transverse diameter of the outlet and also of the sub-public angle, both of which are valuable for obstetrical purposes. The antero-posterior diameter of the outlet cannot, however, be measured as the sacro-coccygeal articulation and the coccyx are obscured by the body of the sacrum.

Further Theoretical Considerations (contd).

There is no doubt that, if only one view is to be taken, that with the brim parallel to the film is much the most informative: for, in addition to a clear view of the outline of the brim itself, it gives much the best outline of the foetal head from which to make measurements. At the same time a knowledge of the size and shape of the outlet is essential in many cases for the estimation of the chances of a normal labour.

Practical Considerations.

(1) The Couch. With this technique it is not necessary to secure that the brim is accurately parallel to the film, and it seemed better to aim at rapid automatic adjustment of the patient on the couch. With this end in view I use the recumbent position of the patient with the film and the tube tilted to the necessary angle. I had a table made (Plate IVb), with its upper surface at an angle of 35 degrees to the horizontal: to this surface a ledge is fixed which is just long enough to fit accurately between the feet of the Potter-Bucky diaphragm, so that when the diaphragm is placed on the table its position is fixed both vertically and laterally. The table can then be bolted rigidly to the foot of the couch, and, when this is done, the centre point of the diaphragm is level with the surface of the couch. To bridge the gap between the end of the couch and the diaphragm, a shelf, (Plate IVa), of plywood is bolted to the foot of the couch so as to prolong its surface to meet the diaphragm.

Now when the patient lies on the couch with the thighs slightly flexed and resting on the top half of the diaphragm, and the legs hanging over the end, the brim of the pelvis is roughly parallel to the film and is centrally placed over it, (Plate V). Again when the

Practical Considerations (contd).

patient sits up with the thighs slightly abducted and the hip-joints completely flexed the outlet of the pelvis becomes roughly parallel to the film (Plate VI). It will be seen therefore that both positions are easily secured and maintained, and are not uncomfortable.

(2) The Tube. The tube is adjusted so that its normal ray strikes the centre point of the diaphragm. Marks on the pillar, the cross-arm, and the stub of the tube-stand with a socket bolted to the side of the couch (Plate IVa), make it easy to repeat this centring at will. The marking of the projections of the tube on the film is achieved by placing a metal marker on the centre point of the diaphragm. At first I used a drawing pin for this purpose, but when two films have to be taken, it is necessary to show the direction of the shift as well as the centre point, and the marker shown in Plate II is now used. The tube-film distance used is 80 cms: at this distance the usual stereoscopic shift of 6 cms makes the distance between the shadows too short for accuracy, and I now use a shift of 10 cms. I use rays equivalent to 85 kilovolts, and a milliamperage of 25: exposures are from 4 to 10 seconds.

Exposing the Films.

One film is taken with the tube in the central position for comparison: the two stereometric exposures are then made, either on one film or on two films as the state of pregnancy demands. One other small point may be mentioned: with the parallel position, the rays passing through the area about the symphysis pubis have very little thickness of tissue to penetrate, and that part of the film becomes grossly over-exposed: to obviate this I use a pad made up of varying

Exposing the Films (contd).

thicknesses of lint impregnated with potassium bromide to screen the part from a certain proportion of the rays: it is not an ideal device. A toy balloon is used as a compressor, and the forceps, which are to be seen in some of the illustrations are on the neck of this balloon, and not in the abdomen.

Work on the Films.

(1) One Film Method. (Plates II, VII, VIII)
The projection of the tube must first be marked out. The metal marker throws two shadows: the surface of the diaphragm is 38 mm. above the surface of the film, and the shadows are 5 mm. apart: a line drawn through the centre points of these shadows is in the line of the stereoscopic shift and the bisection of it is the projection of the central position of the tube: from this point 50 mm. is measured off on each side, and these are the projections of the stereometric positions of the tube.

On one of the shadows of the pelvis the necessary points are carefully marked: through these marks lines are drawn parallel to the stereoscopic shift, and cutting the other shadow: these lines must pass through the second shadows of the marked points. These parallel lines may conveniently be drawn by setting up the film on the viewing box so that the edge of a T-square coincides with the line of the stereoscopic shift, the parallel lines may then be drawn by means of the T-square.

Each marked point is now joined to the appropriate projection of the tube, and the intersection of these lines is the projection of that point. It must not infrequently happen that a pair of shadows is so nearly in line with the stereoscopic shift that the

Work on the Film (contd).

intersection of these lines is too indefinite to permit of measurement from it: this is the case with the right ischial spine in the example illustrated: such a point must then be calculated by dividing the distance from one of the shadows to its appropriate projection of the tube in proportion to the shadow shift and the stereoscopic shift. In the figure, which has the same lettering as before:-

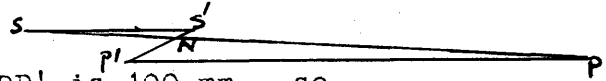
SS' is parallel to PP'

so that $SN : NP :: SS' : PP'$

and $SN : SP :: SS' : SS' + PP'$

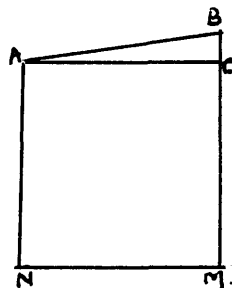
so that $SN = SP \times \frac{SS'}{SS' + PP'}$

SS' , and SP , are measured and PP' is 100 mm., so that SN may be calculated simply.



We now have a true projection of the different diameters on the film, and these may be measured. If the terminal points of a diameter are at an equal height above the film, the length of the projection is the length of the diameter itself. When, however, whether due to faulty positioning of the patient or to an irregular pelvis, the terminals of a diameter are at different levels a correction must be applied. A difference in height is easily recognised by a difference in the amount of the shadow shift, and each shadow shift is carefully measured: from these measurements the actual height of the point may be calculated by the formula in Proposition 3, (p. 14): and the subtraction of the lesser from the greater gives the difference in height: this is squared and added to the square of the length of the projection of the diameter: the square root of this sum is the required diameter. The rationale of this procedure may be gathered from the figure, where A, and B, are the terminal points of a diameter: N, and M, are their projections; and AC is parallel to NM, so that ABC is a triangle right-angled at C. Then:-

AB equals $\sqrt{AC^2 + CB^2}$, i.e. equals $\sqrt{NM^2 + (BM - AN)^2}$



Work on the Film (contd).

If this had to be done for every case at length it would be a very tedious process, but it only requires the preparation of suitable tables to make it a mere matter of reference. The tables I have prepared for my own use are given in Appendix 5.

(2) Two Film Method. (Plates IX, X).

The line of the stereoscopic shift may be marked on each film by drawing a line through the long axis of the shadow of the marker: the projection of the tube is then marked by plotting off 52,5 mm. from the centre of the marker, and in the appropriate direction: the 2,5 mm. is added because the shadow is moved to that extent from true centre. On a piece of tracing paper a line is drawn and points marked on it at distances of 2,5 mm., and 50 mm. on each side of a central point. This paper is placed over one of the films on the viewing box so that the lines and the appropriate points coincide, and the outline of the pelvis is traced. The required points are marked, and lines are drawn through them parallel to the line of the stereoscopic shift. The tracing paper is now transferred to the other film, and again adjusted over the line so that the appropriate points are in register. The rest of the work now follows exactly as in the one film method.

Some Notes on the Technique.

The description of the work on the films seems long and not a little complicated when thus written at length, but it is perfectly simple in practice, and, granted films of average clarity, all the diameters may be measured in less than 15 minutes.

The brim is, in the great majority of cases, so nearly parallel to the film that it is seldom necessary to make the correction for difference of height. It will be seen from

Some Notes on the Technique (contd).
the tables in Appendix 5 that no correction is required until the difference in height exceeds 9 mm., this difference in height corresponds to an angle of inclination deviating from the parallel by some 5 degrees. It is, then, only when the brim makes an angle of less than 50 degrees or more than 60 degrees with the horizontal that the correction must be made.

The difficulty in recognising the promontory of the sacrum is not made easier by the overlapping of the shadows at this place, when the stereoscopic shift is parallel to the transverse diameter. It might be worth while to arrange the shift so that it should be parallel to the conjugate, although this would entail a much more costly addition to the couch.

There is one point in the mechanical part of the technique where it may be thought that accuracy is very doubtfully achieved, and where an appreciable amount of error may be suspected, I refer to the centring of the tube over the Potter-Bucky diaphragm. The geometry of such a faulty centring is discussed in Appendix 6, where it is shown that the error cannot possibly exceed 0,5 mm. As for the inevitable human factor, the technique appears to afford this no more, if, unfortunately, no less, chance to commit its errors than any of the other methods.

III. A REVIEW OF SIXTY CASES.

Introductory.

The radiographic work which is the basis for the pelvimetry of these cases has been done at Moreton and District Cottage Hospital, Moreton-in-Marsh, and the patients have all been delivered as in-patients of that hospital, and have been attended at confinement either by my colleague, Dr Jameson, or by myself: the confinements have all taken place within the last two years. The series has been completed within the last eight months so that most of the work has been done post-natally: in eleven of the cases measurements were made ante-natally. The cases satisfy certain requirements of normality in childbirth:

- (1) pregnancy was not complicated by any obvious sign of toxæmia, or by any other serious disease,
- (2) labour took place within ten days of the expected date, (3) presentation was by vertex, (4) labour was unassisted either manually or by forceps,
- (5) the child was born alive, and weighed more than six pounds at birth. They are all women of the lower or lower-middle classes, living in the country, (there is no town of more than 2,500 inhabitants in the district): there are no cases of obvious undernourishment in the series.

Introductory (contd).

It will be seen that the cases have been arranged according to the length of the conjugate: this has been done for convenience in reference. The measurements show that there is an extraordinary variety in size and shape of the pelvis, even in a series so limited in number, and this impression is still further reinforced by the appearance of the films themselves. There is, one might say, more variety, more individuality, in the shape of the pelvis than there is in the faces of the women in whose bodies they are concealed. The measurements are given in millimeters: there seems to be no reason in the British obstetrician insulating himself from the general current of progress in his art by persisting in the use of a unit of measurement which is quite obsolete for scientific purposes.

Measurements in the Sixty Cases.

Reference to the numbered columns is as follows:-

- I. Conjugate Diameter.
- II. Transverse Diameter.
- III. Left Diagonal Diameter.
- IV. Right Diagonal Diameter.
- V. Pelvic Index.
- VI. Diameter between Ischial Spines.
- VII. Ischio-iliac Index.

No	Name	I	II	III	IV	V	VI	VII
1	Gorton	136	142	129	133	96	113	80
2	Harper	135	133	127	120	102	117	88
3	Hawtin	134	139	127	129	96	119	86
4	Righton	133	140	124	132	95	120	86
5	Arthurs	132	132	127	124	100	112	85

Measurements in the Sixty Cases (contd).								
No	Name	I	II	III	IV	V	VI	VII
6	Clark	132	128	129	112	103	104	81
7	Jones	132	124	119	114	106	99	80
8	Williams	130	132	126	128	98	122	92
9	Nobes	129	151	140	128	85	124	82
10	Rudge	129	138	129	127	93	113	82
11	Ellis	129	137	125	128	94	99	72
12	Wilton	128	145	125	128	88	110	76
13	Bishop	127	132	128	123	96	97	73
14	Ellis	127	130	124	123	98	109	84
15	Cowling	126	140	133	124	90	113	81
16	Hemming	126	139	128	127	90	107	77
17	Handy	126	131	124	126	97	109	83
18	Burden	126	131	124	125	97	115	88
19	Baker	125	140	128	130	89	104	74
20	Wyatt	124	143	127	128	87	125	88
21	Tyler	124	134	133	124	93	119	88
22	James	124	126	118	114	98	97	77
23	Whitehouse	123	136	127	124	90	107	79
24	Dyer	123	132	128	126	93	110	83
25	Read	122	126	127	118	97	100	79
26	Haynes	121	129	126	126	94	112	87
27	Newman	121	127	120	121	95	100	79
28	Price	120	126	122	119	95	103	82
29	Sabin	119	128	123	125	93	106	83
30	Green	119	124	125	127	96	106	86
31	Woodhead	118	139	127	125	85	106	76
32	Herbert	118	136	123	127	87	102	75
33	Harris	118	129	122	123	92	107	84
34	Warner	117	142	130	131	82	116	82
35	Boulter	117	137	126	129	86	113	82
36	Dee	116	147	137	132	79	121	83
37	Newman	116	141	133	129	82	102	87
38	Blagdon	116	131	117	117	88	114	87
39	Clark	115	135	121	121	85	110	81
40	Plested	115	133	114	114	86	99	74

Measurements in the Sixty Cases (contd).								
No	Name	I	II	III	IV	V	VI	VII
41	Morris	114	139	125	127	82	111	80
42	Farman	114	126	120	117	90	97	77
43	Ryman	114	125	112	112	91	94	75
44	Taylor	113	130	121	119	87	107	83
45	Tombs	112	137	125	128	82	103	75
46	Hunt	112	136	123	127	82	101	74
47	Mayo	111	140	130	129	79	125	89
48	Ford	111	131	116	118	85	104	79
49	Basford	111	127	122	120	87	109	86
50	Woolley	111	124	118	117	89	111	90
51	Webb	110	143	125	125	77	109	76
52	Walters	110	141	129	125	78	107	76
53	Scarlsbrook	110	135	128	129	81	113	84
54	Prew	108	133	125	121	81	110	83
55	Shurmer	106	129	121	118	82	107	84
56	Brooks	106	122	111	112	87	91	74
57	Banning	103	138	131	125	75	118	85
58	Nicholls	93	136	126	123	64	111	82
59	Churchill	92	136	124	132	64	118	87
60	Williams	87	140	125	125	62	114	81
Averages		118	134	125	124	88	107	80

The Averages.

It is not without significance that Case No 31, (Plate XI), midway in the series, should make one of the closest approaches to the average figures: moreover the contour of this pelvis is much the commonest type. If we take the figures as given by Robinson (15) in Cunningham's Text Book of Anatomy as the anatomical standard, Conjugate 110 mm., Transverse 135 mm., Diagonals 125 mm., this series shows one rather startling discrepancy: although it agrees with the anatomical figures very exactly in the other diameters, it differs by no less than 8 mm. in the case of the conjugate. Several

The Averages (contd).

explanations of this discrepancy may be offered. The series may contain an undue proportion of dolichopellic cases. The rejection of all cases requiring assistance in labour may have excluded numbers of flat pelves. The position of the sacral promontory may have been persistently misplaced in the skiagrams. The anatomical figure, being taken from the cadaver, and from the aged cadaver, may be too low for the young adult. It seems to me that none of these explanations is quite sufficient in itself to account for the discrepancy, although the last appears to me to be the most cogent. As the lower half of the series by itself gives an average of 110 mm. for the conjugate the first two explanations are certainly not sufficient: and it is virtually impossible that an error as great as 8 mm. should have been made throughout the series.

The Conjugate Diameter.

This is much the most variable of the diameters, the greatest being 136 mm., and the least 87 mm., a difference of 49 mm. Taking first those above average, the long conjugate may be part of a general enlargement of the pelvis, an approach to the just-major: an example of this type of pelvis is that in Case No 9, (Plate XII), with a conjugate of 129 mm., and a transverse of 151 mm., this film was taken in the sixth month of pregnancy and shows a pelvic presentation, although delivery was by vertex. Very frequently, however, the conjugate may be long while the transverse is of average length. When this is the case the lengthening usually occurs at the sacral end of the diameter: the sacrum, instead of being flat or only slightly concave, is deeply concave, and the promontory, instead of being thrust out into the cavity, hardly projects beyond the line of the wings: the sacro-iliac synchondroses thus become prominent, and the extra length of the conjugate makes no extra space available for obstetrical purposes. Case No 5, (Plate XIII), is an example

The Conjugate Diameter (contd).

of this type, with a conjugate of 132 mm., and a transverse exactly the same. The lengthening of the conjugate may, however, occur at the anterior end by a straightening of the pubic rami which thrusts the symphysis forwards. Case No 10, (Plate XIV), is an example of this type with a conjugate of 129 mm., and a transverse of 138 mm. Here again the extra length of the conjugate is certainly not of use for the passage of the foetal head.

In a similar way a shortening of the conjugate may be part of a general contraction of the pelvis, an approach to the justo-minor, or small round pelvis. Case No 56, (Plate XV), is an example of this type with conjugate and transverse of 106, and 122 mm. This is undoubtedly a very small pelvis which was quite unsuspected either from external appearances or measurements, or from her two labours, which were not prolonged and did not produce marked moulding of the head. More commonly the short conjugate is associated with a transverse equal to or above the average: of this type Case No 60, (Plate XVI), is a good example with a conjugate as short as 87 mm. In this case too there has been no suggestion of difficulty in her four labours.

The Transverse Diameter.

This shows much less variability than the conjugate, the difference between the greatest and least being no more than 27 mm. This diameter cannot be much enlarged without enlargement of the other diameters: it can, however, be contracted with a conjugate of average length, this tends to produce the narrow pelvis. Case No 7, (Plate XVII), is an example of this type, with conjugate and transverse of 132, and 124 mm. respectively. There is no note of difficulty in engagement of the head in this case.

The Pelvic Index.

This is of interest to the anthropologist rather than to the obstetrician. It is given in Column V, and is the percentage ratio of the conjugate to the transverse diameter. Using the classification of Sir W. Turner (16), 31 of the cases are platypellic, 15 are mesatipellic, and 14 are dolichopellic, this agrees with the anthropological findings for European women. It is of interest, too, that the angle of inclination of the pelvis to the horizontal tends to increase as the index diminishes, and vice versa.

The Diagonals.

These do not vary greatly from the average, from 111 mm. to 140 mm. The average for the left diagonal is nearly 1,5 mm. greater than the right: this is not sufficient in itself to account for the greater number of vertical presentations in this diagonal, but it may indicate a tendency for the left to be the greater diagonal when there is any marked asymmetry. The pelvis is, indeed, rarely quite symmetrical so that the diagonals are seldom equal, and this asymmetry may almost amount to Naegelism in some cases. Case No 9, (Plate XII), shows a good deal of asymmetry, but a much greater degree is to be seen in Case No 6, (Plate XVIII), where the diagonals are 129, and 112 mm. It will be seen that the irregularity occurs in the sacrum, one wing of which runs back and is very short, although it is not completely atrophied as in the pelvis of Naegele which is illustrated in the text books. This extreme type of asymmetry cannot be very rare as it has occurred in two cases in a series of sixty.

The Ischial Spines.

This diameter varies from 94 mm. to 125 mm., with an average of 107 mm.: Robinson (15) gives

The Ischial Spines (contd).

the average as 110 mm. The value of this diameter in obstetrics is not easy to establish. The obstetrician does not describe difficulty as occurring at this level of the pelvic canal and it is true that the foetal head is not forced to pass directly between the spines, as these, with the body of the sacrum and the sacro-spinous ligaments form the posterior wall of the canal at this level. At the same time they occur in "the plane of least pelvic diameter", and if the spines are placed more anteriorly than normal they would undoubtedly help to bar the advance of the head: also rotation of the head takes place at this level, and a contracted diameter here would make rotation difficult. Nevertheless it is only possible to say definitely that a contraction of this diameter should be read as a warning of possible contraction at the outlet.

In the series this diameter varies to a great extent with the length of the transverse diameter, and that relationship is given in Column VII, where it is called the Ischio-Iliac Index: it is the percentage ratio of this diameter to the transverse. It will be seen that the index does not vary greatly from an average of 80, and is never below 70. It is interesting that in two cases of the series where this diameter is much above average a pessary had to be worn for some time after confinement on account of a tendency to prolapse. In one of these cases, too, labour was almost precipitate.

Developmental Irregularities.

As the os coxae is formed by the fusion of its three parts it would not be surprising if some of the irregularities in the shape of the pelvis were found to be traceable to abnormalities in that fusion. Two such irregularities are to be

Developmental Irregularities (contd).
seen in the view of the pelvis used in this method.

(1) In the majority of the films, the lower rami of the pubis and ischium lie directly under the upper rami of the pubis, but in some cases they appear internal to this ramus. This irregularity is seen in Case No 1, (Plate XIX), where the deformity is so great that the inner face of the obturator foramen is seen. It will be seen, too, that the base of the ischial spine is thrust out into the cavity, and that the ilio-pectineal line fades off, which shows that the angle of the wall of the pelvis is completely altered. The reason for this irregularity seems to be a rotation of the ischium about its point of union with the other bones of the os coxae. In the case illustrated the right side alone is involved, but it is possible that if the deformity occurred on both sides it would reduce the transverse diameter of the outlet very considerably.

(2) The other irregularity appears to arise from a similar rotation of the ilium about its point of union with the other bones. The whole outline of the greater sciatic notch becomes visible in the film, and again the base of the ischial spine is thrust forward into the cavity of the pelvis and the ilio-pectineal line fades off at this point. Minor degrees of this deformity may be seen in Cases Nos 31, and 56, (Plates XI, and XV), but it is seen in a much more severe form in a case which is not in the series, (Plate XX).

Four Cases of Difficulty.

Owing to paucity of material it has not been possible to obtain many measurements in cases which have had difficulty in labour, and I propose to give here details of four only: the references to the

Four Cases of Difficulty (contd).
columns are the same as before (p.24).

Case	I	II	III	IV	V	VI	VII
A	108	124	111	115	87	100	81
B	99	114	108	102	87	89	78
C	120	136	122	119	88	94	69
D	126	137	127	122	92	91	66

Cases A, and B, are cases of the small round pelvis. A. was suspected of being small, and when she failed to come into labour at term was kept under observation: three weeks later the head appeared unable to engage, and Caesarian section was performed. The pelvis, however, is no smaller than that of Case No 56, (Plate XV), and if labour had occurred at term it might very well have been normal. B. has a much smaller pelvis which was measured in the third month of pregnancy: at the thirty-sixth week it was decided that normal labour was impossible, and Caesarian section was done just before term.

Cases C, and D, are cases of the second type of deformity described in the last section, and Case C, (Plate XX), is illustrated: the deformity is unilateral in both cases. C. came into labour in hospital, and as the head showed no sign of advance although well engaged in the brim forceps were applied: delivery was extremely difficult and the child was still-born. Case D. was attended ante-natally by the district nurse: as the second stage of labour was unduly prolonged she sent for Dr Jameson, my colleague, who applied forceps: he at once realised that he could not deliver the head, and he had the patient removed to hospital where Caesarian section was performed. It will be noted that in both these cases the ischio-iliac index is under 70, which seems to suggest that there is some value in this measurement. The sub-pubic angle in Case D. has been measured by X-Rays, and is as low as 71 degrees as compared with an average of 85 degrees.

Conclusion.

This series was originally undertaken with the hope, (possibly even the intention), of establishing a norm for the female pelvis: that hope was very soon found to be illusory as, indeed the experience of the anthropologist had long since shown if it had been heeded. The fact is plain: there is no norm for the female pelvis. There may be an average pelvis: if there is, the measurements are not of much interest, and certainly of less value to the obstetrician. It is at the lower end of the series that any practical lessons are to be learnt, and here the numbers are too small to allow us to make any generalisations however tentative, or to lay down any formula for capacity however full of reservations. It is at this end of the scale that the data are still wanting that can enable a reasoned opinion to be formed from her measurements of a woman's ability to bear children naturally. When those data are supplied, then pelvimetry by X-Rays will come into general use, for there is no doubt that accurate measurements can be made with no more elaborate equipment than is provided in most cottage hospitals: then, too, the ghost of disproportion, which has haunted so many generations of general practitioners, will be laid for ever.

Summary.

- (1) Previous methods of X-Ray pelvimetry can give reasonably accurate measurements of the diameters at the brim.
- (2) This method can give, with simple equipment, very accurate measurements of any diameter of the pelvis whose terminal points can be determined in a skiagram.
- (3) Previous averages for the conjugate are too small.
- (4) Disproportion occurring at the brim is often due to the pelvis being of the justo-minor type.
- (5) The outlet may be contracted, and a contraction at the ischial spines may be a warning of this.

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APPENDICES.

In the appendices the lettering in the figures and in the text always have the following significance:-
 T, is a position of the tube: P, is the projection of that position on the film: A, and B, are objects, the terminal points of a diameter: S, and R, are the shadows cast by them: and N, and M, are their projections on the film: dashes are used to denote second positions in stereometry: similarly t, is the tube-film distance: h, is the height of an object: a, the length of the shadow of a diameter: p, the amount of the stereoscopic shift: and s, the amount of the shadow shift.

1. The Geometry of the Parallel Method.

Let F. denote the plane of the film, and Q. the plane of the brim parallel to it: and let TP cut this plane in C. Then the plane in which TS and TR lie cuts these parallel planes in AB and SR, therefore AB is parallel to SR, and

$$AB : SR :: TA : TS.$$

Similarly in the plane in which TS and TP lie, AC is parallel to SP, and

$$TA : TS :: TC : TP$$

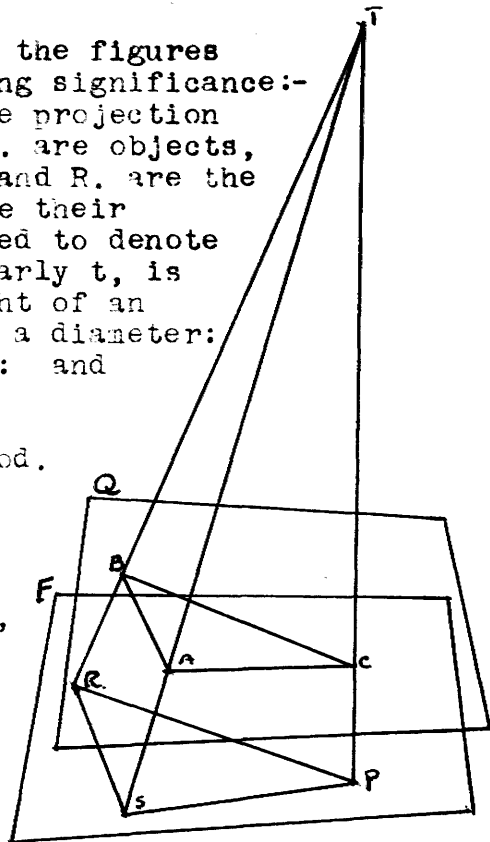
so that $AB : SR :: TC : TP$

$$\text{or } AB : SR :: TP - CP : TP$$

or, as given in the formula, x, the diameter

is equal to $\frac{a(t-h)}{t}$

As a corollary, all equal distances in the plane Q, throw shadows of equal length on the plane of the film.



2, Margin of Error in the Parallel Method.

(a) Due to faulty estimation of the height of the pelvis. Let AB be the true, and A'B' the faulty position of a diameter, then

$$AB : SR :: TC : TP$$

and $A'B' : SR :: TC' : TP$

so that $A'B' : AB :: TC' : TC$

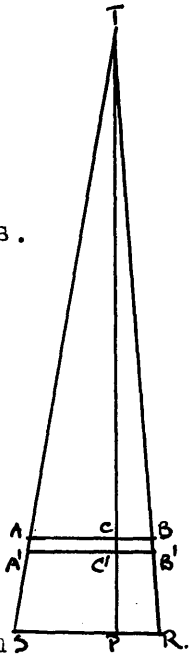
Taking TP as 60 cms, CP is about 15 cms.

TC is then 45 cms., the maximum error is 1 cm.

then $A'B'/AB$ equals $45/44$, ie 1,023, an error of 2,3%

For other values of TP:-

Tube-film distance	60cms.	80 cms.	150 cms.
Percentage error	2,3%	1,5%	0,7%



(b) Due to faulty estimation of the angle of inclination. The figure represents the case where the tube is centred over the symphysis, a common technique.

AB is the true, and AB' the faulty position of a diameter: let the angle at T, be denoted by α , and the angle BAB' by θ .

Then $AB' : AB :: \sin B'BA : \sin BB'A$

$B'BA$ equals $90 - (\alpha + \theta)$, and

$BB'A$ equals $90 + \alpha$, so that

$$AB' : AB :: \cos(\alpha + \theta) : \cos \alpha$$

where the tube is centred over the middle of the pelvis the equation is,

$$AB' : AB :: \cos(\alpha/2 + \theta) : \cos \alpha/2$$

The value of the angle α depends on the

values of TP and AB: taking the former as 60 cms.

the latter is about 11,5 cms., and $\tan \alpha$ is $11,5/45$

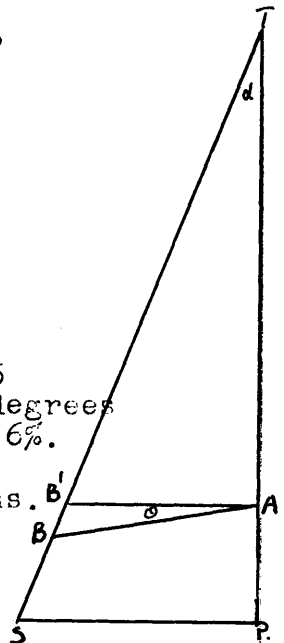
α is then 14 degrees, and the maximum error is 5 degrees

and $AB'/AB = \cos 19/\cos 14$, ie 0,974, an error of 2,6%.

For other values of TP:-

Tube-film distance	60 cms.	80 cms.	150 cms.
Error (tube over symphysis)	2,6%	1,9%	1,1%
(tube over centre)	1,6%	1,1%	0,7%

The total percentage error is the sum of these separate errors, and taking the lower of these last figures the error is at 60 cms., 3,9% at 80 cms., 2,6%, and at 150 cms., 1,4%



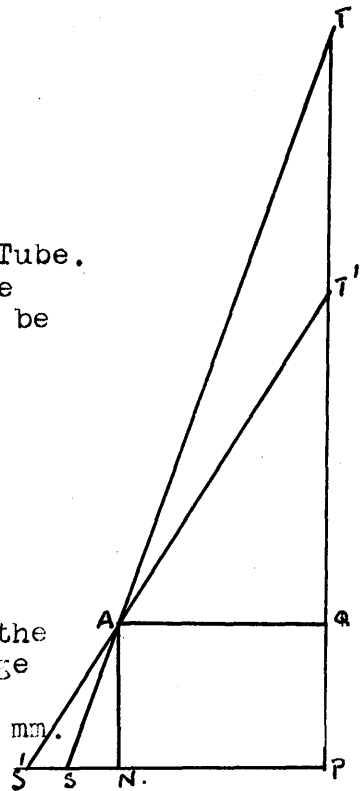
3. Stereometry with a Vertical Shift of the Tube.
 We have defined the position of the point if we know the length of PN, and AN: let the former be denoted by k. and let PS and PS' be b, and b'. Then AN : TP :: SN : SP

$$\text{or } \frac{h}{t} = \frac{b - k}{b}, \quad \text{similarly } \frac{h}{t'} = \frac{b' - k}{b'}$$

$$\text{from these equations } k = \frac{bb'(t - t')}{tb' - t'b}$$

$$\text{and } h = \frac{tt'(b' - b)}{tb' - t'b}$$

These formulae do not lend themselves to the preparation of tables. By substituting average values it is shewn that an error of 1mm. in measuring b, or b' makes an error of naerly 10 mm. in h. It is unlikely that the cross-thread apparatus will be more accurate.



4. Stereometry with a Horizontal Shift of the Tube.
 Since TP is perpendicular to the plane of the film the plane in which TP and TS lie is perpendicular to the film: similarly the plane in which T'P', and T'S' lie is perpendicular to the film, and the line of intersection of these planes AN is perpendicular to the film,

ie N is the projection of A. (2)

Again the triangles SAN and STP are similar, and SN : SP :: AN : TP

also S'N : S'P' :: AN : T'P',

but TP equals T'P'

so that SN : SP :: S'N : S'P'

and the triangles SS'N and PP'N are similar and

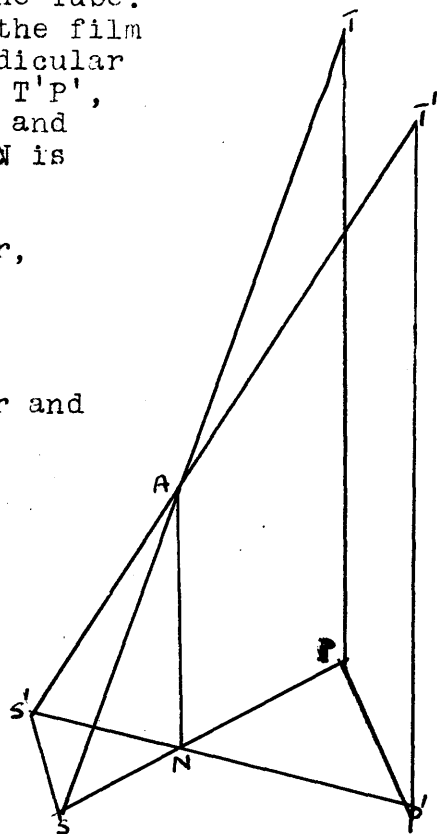
SS' is parallel to PP' (1)

Again AN : TP :: SN : SP ie SN : SN + NP

and SN : SN - SP :: SS' : SS' + PP'

so that AN : TP :: SS' : SS' + PP'

$$\text{ie } h = t \times \frac{s}{s + p} \quad (3)$$



5. Correction Tables.

(a) To find the height of an object.

Column I, The shadow shift, Column II, The Height.

I	II	I	II	I	II
6	45	16	109	26	164
7	52	17	115	27	169
8	59	18	121	28	174
9	66	19	127	29	178
10	72	20	132	30	183
11	79	21	138	31	188
12	85	22	143	32	192
13	91	23	148	33	197
14	97	24	154	34	201
15	103	25	159	35	206

(2) To correct for difference in height.

Uncorrected

Distance	Difference in Height exceeds.									
85	9	16	21	25	28	31	34	36	39	41
90	10	17	21	25	28	32	35	38	40	42
95	10	17	22	26	30	33	36	38	41	44
100	10	17	23	27	30	34	37	39	42	45
105	10	18	23	27	31	34	38	40	43	46
110	11	18	24	28	32	35	38	41	44	47
115	11	19	24	29	32	36	39	42	45	48
120	11	19	25	29	33	37	40	43	46	48
125	11	19	25	30	33	37	41	44	47	50
130	11	20	26	30	35	38	42	45	48	51
135	12	20	26	31	35	39	42	46	49	51
140	12	21	27	32	35	40	43	46	50	52
Add,	1	2	3	4	5	6	7	8	9	10

6. Geometry of Faulty Centring of the Tube.

Let X, be the faulty position of the tube, with projections of two points calculated from it at K, and L., and let PX the amount of the error be denoted by f., LG is parallel to MN.

Then $SN : NP :: s : p$,

In the faulty position too,

$$SK : KX :: s : p$$

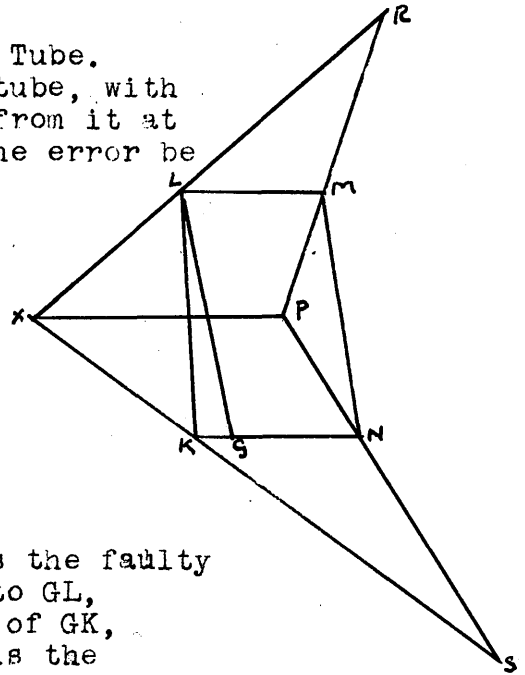
therefore NK is parallel to PX,

and $NK : PX :: SN : SP$ ie $:: h : t$,

$$\text{and } NK = \frac{fh_1}{t}$$

$$\text{Similarly } ML = \frac{fh_2}{t}$$

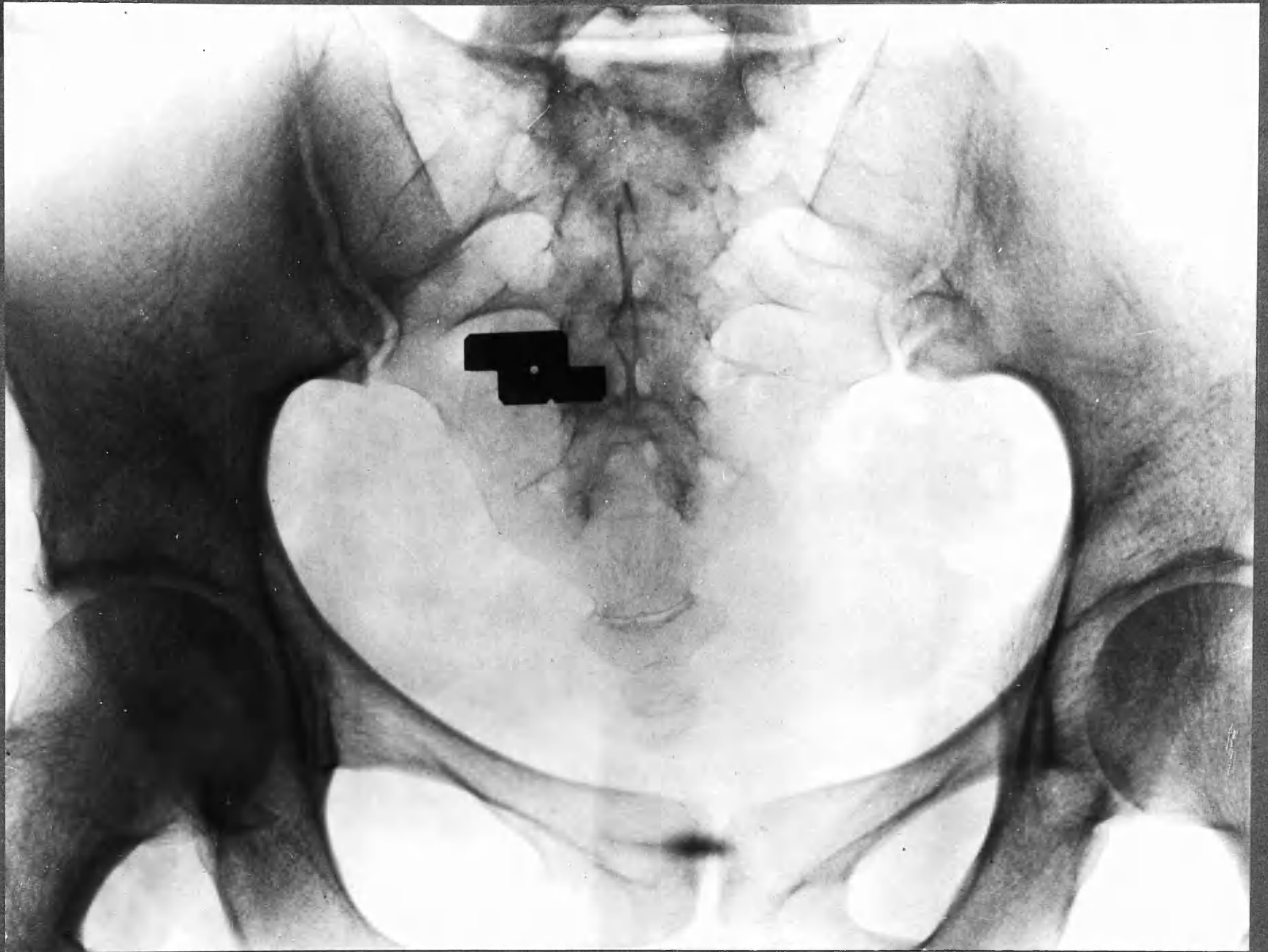
$$\text{and } GK = \frac{f(h_1 - h_2)}{t}$$



Now GL is the true diameter, and KL is the faulty calculation, and if PX were parallel to GL, KL would differ from GL by the amount of GK, either added or subtracted, and that is the greatest error that can be produced.

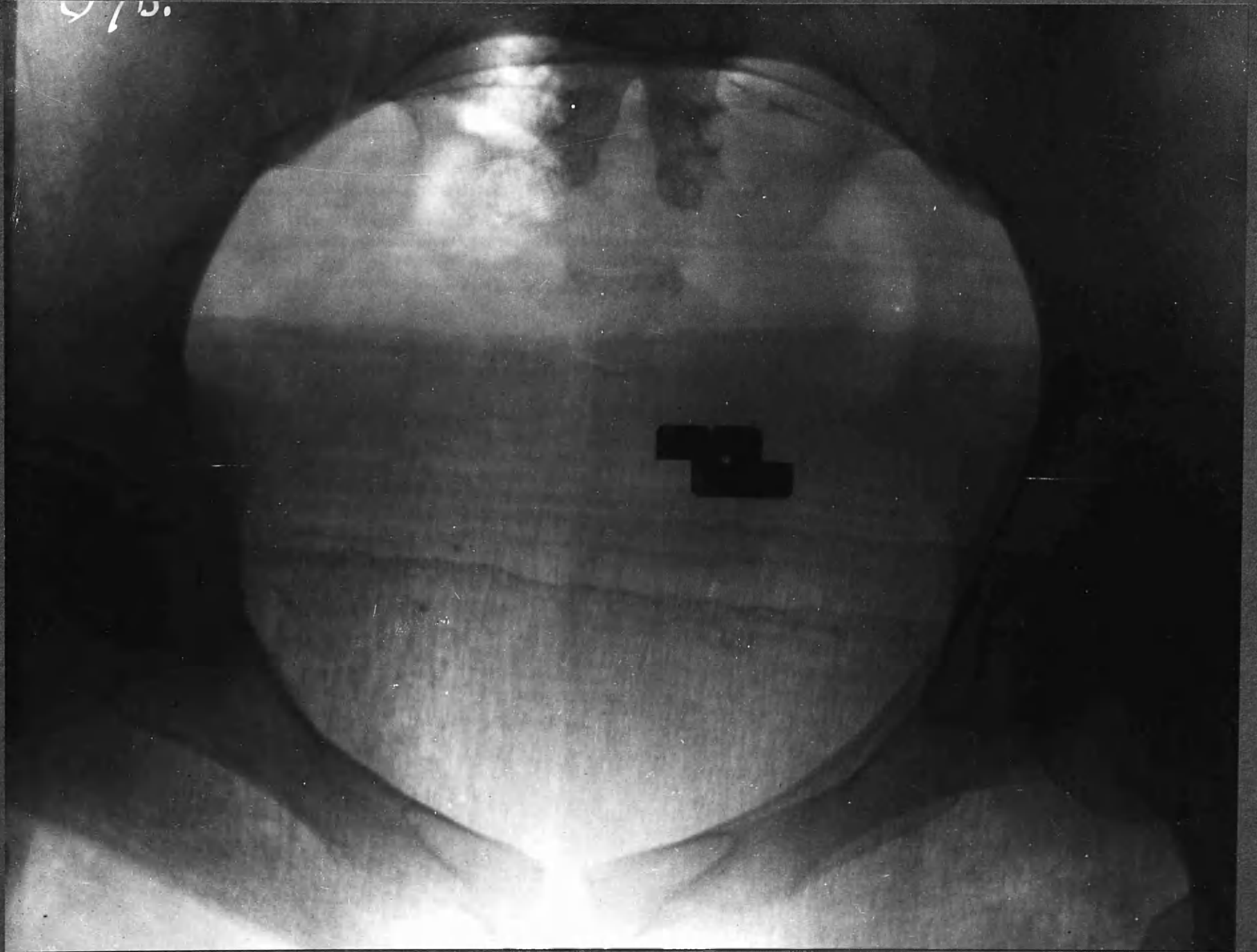
The factor f, can hardly exceed 10 mm. and the factor $h_1 - h_2$ can hardly exceed 40 mm. t, is 800 mm, so that the maximum error is 0,5 mm.

20 plates
(inclusive of Wa & G)



1. ANTERO-POSTERIOR VIEW OF THE PELVIS.

9/15.



11. THE BRIM OF THE PELVIS.

068.



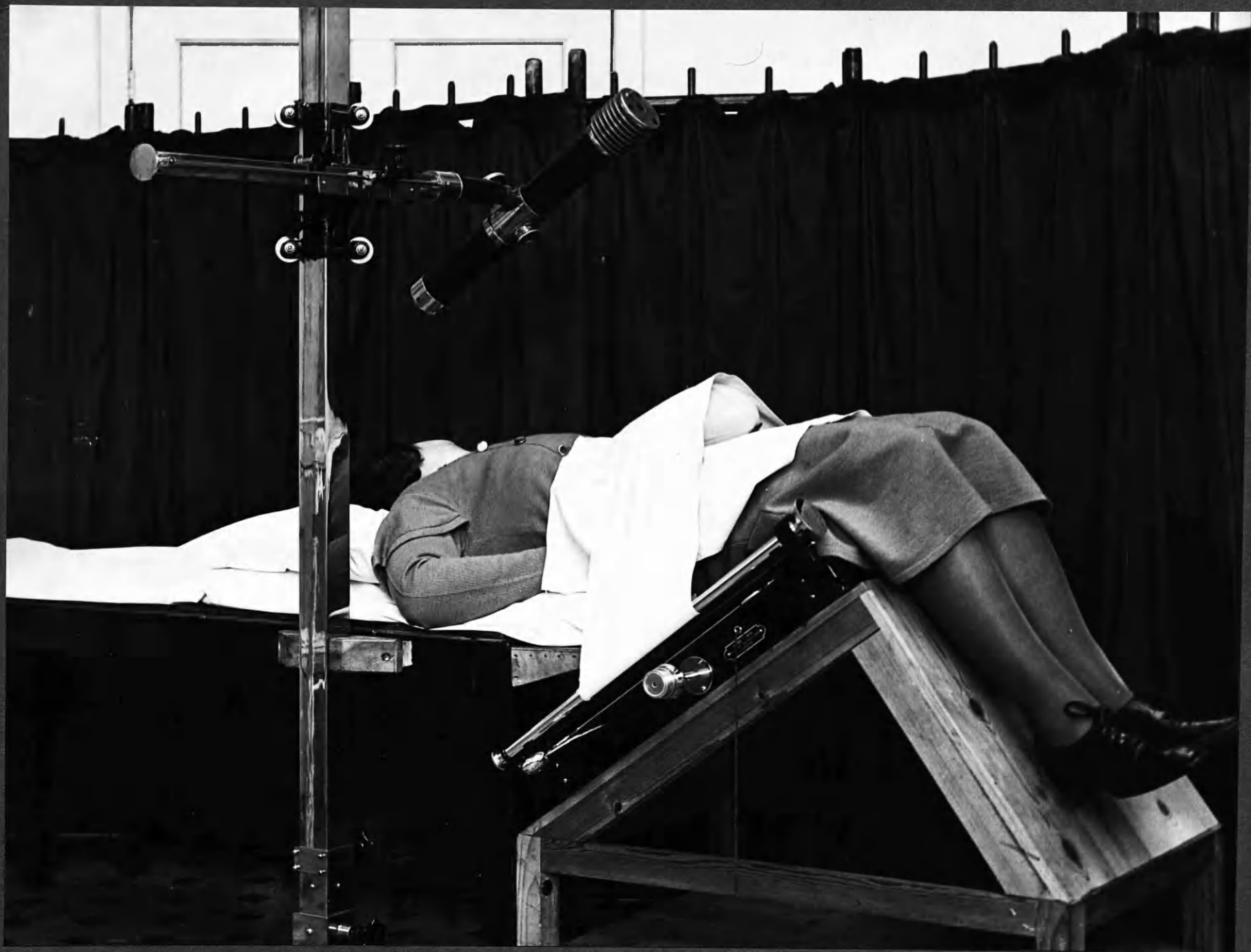
111. THE OUTLET OF THE PELVIS.



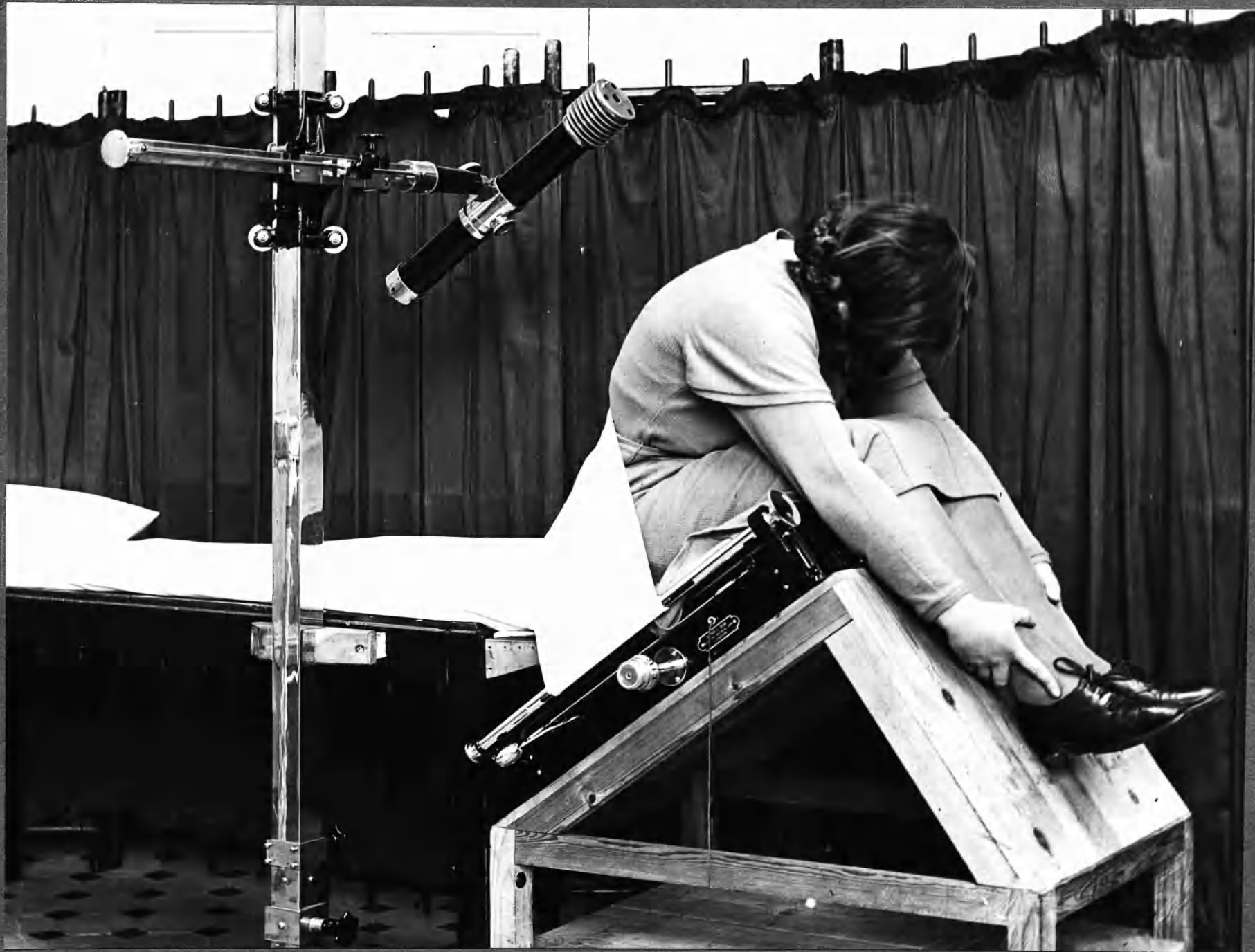
IVa. END OF COUCH WITH SHELF, AND
SOCKET FOR TUBE STAND.



IVb. TABLE FOR POTTER-BUCKY DIAPHRAGM

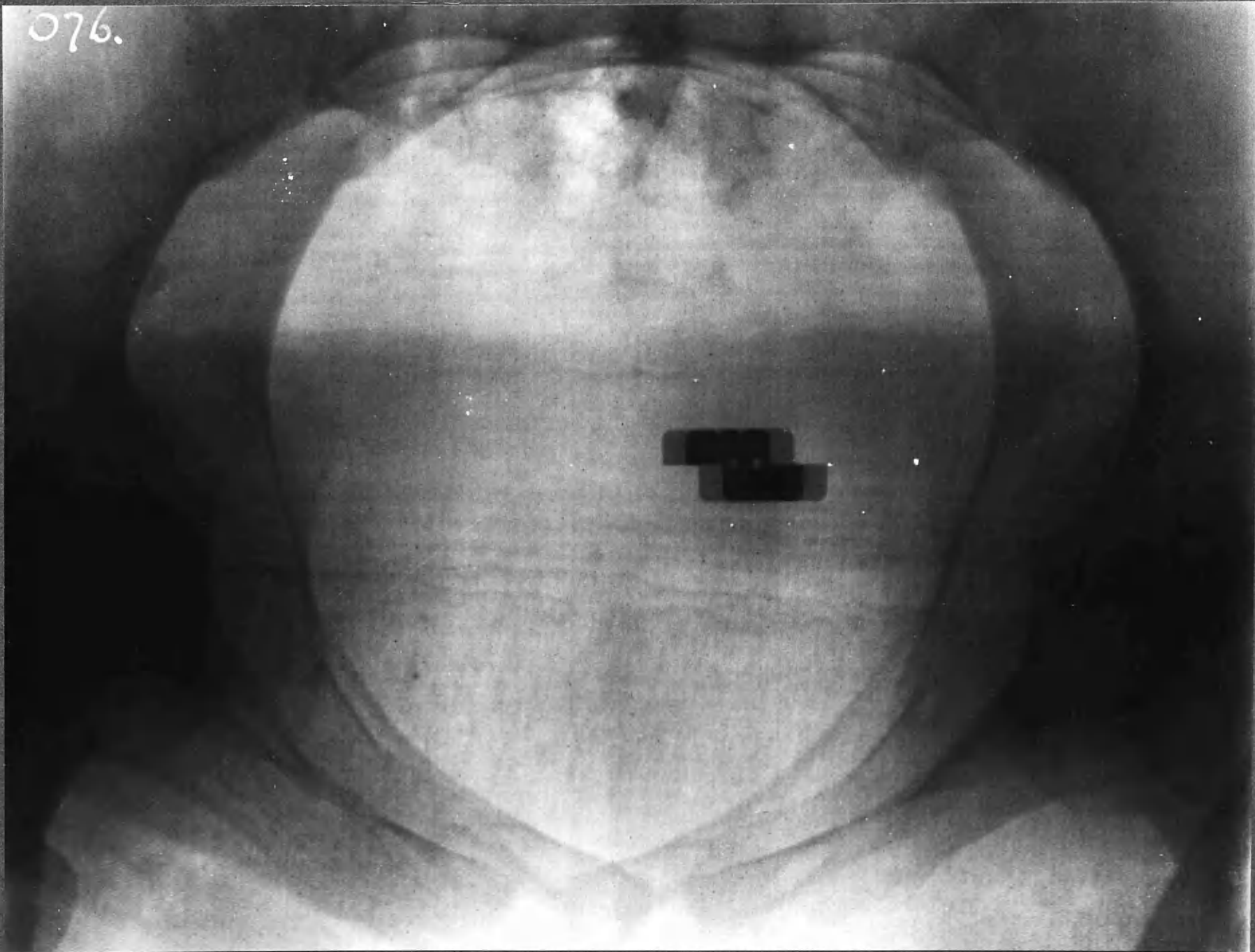


V. POSITION WITH BRIM PARALLEL TO FILM.



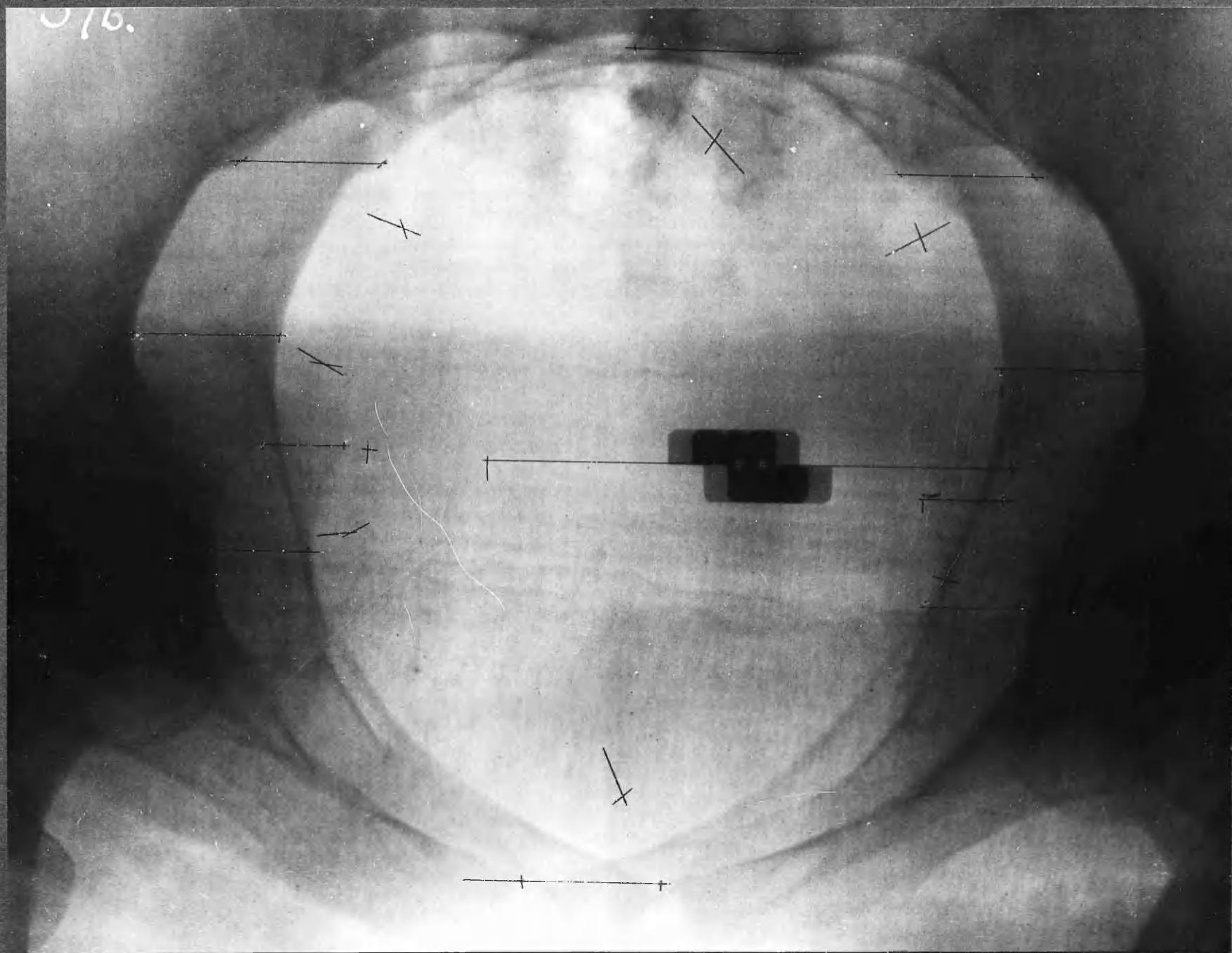
VI. POSITION WITH OUTLET PARALLEL TO FILM.

076.

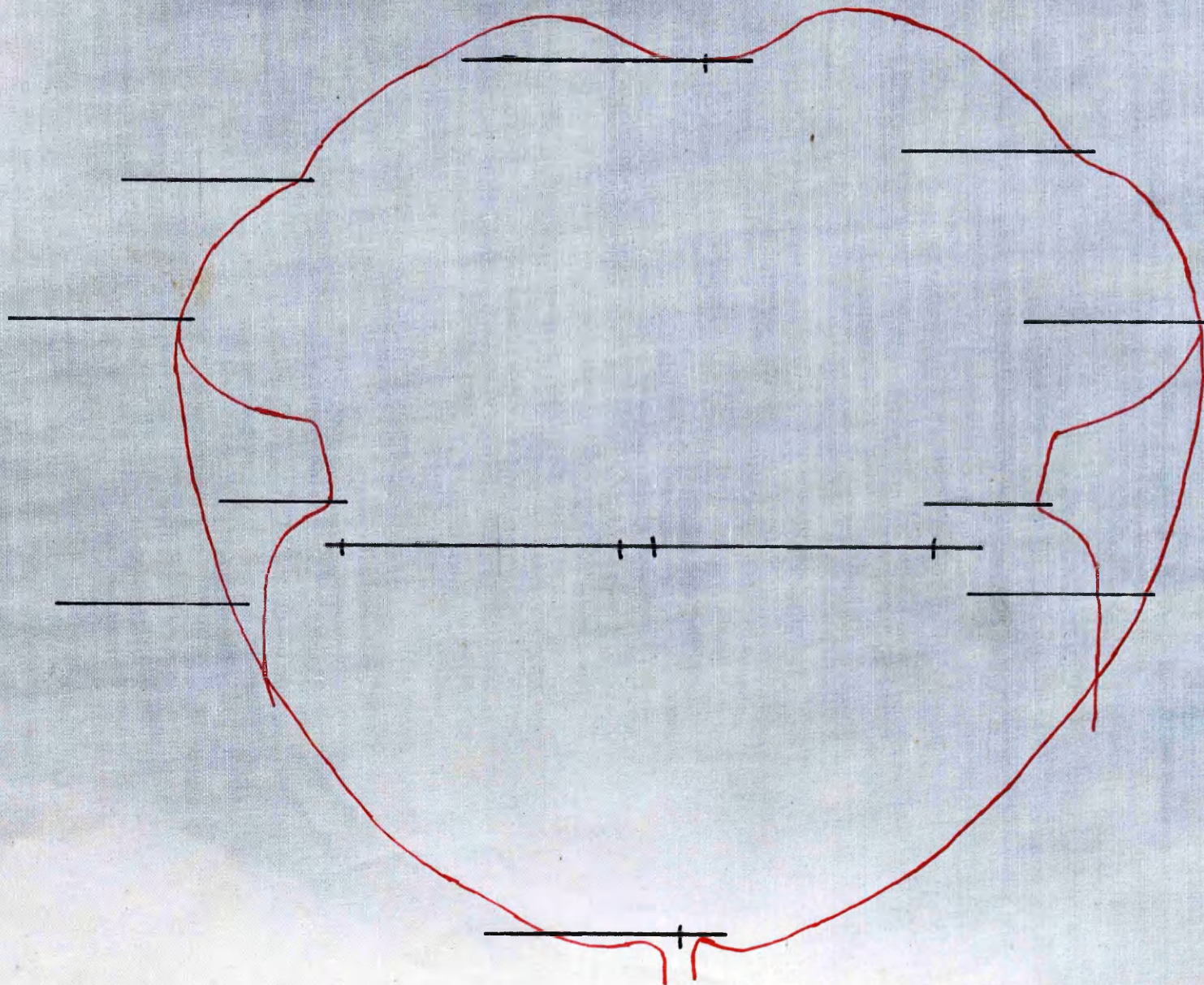


VII. ONE FILM METHOD, BEFORE MEASUREMENT.

576.

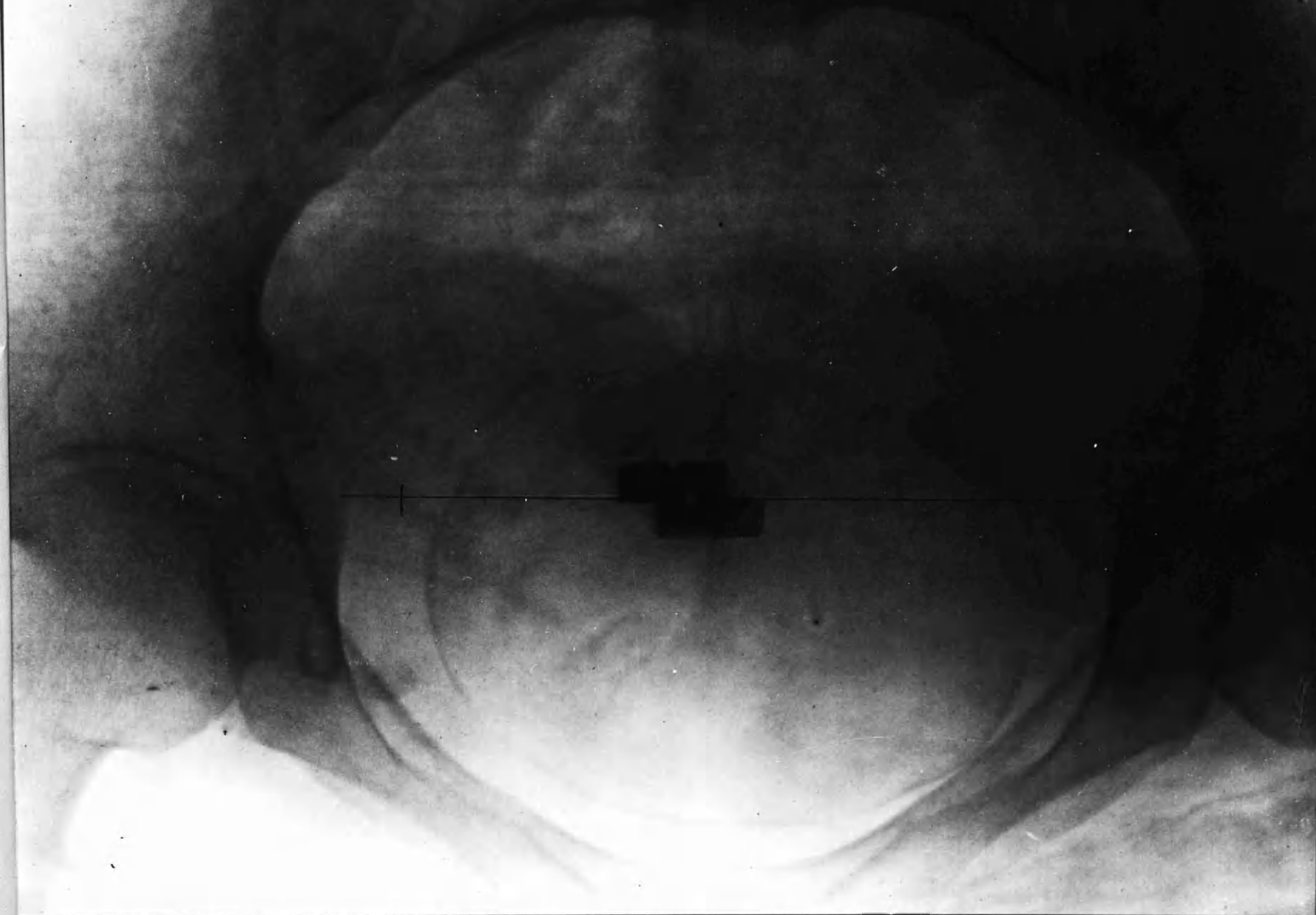


VIII. ONE FILM METHOD, MEASUREMENT COMPLETED.

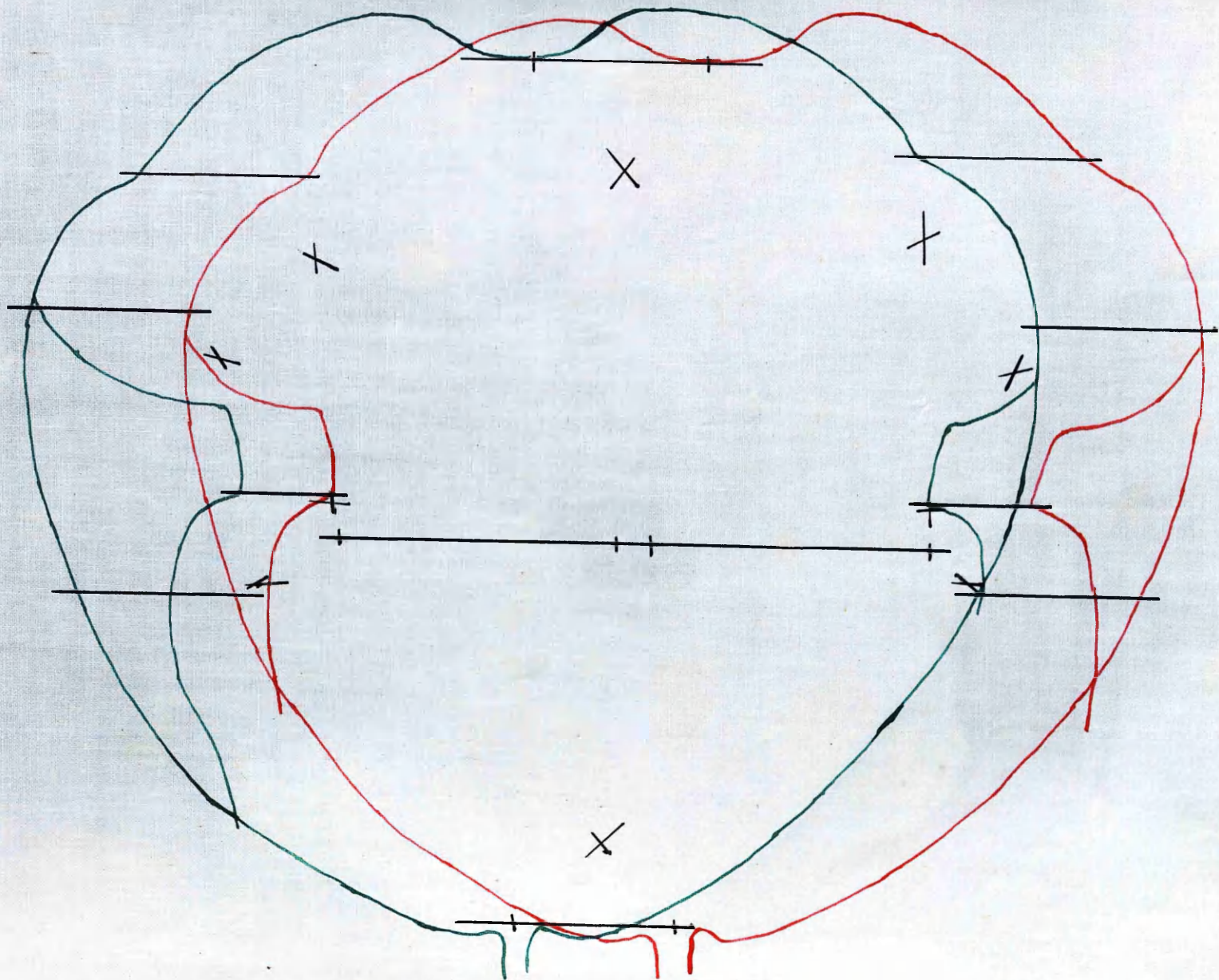


IX. TWO FILM METHOD, FIRST FILM WITH TRACING,

040

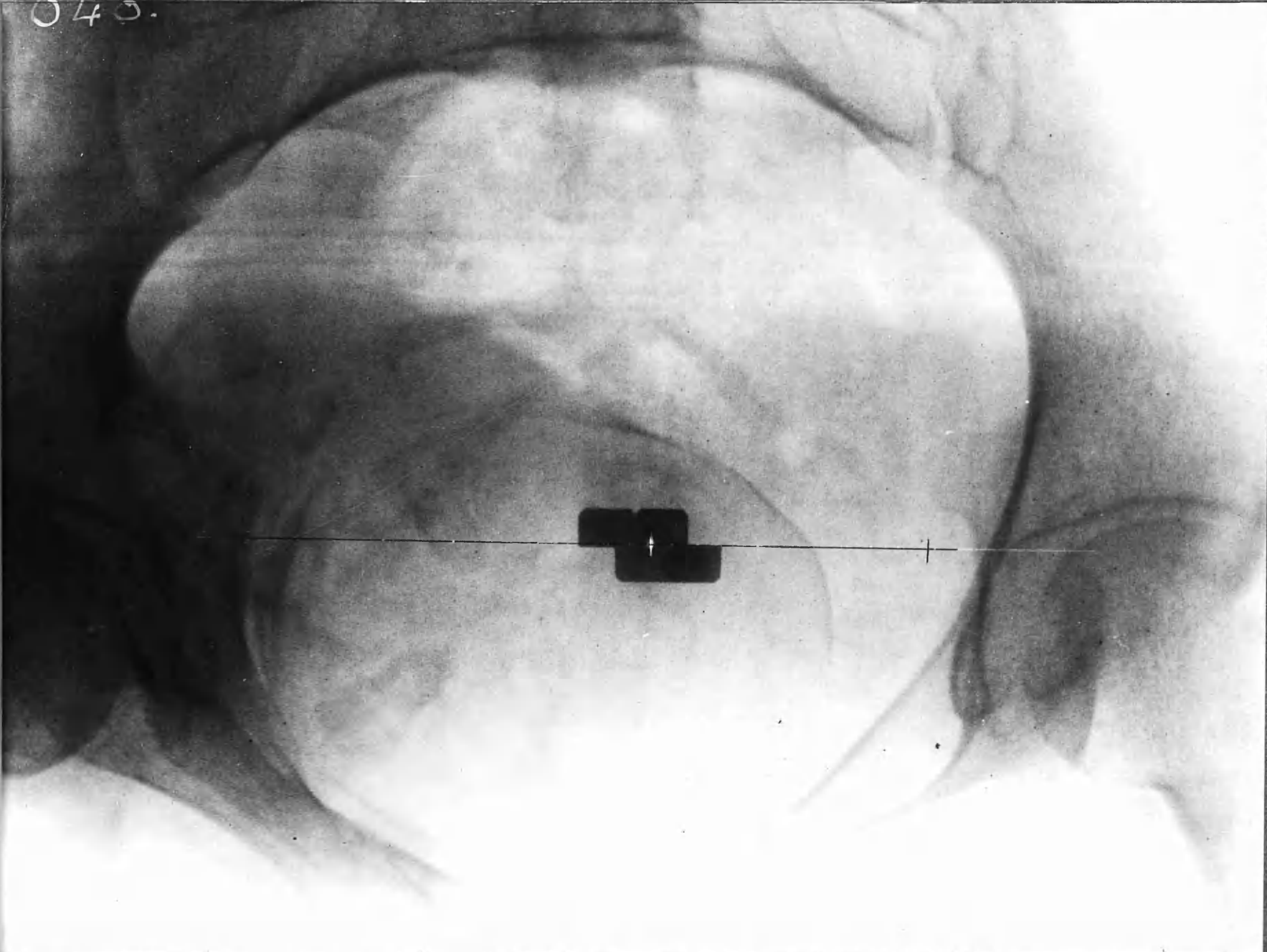


IX. TWO FILM METHOD, FIRST FILM WITH TRACING.

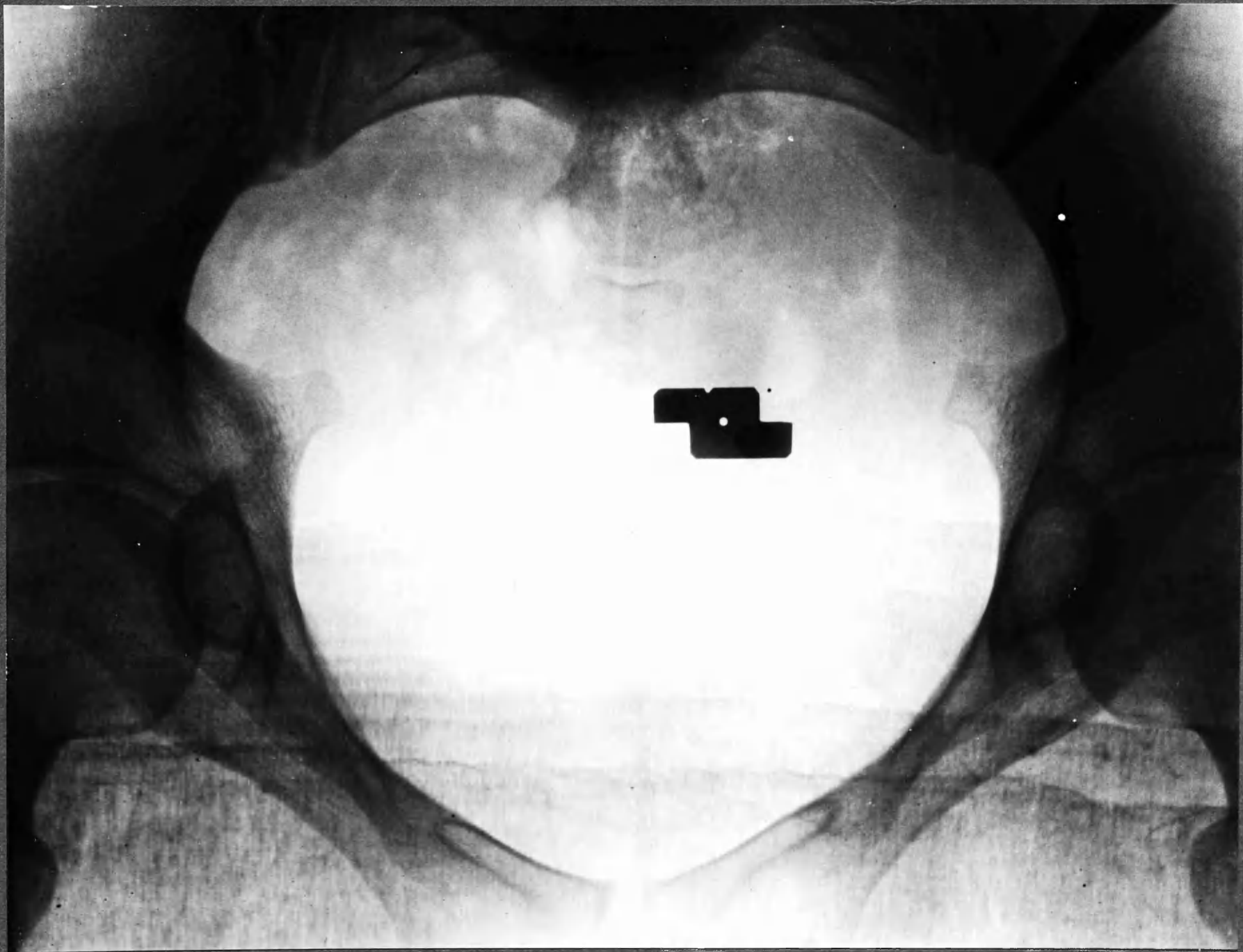


X. TWO FILM METHOD, SECOND FILM WITH TRACING.

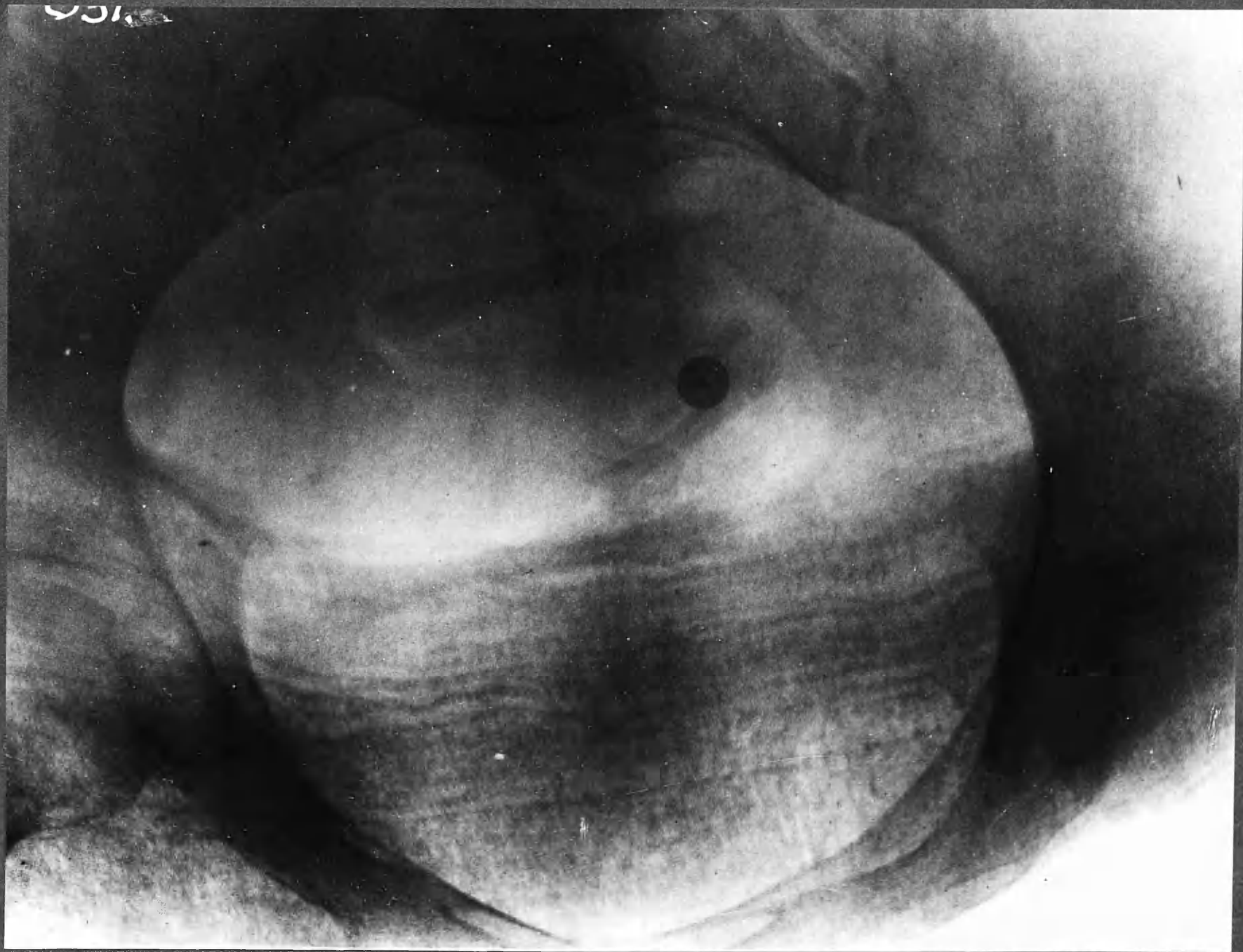
045.



K. TWO FILM METHOD, SECOND FILM WITH TRACING.

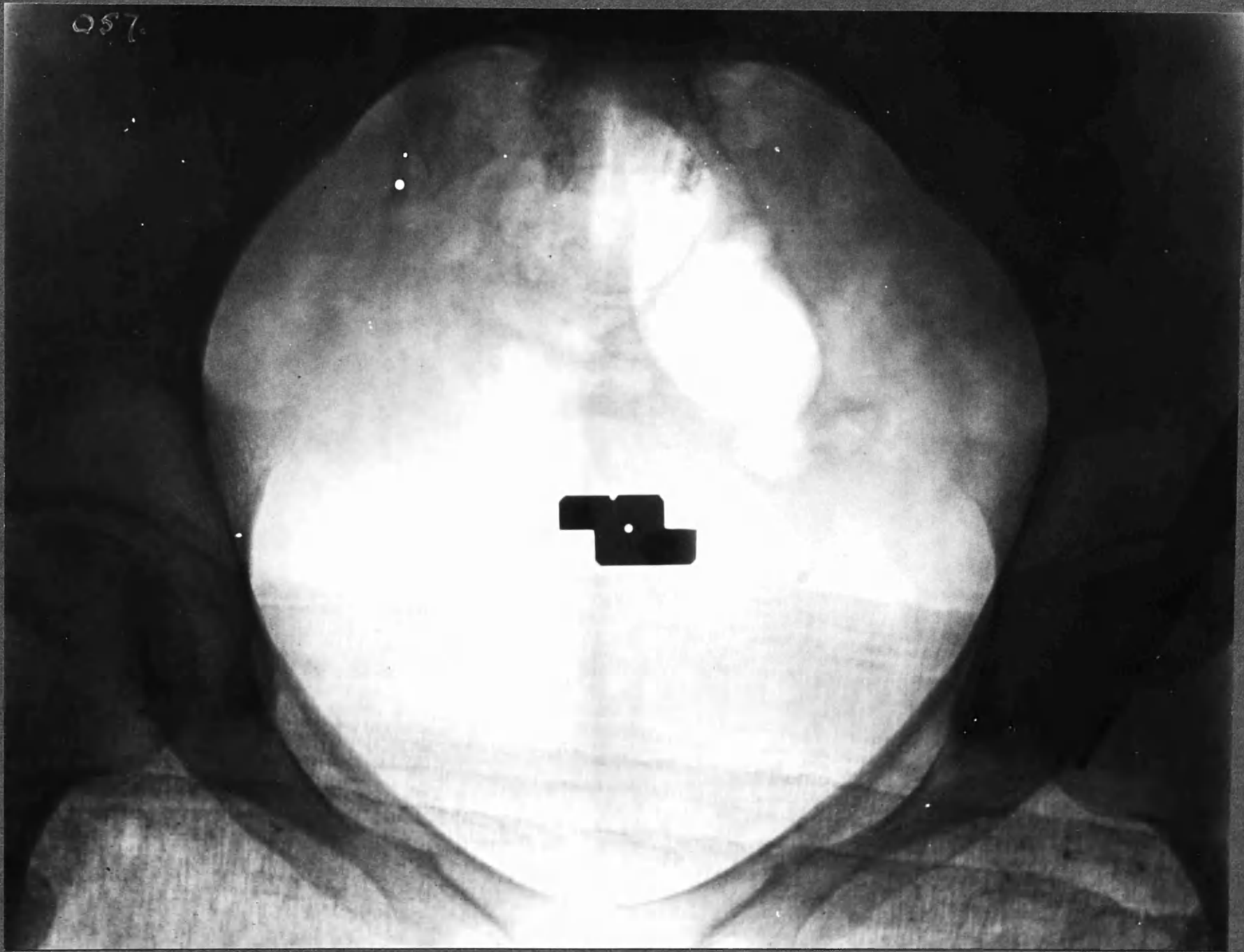


X1. AVERAGE PELVIS.



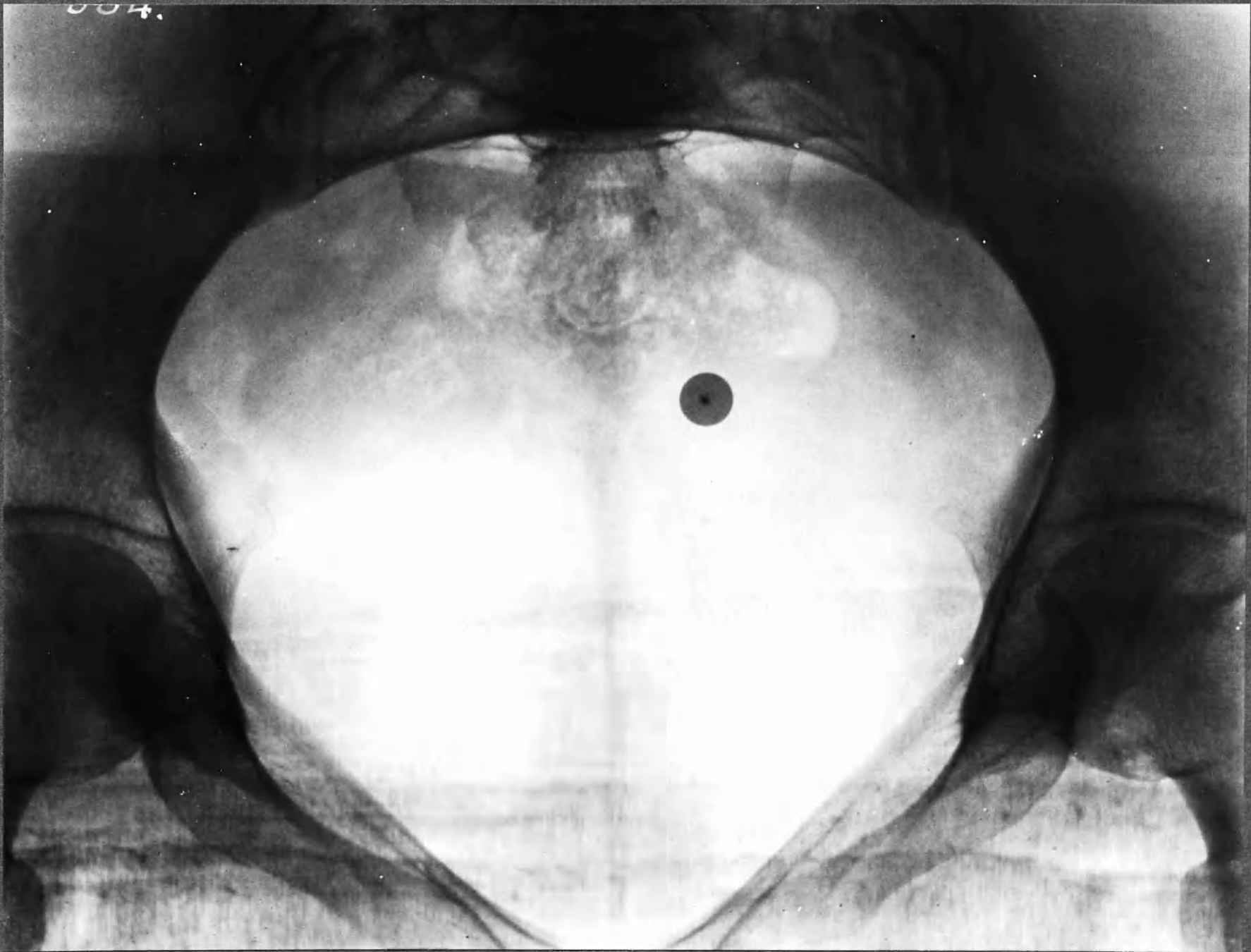
XII. PELVIS WITH ALL DIAMETERS ENLARGED.

057.



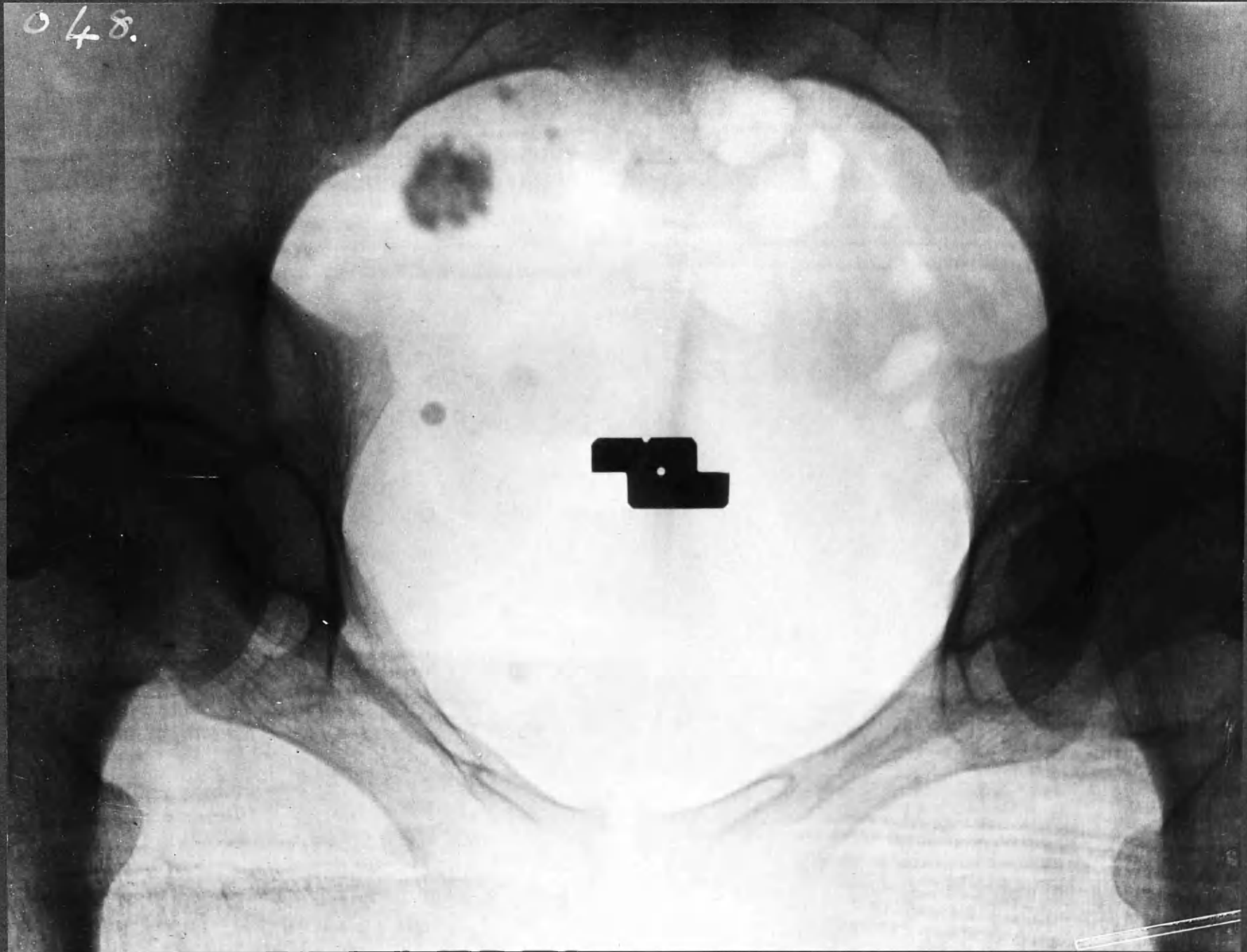
XIII. CONCAVE SACRUM.

504.



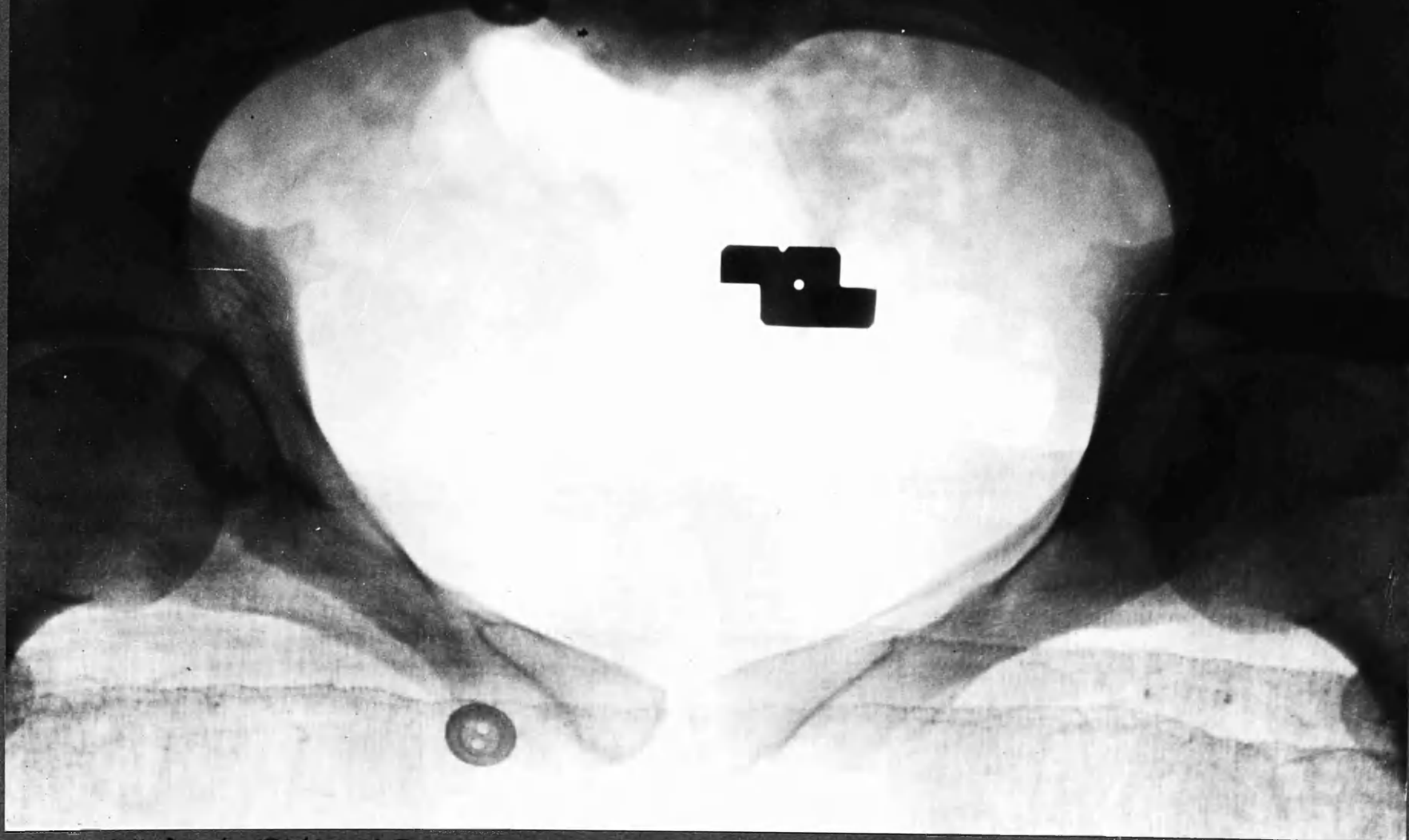
XIV. STRAIGHT PUBES.

048.



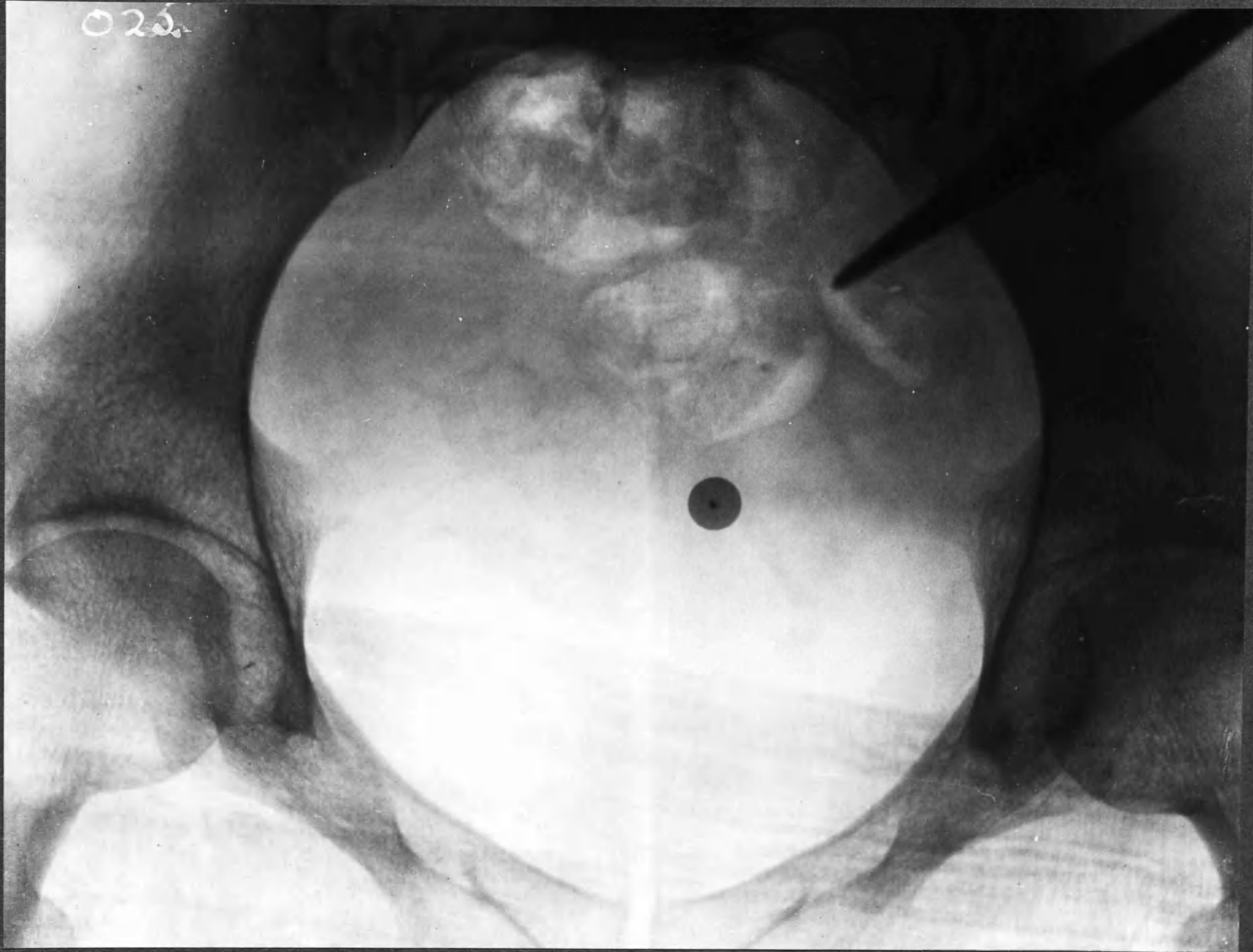
XV. JUSTO-MINOR PELVIS.

Q56.



XVI. FLAT PELVIS.

020.



XVII. NARROW PELVIS.

001.



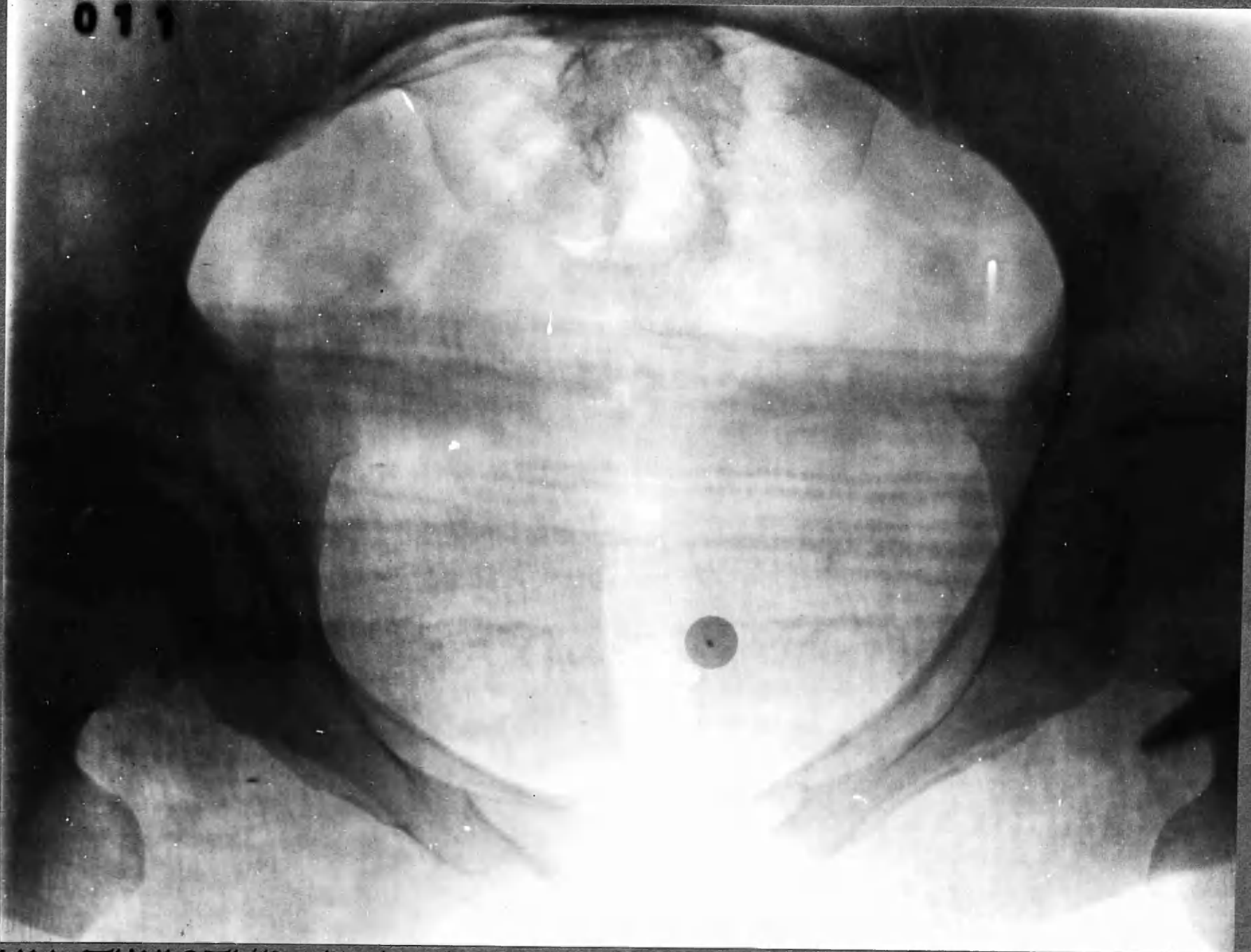
XVIII. ASYMMETRICAL PELVIS.

044.



XIX. TWISTED ISCHIUM.

011



XX. TWISTED ILIUM.