THE CLINICAL APPLICATION

OF THE

RÖNTGEN RAYS.

I. THE APPARATUS AND ITS USE.

By WILLIAM FRANCIS MAGIE, Ph.D.,
PROFESSOR OF PHYSICS AT PRINCETON.

II. THE SURGICAL DIAGNOSIS.

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III. THE STUDY OF THE INFANT'S BODY AND OF THE PREGNANT WOMB BY THE RÖNTGEN RAYS.

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THE CLINICAL APPLICATION OF THE RÖNTGEN RAYS.

So soon as it seemed probable that the Röntgen rays might prove of value to medical science THE AMERICAN JOURNAL OF THE MEDICAL SCIENCES, through its Editor, instituted experiments to ascertain methods and results in the clinical application of the discovery. The results of these experiments are given by the gentlemen conducting the various portions of this investigation.

I.

THE APPARATUS AND ITS USE.

BY WILLIAM FRANCIS MAGIE, PH.D.,
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THE apparatus with which most of the work was done, which is described in this article, was essentially similar to that used by Röntgen in his original work. The Crookes' or vacuum tube was excited by a large inductorium or Ruhmkorff's coil, made by Apps, of London, and belonging to the Physical Collection of Princeton College. The coil is 14 inches long and 8 inches in diameter. When actuated by 6 or 8 cells, made by the Electric Storage Battery Company of Philadelphia, each having an electro-motive force of about 2 volts and a capacity of about 150 ampere-hours, the instrument ran steadily and gave a spark 6 inches long between points in air at each break of the primary current. A smaller inductorium, with a coil 9½ inches long and 6 inches in diameter, was also used successfully, but the larger coil seemed most efficient, and was used in most of my work. It is probable that when the vacuum-tubes are improved the Röntgen action may be obtained by the use of much less expensive apparatus than that here employed. It is hardly necessary to statethat any voltaic cells or storage-batteries may be used as the source of current, and that care must be taken that no higher electro-motive force is present in the circuit containing the primary coil than that which the coil is designed to bear. This is generally not greater than 12 to 15 volts, and with smaller coils may be less. It is thus manifestly impossible to use the current from a city supply directly with the coil. If it is used at all, a shunt must be introduced. The best form of shunt is the proper number of cells of a storage-battery, which can be receiving their charge at the same time that they are setting the coil in action.

The vacuum-tubes used in my first trials were in the collection at Princeton; after they broke down others obtained from Queen & Co., Philadelphia, were found equally serviceable. My experience agrees with that of others, that the ordinary Crookes' tubes differ very much in their efficiency. Of those in the Princeton cabinet, only three or four, when tested by the *skiascope*, showed that they were furnishing an abundant supply of the Röntgen rays; and most of those on sale in the shops are worthless. The cause for the superior excellence of some tubes over others seems to lie largely in the different thickness of the glass wall. This has been stated by Mr. Edison, and an observation which I made suggested the same explanation to me.

One of the Crookes' tubes with which I worked had the form of a nearly spherical bulb with two conical projections. Four aluminum electrodes were inserted into this bulb, two at the ends of the conical projections, the other two, one a straight wire, the other a flat disk, through the wall of the bulb. Those who are familiar with the ordinary form of the Crookes' tubes will recognize this at once as the one furnished as a companion to another of similar form, but less highly exhausted, to show the difference between the Crookes' cathode-action and the ordinary stratified discharge. If the flat disk-electrode of this tube was made the cathode, a patch of green phosphorescence appeared on the opposite wall of the tube. This spot I made the source of the Röntgen rays in my first attempt to get a photograph; though sufficient was obtained to show the Röntgen effect, yet the action was very feeble; and when the tube in this condition is examined by the skiascope it is evident that the tube is not doing efficient work. Other tubes in which the cathode-rays travel long distances from flat electrodes before they fall on the glass show similar feeble action. When any one of the three wire electrodes was made the cathode the characteristic green phosphorescence appeared around it; in the case of the electrodes in the projections the phosphorescence was very brilliant and confined almost entirely to the walls of the projection. Contrary to my expectation, I found that the tube, when these electrodes were cathodes, gave little or no evidence of the Röntgen rays. The only electrode which made an efficient cathode was the wire projecting into the bulb. When it was made the cathode all parts of the surface of the bulb became phosphorescent, with a yellowish-green light, and the skiascope showed a copious emission of the Röntgen rays. By placing in front of the bulb a plate of lead in which a hole about three centimetres in diameter was cut, the rays from all but a small part of the surface of the bulb could be cut off and the efficiency of different parts of the bulb tested with the skiascope. It became at once evident that the most efficient parts were the thin walls of the bulb, and that the places where the glass was thicker exhibited the action either less well or not at all.

If the Röntgen rays are excited, as Röntgen says, where the cathode-rays fall on the glass, and therefore start at the inner surface of the bulb, the known resistance of glass to the passage of the rays will easily explain this observation.

Another requisite for the production of the Röntgen rays seems to be a high vacuum in the tube. Some observers have made statements which contradict this, but my experience with the tubes in the Princeton cabinet, as well as with others that have been made for me, generally supports it. Some ordinary Geissler tubes, however, showed the Röntgen rays. They were such as had a narrow portion made of uranium glass. This portion seemed to be the source of the rays. I have used one of these tubes with the photographic plate with good results.

The photographic plates used were Hammer's Extra Fast, Carbutt's Eclipse, and plates specially prepared by Carbutt for the Röntgen rays. Most of the pictures of this article were taken on the Carbutt's Eclipse plates. One of them, No. 1, was taken on a freshly prepared Carbutt's special plate, with a material reduction in the time of exposure.

To take a picture or skiagraph by the Röntgen method the photographic plate is placed in an ordinary plate-holder, or shut up carefully in a cardboard box, such as those in which photographic plates are sold, with the sensitized surface turned toward the object to be taken. The plate in its holder is then placed in a convenient position, so that the object may rest upon the cover of the plate-holder, or at least be as near it as possible. The vacuum-tube is set up so that the most efficient part of its surface confronts the plate. I have found that in the case of objects like the bones of the hand or arm, which cannot rest directly on the cover of the plate-holder, increased distinctness of definition is obtained by using as a radiant surface only a small portion of the tube, shutting off the rest by means of the sheet of lead already mentioned. This greater definiteness of outline is gained at the expense of longer time required for the exposure and of less marked contrasts of light and shade. For much work the whole tube may be used, and a fairly definite outline secured by setting the vacuum-tube at a greater distance from the photographic plate. When the radiant source was that portion of the tube which was exposed by the circular hole in the lead diaphragm, the vacuum-tube could be set about 6 or 8 inches from the plate, and a good picture taken of thin objects, like the hand, by an exposure of one hour. When the whole tube served as a source, an exposure of an hour for the thinner and an hour and a half for the thicker objects was sufficient, the tube standing 12 inches or more from the plate.

It should be noticed that the outline will be better and success more certain if those parts which are specially desired are brought as close to the plate as possible. The proper relative positions of object, plate, and tube may be readily seen by remembering that these pictures are shadow-pictures, and that if for the vacuum-tube we were to substitute an equally large globe of ground glass, illuminated from within, the object would cast a shadow on the plate very like that which it makes in the Röntgen rays. The arrangement which will cast the best defined shadows of the desired object will yield the best results.

The photographic plates are developed in the ordinary way. As the pictures are only shadows, and no artistic effect is required, the development can be pushed further than would be suitable with an ordinary plate, with the result sometimes of bringing out detail that does not appear at first.

The *skiascope*, to which reference has already been made, is an instrument designed to take advantage of the fact that the Röntgen rays cause fluorescence in certain substances, to make direct visual observations of these rays and the shadows cast by them. The fluorescent substance which I have used is the double cyanide of platinum and barium, which is so excellent for the observation of the ultra-violet rays of light, and whose usefulness in connection with the Röntgen rays was announced by their discoverer. Much of the salt which I have obtained from the chemists either exhibits no fluorescence at all with the Röntgen rays, or only a trace of it, and I cannot at present state the conditions of preparation which will insure good fluorescence.[1] The successful results which I obtained were secured with a piece of platino-bari-cyanide paper imported from Germany recently for the Princeton cabinet. A circular disk cut from this paper was fastened, with the fluorescent side inward, by non-actinic black photographer's paper in one end of a brass tube blackened on the inside. By fitting the other end of the tube around the eye, both the eye and the fluorescent sub-

[1] Dr. G. D. Rosengarten has investigated for us the chemical and physical properties of the platino-bari-cyanide.

stance are protected from the light. When this instrument is anywhere near the excited vacuum-tube, provided that the Röntgen rays can fall directly on the fluorescent paper, the fluorescent salt will glow, and the shadows of objects interposed between it and the vacuum-tube appear upon it. It is advantageous to bring the interposed objects as close to the paper as possible. The shadows thus cast have the same distinctions of intensity that they show by their action on the photographic plate. The outlines are generally not so distinct as they are on the plate. With a larger sheet of the fluorescent paper a larger instrument of the same sort can be constructed, which will enable the observer to use both eyes at once and to view a larger field.

This skiascope is very useful as a means of testing the behavior of the vacuum-tube. I have assumed that the vacuum-tube that affects the phosphorescent substance most vigorously will also act most vigorously on the photographic plate; all my experience is in harmony with this assumption, but I have as yet made no experiments to test it. Since slight changes in the performance of the inductorium will make considerable difference in the action of the vacuum-tube, it is convenient to have a test of proper action, such as can easily be made by this instrument.

This skiascope is obviously the instrument which is best adapted to the study of the physical questions connected with the Röntgen rays.

In describing this instrument as my own, I do not wish to be considered as asserting priority over Professor Salvioni, of Perugia, who has described an instrument essentially similar, but only independence in the invention.

In closing this account of the physical matters involved in our joint labors one or two isolated observations may be mentioned. In one case, when the photographic plate, which had been exposed to the Röntgen rays for over an hour, was taken from the plate-holder, the object—an arm and an elbow-joint—was seen by two photographers as a dark band across a light field. This seems to show that the sensitive film is phosphorescent and that the photographic effect is secondary. I have not as yet repeated this observation.

In the opinion of three observers the interposition of a thin plate of aluminum between the vacuum-tube and the fluorescent paper of the skiascope did not merely leave the fluorescence undiminished, but actually intensified it considerably. This effect was observed when the aluminum plate was first used. I tried to verify it later without success. I report it because the result was certain and because it may have some bearing on the success that has been obtained in rapid skiagraphy by those who have used aluminum covers for their plate-holders.

II.

IN SURGICAL DIAGNOSIS.

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The surgical cases that were examined by this method consisted of:

1. A burned hand (Plate I.) with anchylosis of all the fingers at the knuckle-joints and some necrosis of the metacarpal bones, which were in great part soldered together, the little finger being curved under the ring-finger. The skiagraph shows well the bones in the fingers. In the metacarpus, the reason for the fusing of nearly all the picture is that the bones, as a consequence of the very severe burn between the rollers of a heated mangle, were completely soldered together in one mass. It will be noticed that the little finger, even where it passes under the ring-finger, is well seen. Fig. 1 is an ordinary photograph of the same hand.

2. A tubercular elbow-joint (Plate II.) in a child of twelve years, in which it will be observed that not only the humerus shows, but also the radius and ulna. (Compare this with Plate III. of a stouter arm.)

3. The elbow-joint (Plate III.) of a young man of twenty years, who, twelve years ago fell, striking his olecranon violently on a bit of railroad iron, driving the ulna into tbe groove between the two condyles of the humerus and wedging them apart. The condyles, especially the inner, show well; the radius and ulna were in such contact as to appear only as one. Fig. 2 shows an ordinary photograph of the same elbow, though it by no means presents the extreme deformity as one sees it from various points of view. Strange to say, flexion and extension were excellent.

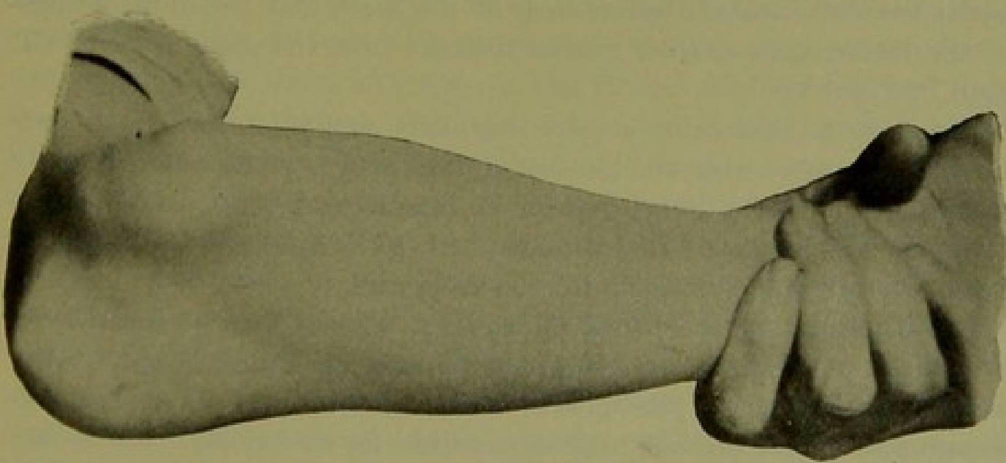
4. An elbow (Plate IV.) which had been resected for tubercular disease a few days before. This was in plaster-of-Paris splints encasing respectively the arm and the forearm, with a bar of iron extending between the two in order to fix the elbow rigidly. The skiagraph shows the plaster-of-Paris splint and the iron cross-bar. It is to be observed that the plaster is opaque to the rays, while on the contrary the gauze-dressing and the bandages which thickly encased the elbow and the bar were translucent to them. The ends of the resected bones of the forearm show only very faintly, and the end of the humerus also, probably (as the bar shows) from the movements of the child or some modification of the rays by the dressing and bandages.

5. A shoulder-joint with a recent resection of about three inches of the humerus, on account of an old dislocation with fracture of the surgical neck followed by a late osteomyelitis. This picture was also

Fig. 1.

Photograph of burned hand.

Fig. 2.



Photograph of fractured elbow.

taken without removing the bandage and dressing, by fastening the sensitized plate in its holder immediately behind the shoulder, while the Crookes' tube was placed in front of the shoulder, the patient lying sidewise in a bed. The skiagraph shows the outline of the edge of the scapula only; presumably the parts were too thick. Another difficulty was the constant respiratory movement, which has aided in blurring the outlines.

6. I attempted to skiagraph the trephine-opening in a case operated on four years ago, but, though the sensitized plate was left exposed for somewhat over an hour, no picture whatever appeared upon it. Whether this was due to a defect in the plate or in the tubes, or whether, as it seems to me more likely, to the impossibility at present to skiagraph through even one thickness of the skull, I do not know. The patient lay upon a bed with her head resting on a sensitized plate, the trephine-opening being next the plate and the Crookes' tube on the opposite side of the head. The head was not shaven.

7. Plate V. shows a hand of an uninjected cadaver. In it will be observed not only the bones and their cartilaginous extremities, but also in the thumb the sesamoid bones. A needle was thrust into the thumb up to its eye. This foreign and more opaque body comes out much more sharply than do the bones. Under the metacarpal bones of the fore and middle fingers are seen two large buckshot. These were inserted on the palmar surface of the hand, and are, therefore, seen through the bones. The skiagraph shows an enlargement of the head of the metacarpal bone of the thumb, which was found, by subsequent dissection, to be the result of an old injury. Plate VI. shows the wrist of the same hand, the carpal bones and the radius being fairly distinct. The metacarpals and the needle are much less distinct than in Plate V., and the buckshot show blurring at the edges. This is probably due partly to an accidental displacement of the hand, and the indistinctness of the metacarpals to their greater distance from the plate in Plate VI. than in Plate V.

We were anxious, also, at the ingenious suggestion of Mr. Arthur H. Lea, to see whether the hand of a dead person would act differently from the hand of a living person in intercepting the passage of the Röntgen rays, in order that it might be used as a test of death, but, so far as we can judge, no such difference appears.

8. The following specimens of bacteria were exposed to the rays in order to test their effect on the bacteria, namely: pink streptococcus, anthrax, micrococcus prodigiosus, micrococcus cereus flavus, sarcina aurantiaca, yellow sarcine, tubercle-bacillus, for first thirty minutes and then twice for fifteen minutes. In order to prevent the unfavorable effect of the glass tubes, they were so placed that the rays reached the bacteria through the cotton stopper. The tube of tubercle-bacilli was exposed

sidewise through the glass, and not lengthwise through the cotton, for one hour. Dr. Kyle reported that inoculations showed a good, strong growth from all of them. No lethal or even inhibitory effect was therefore seemingly produced upon these bacteria by an hour's exposure to the rays.

Clinical Conclusions. The above facts, together with other reports in various medical and lay journals, show clearly that the thinner portions of the body can be skiagraphed with considerable accuracy. This is true of parts of the body as thick as an ordinary elbow. Whether it will be true of the thicker parts of the body, *e. g.*, shoulder and trunk, is doubtful with present methods.

The effect of doubling the thickness through which the rays pass is admirably shown in the skiagraph of a foot in the *British Medical Journal*, February 8, 1896. Where two toes overlapped the skiagraph is twice as dark as where it was taken through a single toe.

One of the difficulties we have had has been the length of time necessary to take the pictures. The shortest exposure in any of these has been twenty minutes with extra quick plates made specially for us by Mr. Carbutt. We observe in the newspapers that it has been stated that instantaneous pictures have been lately taken by Edison and others. If this be so, it will aid materially in getting better-defined pictures both by relieving the patient of the irksomeness and even impossibility of remaining absolutely still for so long a time, as in the old daguerrotype, and by obviating the blurring consequent upon respiratory movements of the chest and the abdomen. The skiagraph of five years hence will be as superior to such as we present herewith as our present photographs are superior to those of forty years ago.

To sum up the clinical results obtained by ourselves and others, it is evident that of the *normal structures of the body* it would seem that all are permeable to the rays except the bones, and, therefore, it is not very probable, at least with our present methods, that we can determine much about them, although in the *British Medical Journal*, February 8, 1896, Mr. Sidney Rowland states that Adolph and Lenz, of Elberfeld, have been able to get pictures of *connective tissue*.

The *bones* are opaque to the rays, hence deformities, injuries, and diseases of bone will be more or less amenable to diagnosis by this method. The best illustration of this that we have seen is the case reported and figured in the *British Medical Journal*, already alluded to. In this case the distal phalanx of the great toe appeared to be double, as though there were two bones in the last joint. There was difficulty in distinguishing which of the two bones was the normal phalanx and which the supernumerary. Prof. Mosetig, therefore, took a skiagraph and was able instantly to determine which was the normal and which the abnormal phalanx.

We shall probably be able to differentiate *fracture* and *dislocation* even possibly in the thicker parts of the body when our methods have become more perfect. As has been pointed out in *The Medical News* of February 22, 1896, this may be of much use in obscure cases with great swelling, for the swelling is not impermeable to the rays. Suspected greenstick fractures can be made evident, and in any case in which possibly a claim for malpractice would be made, if, after the bones are adjusted, they were skiagraphed through the dressings, including even the ordinary board splints (plaster, of course, would not do), such a skiagraph might be of great value in court. Even if not needed for such medico-legal purposes, it would be of value to the surgeon in assuring him that everything is in proper order. *Exostoses and bony tumors* of any kind can thus undoubtedly be diagnosticated. *Cartilage* is translucent to the rays.

Gall-stones have been skiagraphed outside of the body (but not yet in the living body) by Neusser, Goodspeed, and Cattell (*The Medical News*, February 15, 1896, p. 169), but although only obscured by the thickness of the wall of the bowel into which the gall-stone had been thrust, no diagnosis could have been made from it. If we did not know a gall-stone was there, we could not have guessed it.

Phosphatic and probably other *urinary calculi* Neusser has shown to be quite impenetrable to Röntgen rays (as would be suspected by the impermeability of plaster-of-Paris in Plate IV.), but it is very doubtful whether we will be able to utilize them in diagnosis, on account of the bladder lying in the pelvic basin, the bones of which would cut off the rays. The kidneys at present cannot be skiagraphed, as the rays will not pass through so thick a part of the body. *Renal calculi* are as yet beyond our diagnosis by this method.

It is very doubtful also whether our diagnosis of *tumors* will be much aided by this new method, excepting in cases of bony tumors. Other tumors seem to be as translucent to the rays as the soft parts of the body. In tumors of the brain, the bones of the head (especially as the rays would have to penetrate *two* thicknesses of bone) will absolutely preclude any use of this method in diagnosis.

All such statements as the above apply, of course, only to our present knowledge. It is not only possible, but very probable, that we shall be able to accomplish very much more by the improvements which will be introduced into the method within the next few years.

Probably the most important use of the method will be in the location of *foreign bodies*. While some metals are translucent to the rays, others, and fortunately the common foreign bodies, are not translucent: thus in Plate V., of a dead hand, a *needle* thrust into the soft parts of the thumb shows with such striking clearness that we may positively say that, if a needle is suspected to exist in *any* part of the hand (and very often the history is obscure, so that we are doubtful whether the needle is really in the hand or not), by means of the Röntgen rays we can positively determine its existence and location.

The same skiagraph shows two *buckshot* which were placed purposely in the palm of the dead hand, and they are clearly seen even through the metacarpal bones. This method has actually been utilized already in several instances, according to the daily papers. Once by von Bergmann, in Berlin, Bury, of Chicago, and several others who have been able to find bullets and shot believed to be imbedded for a long while in the body. It is almost needless to add, as von Bergmann has pointed out, that most of such missiles, if they are quiescent, would be best utilized as phenomena than removed.

Fortunately, also, *glass* is very opaque to the rays, and if the hand is cut by glass, the existence of any pieces which might otherwise be overlooked can be disclosed by the Röntgen rays. One peculiar advantage of the method also is this: A hand supposed still to have a fragment of glass in it can be skiagraphed without removing the dressings even though they be moderately thick, as both gauze and bandages are permeable to the Röntgen rays. Thus Plate IV., of an elbow, was taken while covered with the ordinary voluminous surgical dressings.

The hand from which Plate VII. was taken is that of a patient, a young colored woman, who had suffered amputation of the third finger some months previously. There remains a very sensitive condition of the stump, and at one point a small area exquisitely painful to pressure. The skiagraph was undertaken to determine the condition of the end of the bone, to ascertain whether an enlarged nerve-end would give a shadow to the rays, and to secure any information leading to a choice of operative procedures for relief. The patient was brought for examination by Dr. Stricker Coles, to whom she had come for treatment. An examination of the end of the finger will show upon its ulnar aspect a slight enlargement of the tissues next the bone. No distinct enlargement of the nerve is visible by this method of inspection. This skiagraph was taken with an exposure of one hour without the use of the lead diaphragm and with the Crookes' tube a distance about fifteen inches from the hand. The plate is interesting for its clear delineation of the wrist. In view of the fact that no one point at the end of the stump could be demonstrated to be in a pathological condition capable of cure by operation, the patient was advised to submit to amputation of the metacarpal bone.

Fig. 3.

Pelvis and fœtal skull.

III.

THE STUDY OF THE INFANT'S BODY AND OF THE PREGNANT WOMB BY THE RÖNTGEN RAYS.

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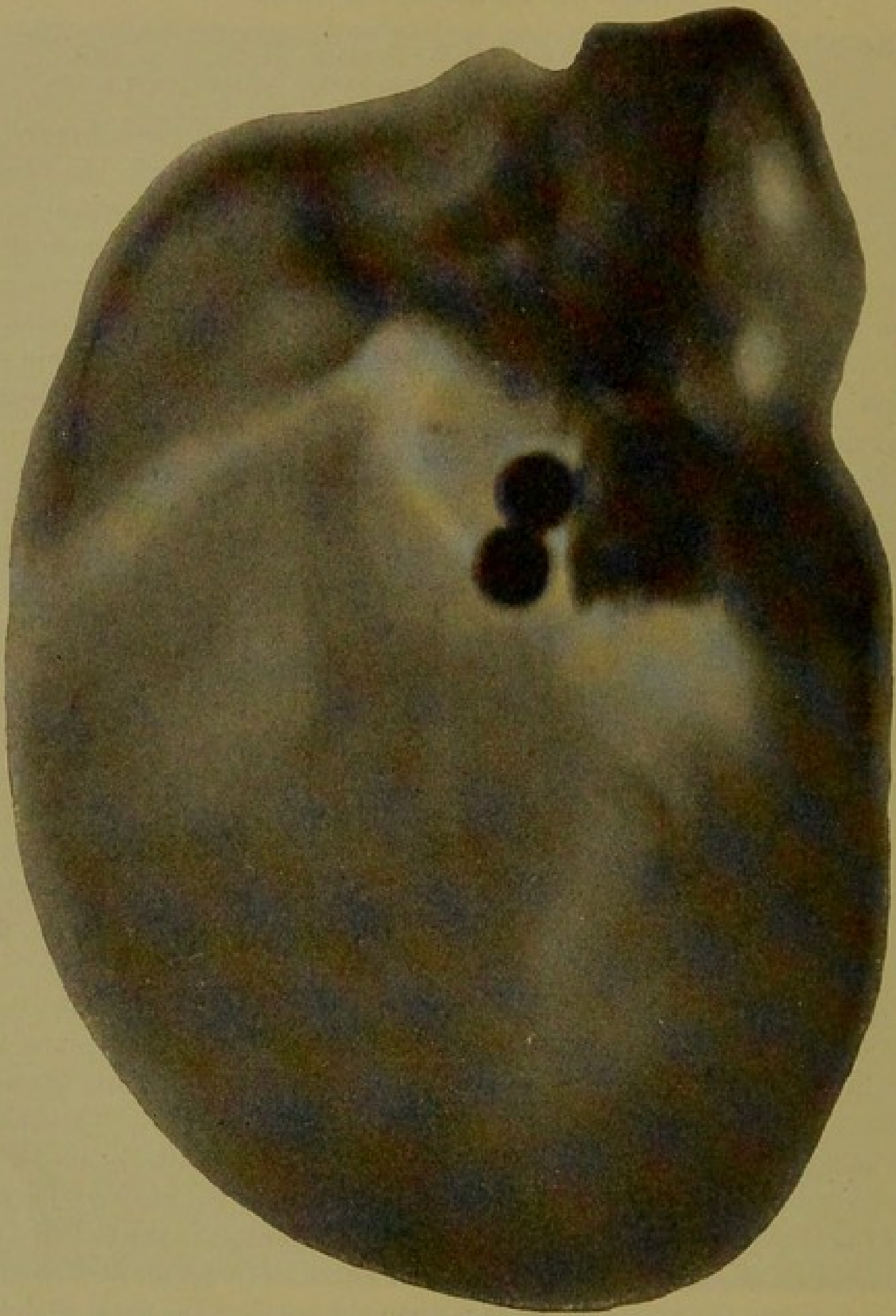
THE body of the infant and pregnant womb present conditions alike favorable and unfavorable for investigation by this method. The body of the infant contains a skeleton so much less completely ossified than that of the adult that it is scarcely to be expected that the same clear shadows can be obtained with the apparatus at present at our command. The problem naturally presents itself, Can the skeleton of the fœtus be recognized by this method within the mother's womb? To ascertain the relative density of the pelvis and fœtal skull to the rays, the following experiments were undertaken :

The skull of an infant at term was placed in a female bony pelvis upon a sensitized plate completely sealed in a pasteboard box. The pelvis was placed in such a position that it rested upon the plate upon the tuberosities of the ischia and the coccyx. The skull was laid obliquely in the pelvis. To secure as much definition as possible a lead diaphragm was interposed between the tube and the pelvis. An exposure of one and one-half hours was made to test thoroughly the various portions of the skull and pelvis subjected to the rays. The result is appended in Fig. 3. Reference to this illustration shows the fact that the greater portion of the fœtal skull gives but a very faint shadow under the action of these rays. The base of the skull is darker, while the temporal region scarcely gives a reaction. In marked contrast to this is seen the black coccyx, which rested upon the plate, and also the rami of the pubes and the spines of the ischia.

A further test was made of the permeability of the fœtal skull by placing the skull upon its parietal surface upon a sensitized plate, and by dropping into it two buckshot, which rested upon the lower parietal bone. In order to reproduce these shot the rays traversed both sides of the fœtal skull. An exposure of one hour was made, with the use of the lead diaphragm. The accompanying illustration (Fig. 4) shows again the transparency of the temporal portion of the skull, and the fact that the lead bullets are clearly seen through the skull. It was next determined to investigate the action of the rays upon the bones of the fœtal skeleton. To ascertain this the skiascope of Magie was employed with direct inspection. In a darkened room, and with the head of the observer covered by a camera-cloth, the foot of an infant three days old, born at term, was held against the skiascope, exposed to the rays of the tube.

FIG. 4.

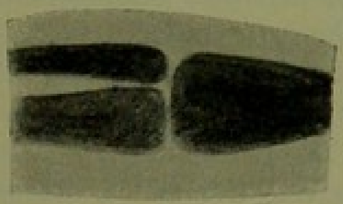


Fœtal skull containing buckshot.

FIG. 5.

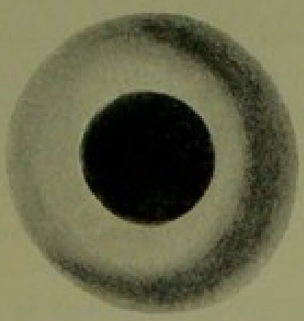
Sketch of living infant's foot, from skiascope.

FIG. 6.



Sketch of living infant's knee, from skiascope

FIG. 7.



Sketch of orbital plate and eye, living infant's head, from skiascope.

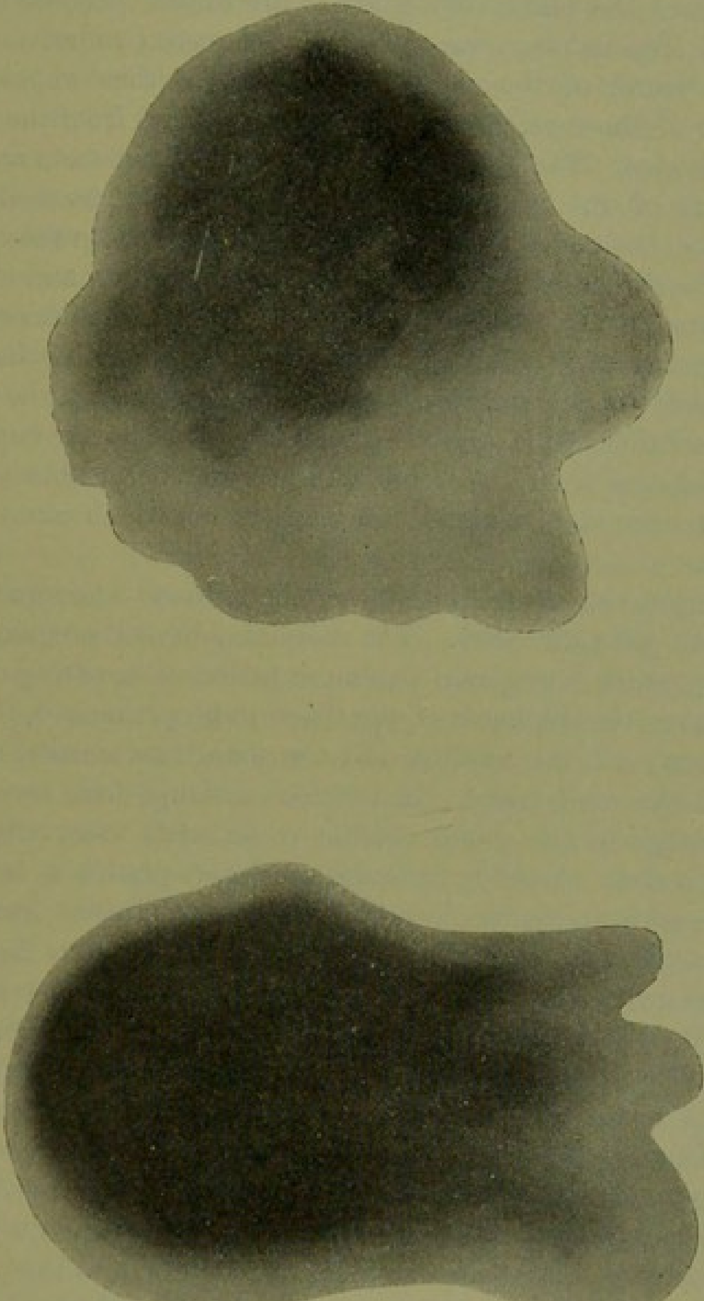
The bones of the tarsus and metatarsus and the outline of the foot were readily seen by three observers. One of these, Mr. W. H. Alcott, an artist in attendance, immediately made a sketch of what he saw. The accompanying illustration is a reproduction of his sketch. (Fig. 5.) The knee of the same child was next investigated in the same manner, and a sketch made of what was seen. Here it will be observed that the cartilaginous portions of the joint offer no shadow by the passage of the rays. (Fig. 6.)

The skull of the infant was next turned, with its temporal region toward the tube, and an effort made to appreciate the passage of the rays through the skull by direct inspection with the skiascope. Here again the temporal region and the brain gave no shadow upon inspection. Upon moving the instrument toward the orbital plate the outline of the border of the orbit and the eyeball appeared, as shown in the accompanying illustration. (Fig. 7.) This led to the question as to the permeability of the eye to these rays. Dr. G. E. de Schweinitz very kindly subjected a pig's eye to direct inspection with the skiascope, and found that the eye does not cast so deep a shadow as do the adult bones, but that the eyeball does not transmit the rays as do the soft portions of the body. The eye was inspected in its longitudinal axis, and also transversely. When the rays pass longitudinally the eye seemed more permeable than when the rays traverse the sclerotic. To test further this question, Dr. de Schweinitz sent me two bullock's eyes, of which a skiagraph was taken by direct exposure to the rays for half an hour. A considerable mass of fat and connective tissue was adherent to the eyes, as they had been removed at the slaughter-house and had not been dissected. It will be observed that this fatty tissue is much more permeable than is the eyeball. In one of these the rays passed through the eye transversely and in the other longitudinally. (Fig. 8.)

The direct inspection of the trunk of the fœtus with the skiascope revealed the fact that the rays permeate the trunk of the newborn child with facility, but that the skeleton casts but a faint shadow. It was possible to appreciate by direct inspection the passage of the rays through the body of a child weighing five and a half pounds, three days old, and born in the ninth month of gestation. The infant was held with its back toward the tube, while the skiascope was applied directly to the chest. The infant's body was not exposed, but remained covered by two thicknesses of light flannel. It was impossible, however, to outline the skeleton clearly or to observe movement in the internal organs.

An investigation of the trunk of the infant by passing the rays directly through the body of the child to a sensitized plate resulted in a very interesting demonstration; the child was clothed in two flannel garments, making four thicknesses which the rays permeated. The umbilical cord

FIG. 8.



Skiagraph of bullock's eyes.

had not separated, and at the umbilicus there was a considerable area of granulating tissue with a slight extravasation of blood, occasioned by pulling upon the cord when the belly-band was taken off for the inspection of the child. The stump of cord remained wrapped in its dressing of aseptic cotton. The child was bandaged upon a sensitized plate, with its back toward the plate, very much as the Indian papoose is fastened to its board. The bandage was the ordinary surgical roller, and entirely covered the trunk of the child's body. It was then exposed to the direct action of the rays, the tube being ten inches from the body, for forty-five minutes. The child remained quiet, did not seem annoyed by the crackling of the tube, and experienced no apparent discomfort. (Plate VIII.) Reference to the accompanying illustration shows the faint outline of the ribs, a dark shadow given by the sternum and underlying spinal column, a trace of the vertebral column, dark shadows cast by the crests of the ilia upon each side, and a shadow given by the stump of umbilical cord, which lay obliquely across the body toward the right, and by the granulating tissue at the umbilicus. The shorter exposure was made in this case from the belief that in very permeable objects too great an exposure may result in losing an outline which could otherwise be obtained.

The attempt to secure a skiagraph of the fœtus *in utero* was naturally attended with great difficulty. The usual timidity of pregnant women, the difficulty which a pregnant patient experiences in sitting or lying in a fixed position, the thickness of the tissue to be permeated, the respiratory movements of the mother, and the fœtal movements, necessarily complicated the experiment. A previous attempt had been made to secure an outline of the spinal column in an adult man, with an exposure of two hours. A newly invented sensitized plate was used for this experiment, with a negative result. A similar plate was employed in the case of a girl, aged eighteen years, pregnant eight and a half months, her fœtus occupying the usual position in the womb. She was placed in a comfortable position upon a clinical table, the abdomen covered with a sheet, and the patient attended by a nurse. A sensitized plate recently devised by Carbutt was placed against the abdomen upon the patient's left side. The lead diaphragm was interposed between the Crookes' tube and the right side of the patient's body, and any danger of the transmission of shock to the patient was obviated by connecting the diaphragm with a gas-fixture. The tube was placed vertically, and the patient subjected to the action of the rays for one hour. The plate was uniformly acted upon by the rays, but without definition.

A second attempt was made with the same patient, using the Eclipse plates, which we have found most successful, without the use of the lead diaphragm, and with an exposure of one hour and fifteen minutes. It was interesting to observe on both occasions that the proximity of the electric apparatus seemed to have no perturbing effect upon the patient. She was informed that an effort would be made to ascertain the position of the child by the use of the electric light; she readily consented to the attempt, and, aside from slight fatigue from remaining quiet in one position, she seemed rather to be soothed by the constant sound of the apparatus, her pulse not varying through the entire time. The result of this second effort to investigate the pregnant uterus shows a difference in the permeability of the fœtal body and limbs from that of the uterine wall and amniotic liquid. By reference to the negative it was seen that the faint outline of the trunk of the fœtus could be recognized, the darker shadow of its pelvis occupying the upper right-hand portion of the plate, while projecting downward at about the centre were irregular white masses showing the situation of the fœtal limbs. The head of the child was so hidden by the mother's pelvis that no definite indication of its presence was obtained. While this experiment failed to outline distinctly the skeleton of the fœtus, it offers information which may be of value in further attempts. There has not been the slightest evidence that the passage of the rays through the uterus has affected either mother or child.

From our study of the pelvis and skull, and from our investigation of the living patient, it seems probable that information of practical value regarding the position and attitude of the fœtus may be obtained with the future development of this method. It seems probable that the contour of contracted pelves may also be recognized in future. An abnormal condition of the fœtus, such as a tumor, or an accumulation of fluid within a cavity of the fœtal body, might be recognized by the abnormal contour of the tissues. The presence of more than one fœtus in the uterus could possibly be appreciated. That a distinct outline of the individual parts of the fœtal skeleton is to be obtained seems scarcely probable with our present knowledge and the apparatus at present at our disposal. The attempt to obtain information by this method is certainly a justifiable one, as it requires no exposure of the patient, no vaginal manipulation, and puts her to no essential discomfort.

In concluding our account of these studies there are some general observations which may prove of value to clinicians in adopting this method. From Magie's description of the apparatus, it is evident that a well-equipped hospital, lighted by electricity, can readily add to its resources a clinic-room for this investigation. The ten patients whom we examined experienced no discomfort during the application of this process. Where the hand is to be examined, the patient is most readily accommodated in a comfortable chair, with the hand resting upon a table. Where a child's limb is to be investigated, it is best to lay the child upon a comfortable table, and to bandage the sensitized plate upon the limb. We find that surgical dressings, cotton, and the ordinary bandage interpose no essential obstacle to the passage of the rays. The four children subjected to examination by this method gave us no trouble by restlessness, and, after the first crackling noise of the apparatus became familiar, were not in the least disturbed. This method can be readily applied to bedridden patients. It would be necessary to secure a proper holder for the Crookes' tube, so jointed that the tube can be raised or lowered and extended over the body. The patient could be brought to the examining-room in his bed, the sensitized plate bandaged upon the portion of his body to be examined, and the tube suitably adjusted. The services of a practical electrician and of an expert photographer are necessary for the application of this method.[1] The electric current can be obtained from the Edison Lighting Company, and an additional apparatus could be supplied by the hospital. As dry plates are used, the photographer's apparatus need not be elaborate. A small dark-room adjacent to the clinic-room would be required, with running water.

By the use of the skiascope, at the present stage of our knowledge, the fingers and hands are open to limited investigation. During these studies we had occasion repeatedly to examine the bones in our fingers, and to recognize the metacarpal bones. It was also possible to observe the rays coming between the radius and ulna by looking directly through the arm, and to observe the penetration of the rays behind the trachea by placing the skiascope just behind the larynx. A more extended application of this method depends upon chemical and physical research as outlined by Magie.

It is evident, however, that at present we may obtain by this method valuable information regarding the terminal portions of the skeleton, and regarding the contour of various portions of the body. The presence of metallic substances in the body may be demonstrated. It remains for physical laboratories to furnish the clinician with improved apparatus for the further application of this method of clinical research. It remains for the physiologist to supply us with indices to the permeability of the various normal tissues of the body, and for the pathologist to furnish us similar information regarding the effect of the rays upon diseased tissues. So far as our observation goes, bacteria exposed to the action of the rays are not influenced by them.

[1] We desire to express our obligation to Walker & Kepler, electricians, and especially to Messrs. George Teffeau and Redmond, for their kind and efficient assistance in this investigation. We are also greatly indebted to Mr. F. E. Manning and to Mr. John F. Reese, photographer, for constant and intelligent work with us.

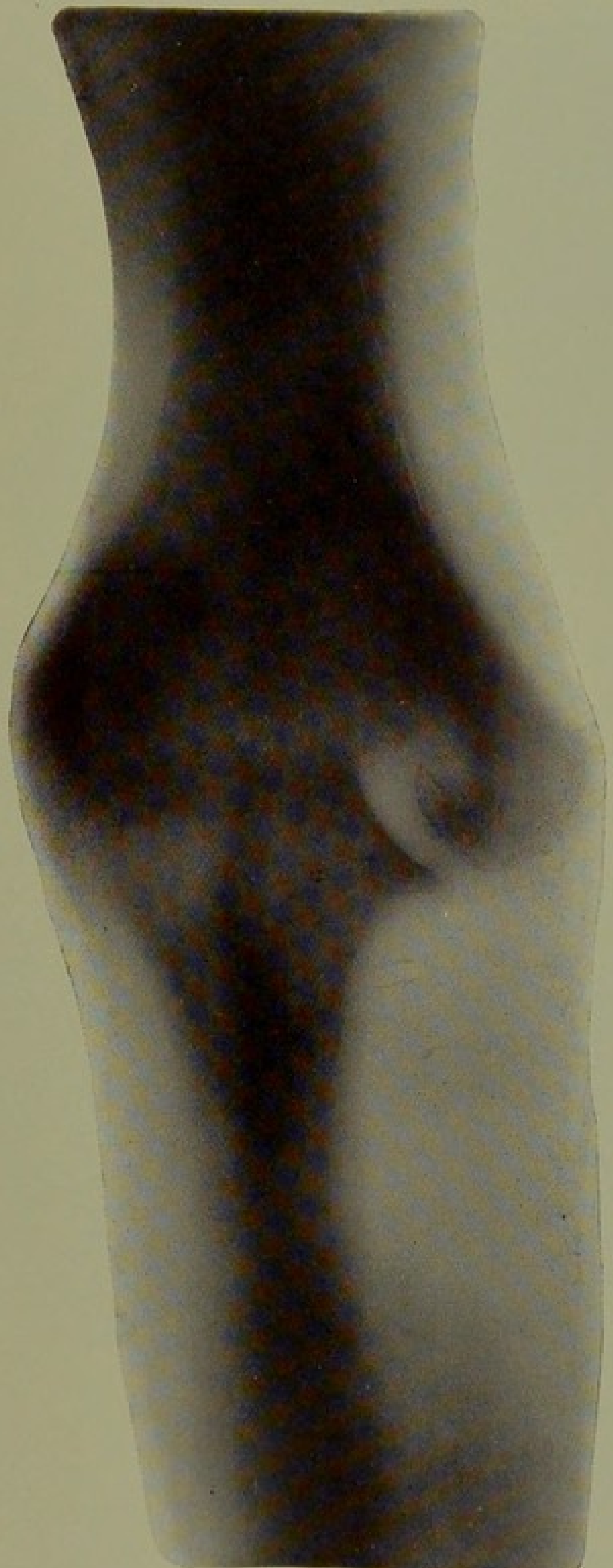
PLATE I.

Hand with anchylosis of all fingers and deformity of little finger from a burn on the dorsum of the hand. Exposure twenty minutes. Carbutt extra sensitive plate.

PLATE II.

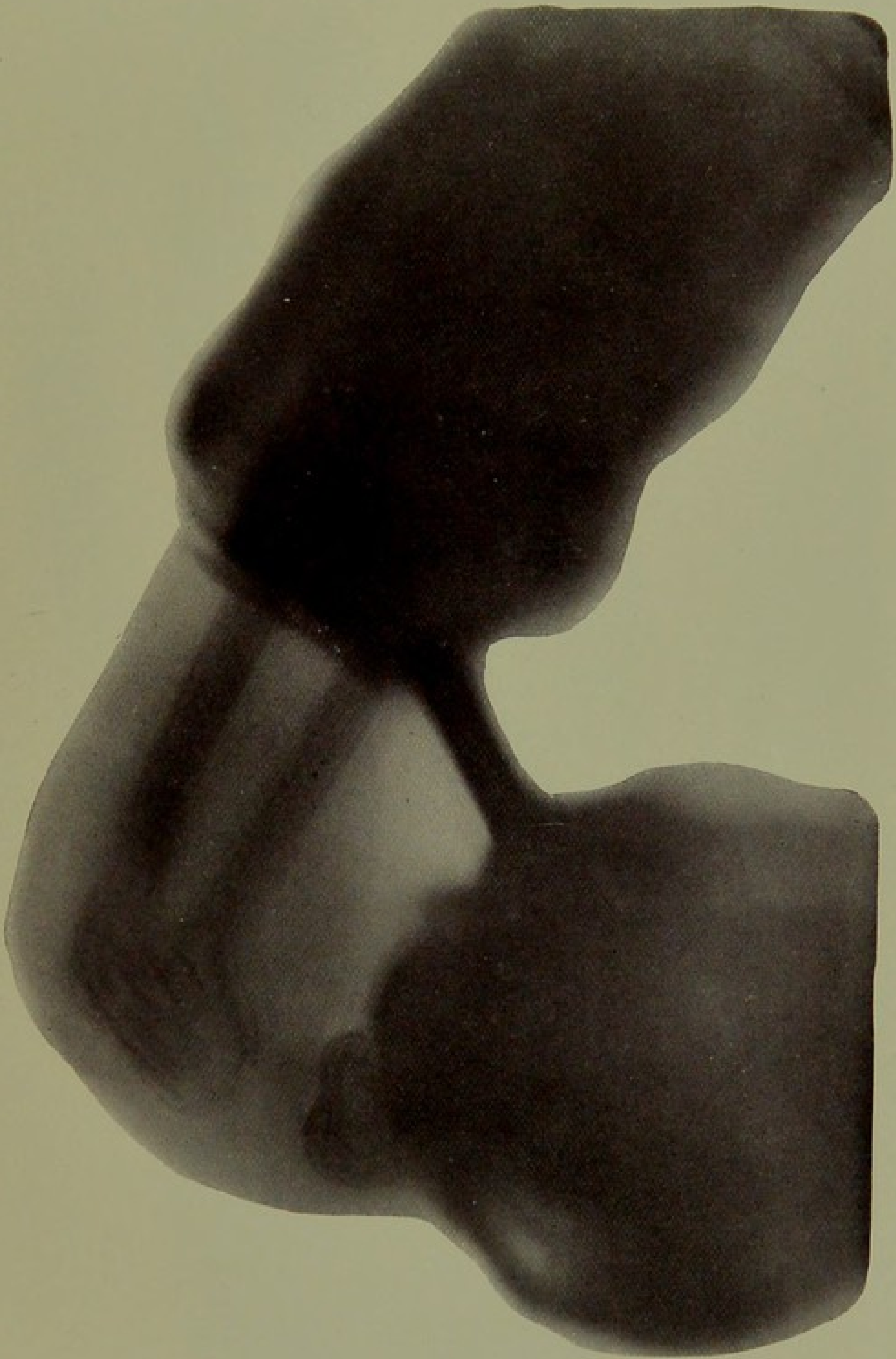
Tubercular disease of elbow-joint. Exposure one hour and twenty minutes.

PLATE III.



Intercondyloid fracture of humerus. Exposure one hour and thirteen minutes.

PLATE IV.



Resection of elbow. Plaster-dressing to arm and forearm, with iron cross-bar between. Skiagraphed through the dressing and bandage. Exposure one hour and ten minutes.

PLATE V.

Hand and wrist of an uninjected cadaver, into palmar aspect ot which a needle and two buckshot were thrust.

The same hand as Plate V., to show the bones of the wrist and forearm.

PLATE VII.

Hand with painful stump of phalanx.

Skiagraph of infant's body.