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Modern Surgery - Chapter 39. Skiagraphy, or the Employment of the Rontgen Rays

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XXXIX. SKIAGRAPHY, OR THE EMPLOYMENT OF THE RÖNTGEN RAYS.

THE cathode rays were discovered by Hittorf, in 1869, while passing an induction current through a vacuum tube. Crookes, of London, greatly improved the vacuum tube, and obtained a rarefaction which left in the tube but the one-millionth of an atmosphere. This last-named observer found that when an interrupted current of high potential is passed through a vacuum which is nearly perfect, fluorescence takes place. In a Crookes tube the positive electrode is placed at some indifferent point, and the current from the negative electrode flows not to the positive, but directly to the wall of the tube opposite the cathode, and at this point the phosphorescent glow is detected.

In 1895, Röntgen, of Würzburg, while making a study of cathode rays as developed in Crookes's tubes, discovered the energy which he named the *x*-rays. Röntgen showed that at the wall of the Crookes tube opposite the negative electrode a new and hitherto unknown energy is generated. Because of the uncertain character of this energy he gave to its manifestation the name of the *x* or unknown rays.

The *x*-rays are invisible; cannot be deflected, reflected, refracted, or concentrated; are not influenced by the magnet; and produce none of the ordinarily recognized effects of heat. They cause fluorescence in certain substances, notably in tungstate of calcium (Edison), platinocyanid of barium (Röntgen), and platinocyanid of potassium. They have a marvellous power of penetration, and pass through many substances which are opaque to sunlight, ultraviolet light, and ordinary electric light. They are readily transmitted by water, organic substances, leather, cloth, paper, and flesh. Bone transmits them less easily, and metal still less easily, but no substance absolutely prevents their transmission. An ordinary dry photographic plate is sensitive to the rays. If the rays are intercepted by a body not readily permeable which is placed between the Crookes tube and the photographic plate, a shadow will be cast, and a picture of this shadow will be formed upon the plate. Such a picture is known as a skiagraph or radiograph. If a body more or less resistant to the rays is placed between the tube and a fluorescent screen, the body casts a shadow on the screen, and the portion of the screen free from shadow glows with fluorescence. Such a screen is known as a fluoroscope. It will thus be seen that the *x*-rays enable the surgeon to look beneath the skin and to see those things which before the discovery of Röntgen were unseeable during life.*

The real nature of the *x*-rays is unknown. They are not heat-rays; they are not ultraviolet rays. Röntgen thinks they are longitudinal ether-waves.

* See particularly Röntgen's report to the Physico-Medical Society of Würzburg, Dec., 1895; also the article upon the *x*-rays by S. H. Monell, in the Brooklyn Med. Jour., May, 1896. "The Röntgen Rays in Therapeutics and Diagnosis," by W. A. Pusey and E. W. Caldwell; "Fractures," by Carl Beck; "The Röntgen Rays in Medicine and Surgery," by F. H. Williams. L. Herschel Harris, in Australasian Med. Gaz., Jan. 25 and Feb. 20, 1902. J. Rudis-Jicinsky, in N. Y. Med. Jour., March 23, 1902. Carl Beck, in Jour. Am. Med. Assoc., Jan. 5, 1901. C. L. Leonard, in Annals of Surgery, April, 1901, and in Jour. Am. Med. Assoc., July 21, 1901.

L. Herschel Harris ("Australasian Med. Gaz.," Jan. 25 and Feb. 20, 1902) says it is generally believed that they are transverse ether vibrations of short period, wave-like in character and produced by a bombardment of the anti-cathode with highly charged molecules from the cathode. Monell says: "They appear to be originated at the site of the greatest electrical activity within the tube, and their real nature is as unknown as the nature of heat, gravity, electricity, mind, and of life itself."

To obtain the rays a good apparatus is essential. An ordinary medical battery is incapable of producing them, as it is absolutely necessary to have a current of high tension. The discoverer used a Ruhmkorff coil, but this is by no means the most satisfactory apparatus to employ. Some experimenters have made use of a "powerful static machine and transformer coils" (Monell). Swinton uses twelve half-gallon Leyden jars and discharges them through the primary coil, the secondary circuit being a Tesla oil coil.

The current is best taken from the street-light circuit. Monell says that this current should be controlled by an interrupter, the interruptions of which are 100 per second. The interrupted current is to be passed into an induction coil, and the secondary current is to be conveyed into the Crookes tube by two wires. The secondary current thus produced will furnish a spark five or six inches long. In order to take a skiagraph of deep structures a high vacuum should be used. For *x*-ray therapy the ordinary tube should not be used because the intensity of the vacuum is too changeable. A tube with a definite or controllable vacuum is required for such work.

When the surgeon is about to use the *x*-rays, he must remove from the person of the individual anything that might cause confusion or lead to error. If the foot is to be examined, remove the shoes, because shoes contain nails; if the hand is to be examined, remove the gloves if they are fastened with buttons of bone or metal; if the thigh is to be examined, remove coins, keys, knives, etc., from the pocket; a garter, if it has a metal clasp, should be taken off.

In order to get the best results from the Röntgen rays, not only must the apparatus be good, but the man who uses it must be expert. Pictures taken by an unskilled man lack clearness of outline, and may even lead to positively erroneous conclusions. Nevertheless, a person used to the employment of scientific apparatus can very soon become sufficiently expert to take fairly clear pictures which should not lead to error. Maurice H. Richardson * maintains that the Röntgen rays can be employed successfully in the routine office practice of a general practitioner.

The surgeon may utilize the *x*-rays by means of a fluoroscope. Edison's fluoroscope consists of four sides of a box, one end being open and made to fit tightly over the observer's eyes, the other end being closed with cardboard made fluorescent by smearing it with mucilage, and, before the mucilage is quite dry, sprinkling it with crystals of tungstate of calcium. If it is desired to examine the hand with a fluoroscope, the extremity is held opposite an excited Crookes tube and from six to ten inches away from it, the end of the fluoroscope which is covered with fluorescent paper is placed near the surface of the hand which is away from the tube, and the observer looks through the other end of the instrument. The flesh seems but a dim haze and the shadows

* Med. News, Dec., 1896.

of the bones are distinctly outlined. The fluoroscope can be easily used, and gives reliable results in studies upon the hands and feet, but when deeper structures are to be investigated, or when absolute accuracy is essential, it is better to take a skiagraph. The value of flouroscopy is constantly increasing as better electrical appliances and Crookes's tubes are being made.

If thick tissues require to be penetrated by the rays, if great accuracy is necessary, or if a permanent record is to be retained, a skiagraph must be taken. In taking these pictures dry plates can be used; the plate need not be removed from its wooden case during the process, and it is not necessary to conduct the proceeding in a dark room. The tube should be from twelve to fifteen inches away from the surface of the body. The plate must be fastened to the surface *exactly opposite* the tube. It is necessary to observe care in the adjustment of the plate, because the *x*-rays travel only in straight lines, and any carelessness of adjustment will lead to curious and misleading aberration in the picture. The length of exposure necessary varies with the thickness of the tissues, the structure of the part, the nature of the body we wish a picture of, and the perfection of the apparatus. The time may be from three minutes to thirty minutes or more. Prolonged exposure is undesirable if it can be avoided, as it may produce an *x*-ray "burn." The use of an improper apparatus or placing the tube too close to the body may be followed by a burn. Occasionally, in spite of the utmost care, injury will be done by the *x*-rays. In treating a malignant growth by the *x*-rays the adjacent healthy tissue is protected from burning by a covering of lead foil.

The so-called *x*-ray "burn" is not a burn at all. A burn is due to the contact of heat, begins upon the surface, is accompanied with pain from the moment of application, and is followed by inflammatory changes, beginning on the surface. An *x*-ray "burn" is not manifest for several days or even several weeks after the application of the rays, at which period an inflammatory or a gangrenous process arises, which begins within the tissues and subsequently involves the surface.* Inflammation may pass away or may eventuate in gangrene, and a gangrenous area is white in color, "leathery, stringy, tough" (Hopkins). Hopkins calls the process "white gangrene."† These burns are often accompanied by loss of hair or nails in the damaged area, they require months to heal, if they heal at all, are very painful, and are not improved by the treatment which relieves ordinary burns. In some cases the consequences are very serious. In a case reported by J. P. Tuttle, it became necessary to amputate the thigh.‡ The lesions occasionally produced by the *x*-rays are probably trophic changes. Sections made by Vissman from Tuttle's case indicated that the lesion was a gangrenous process due to arteritis of the smaller vessels. Various theories have been advanced to account for the occurrence of *x*-ray gangrene, viz.: liberation of ozone in the tissues (Tesla); interference with cellular nutrition caused by static electric currents "induced by the introduction of the patient's tissues into the high potential induction-field surrounding the tube" (Leonard); the destruction of the nerve-supply of the tissue (Hopkins); irritation of the peripheral extremities of the sensory nerves, causing paralysis of the vaso-motors (Rudis-Jicinsky);

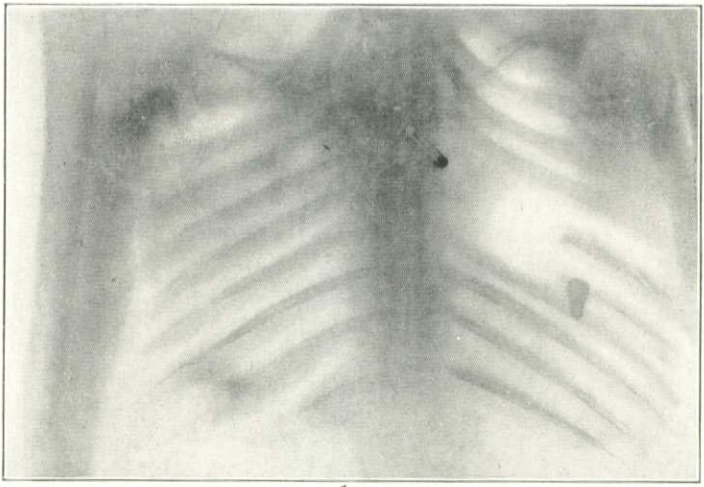
* E. B. Bronson, in the debate on J. B. Tuttle's case, Med. Record, March 5, 1898.
† G. G. Hopkins, Phila. Med. Jour., Jan. 6, 1900.
‡ Med. Record, May 5, 1898.

an electrolytic action of a current generated in the tissues by induction from the tube (Judd). These *x*-ray injuries are most liable to occur when a Ruhmkorff coil is used, and such a condition is very rarely caused by a static machine. Hopkins says the lesions "are produced more frequently by tubes that are energized by alternating currents than by those energized in any other way." He has only found record of four cases produced when a static machine was used. It has been suggested that a thin piece of aluminum, a plate of platinum, or a sheet of gold-leaf, placed upon the part while it is exposed to the *x*-rays, will prevent the occurrence of these injuries.

A recent *x*-ray burn may be treated for a time with vaselin. No irritant application should be employed. In a non-ulcerated area the itching will be allayed and repair favored by a preparation used by Dr. Martin F. Engman ("Interstate Med. Jour.," July, 1903). It consists of 12 drams of boric acid, 1 ounce of zinc oxid, 1 ounce of starch, 1 ounce of subnitrate of bismuth, 1 ounce of olive oil, 3 ounces of lime-water, 3 ounces of lanolin, and 12 drams of rose-water. The powder is rubbed in a mortar, the lanolin is added. The olive oil and lime-water mixed are slowly added to the powder and lanolin. The mixture is stirred, the rose-water is added, and the preparation is beaten into a creamy paste. If itching is severe, 1 to 2 per cent. of carbolic acid is added. The paste is spread on several thicknesses of gauze and the gauze is covered with a rubber dam. When ulceration occurs, dressings of normal salt solution may prove of benefit. Skin-grafting may succeed in remedying an ulceration following an *x*-ray injury; but, as a rule, the grafts do not grow, or if they adhere are very apt to break down after a time. In many cases the best treatment is excision (Powell). Can the *x*-rays cause death? Death may follow a burn without being directly due to it. There are 4 reported cases in which death followed *x*-ray burns, but in not one case is it certain that the burn was directly responsible (Rubel, in "Jour. Amer. Med. Assoc.," Nov. 22, 1902).

The uses of the *x*-rays are legion. They are of the greatest possible value in the location of foreign bodies, especially bodies of metal, glass, or bone, such as bullets, and needles, glass, splinters, etc. Bullets are readily detected in the extremities; have been found in the lung-substance and bronchi (Rowland), in the brain (Schier, Brissaud and Londe, Keen and Sweet, Henchen and Sennauer, Bruce, Willy Meyer), in the abdomen, the pelvis, a joint, the spine, and the eye. The *x*-rays will enable us after an abdominal operation to locate a Murphy button and tell when it has loosened and descended. Foreign bodies, especially if metallic, in the esophagus, stomach, intestine, and air-passages; enteroliths and mineral calculi in the salivary ducts, bladder, ureter, and kidney can be detected. Henry Morris tells us that a calculus in the kidney may exist and yet escape detection with the rays, because the kidney is very deeply placed, is under the ribs and close to the vertebral column. Occasionally a drainage-tube lost in the pleural sac may be discovered. Most observers state that gall-stones cannot be skiagraphed in the living body. Cattell has succeeded in one case and Carl Beck has succeeded.* The rays may fail to disclose a foreign body because of its being overshadowed by a bone (Carless), but prolonged exposure or the taking of another picture with the part in another position will bring it into view. In many cases a

*N. Y. Med. Jour., Jan. 20, 1900.



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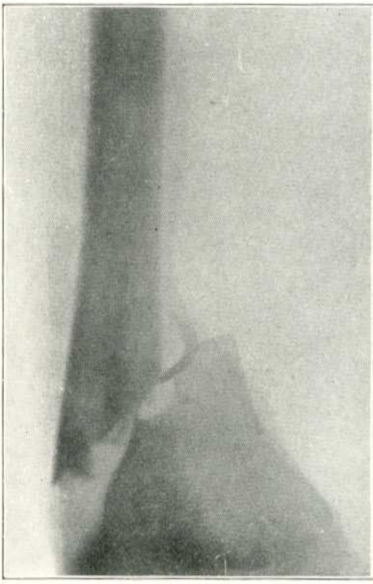

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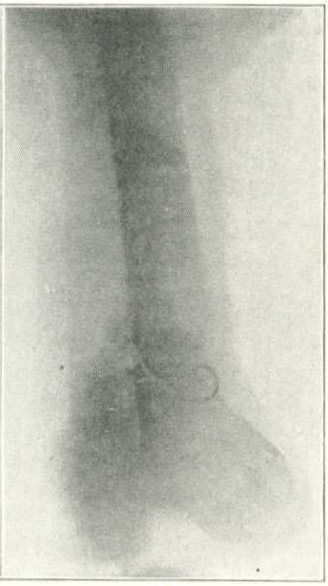

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1. Gunshot-wound of the Lung. Rib-resection for secondary hemorrhage into the pleural sac ten days after the injury; bullet not removed. Hemorrhage arrested by packing with gauze. Skiagraph taken three months afterward shows the bullet. (Author's case.)

2. Fracture of Lower End of the Femur. Reduction of fragments impossible because of the interposition of a loose piece of bone and much muscle between fragments. (Author's case.)

3. Case shown in Figure 2, Three Months after the Operation of Wiring. Nine months after operation, the man is walking about with ease, and the wire is still in place.

(The above skiagraphs are from the X-Ray Laboratory of the Jefferson Medical College Hospital.)

skiagraph does not indicate how deeply in the tissues a foreign body lies, or upon which side of a bone it is lodged.* If there is doubt, take several pictures from different positions (triangulation), skiagraph over a surface marked in squares, insert guide-needles into the tissues before taking the final picture, or employ Sweet's apparatus. Sweet's apparatus has been used successfully for the location of foreign bodies in the eye, but a modification of the original apparatus has recently been used to skiagraph other regions of the body. Sweet's apparatus is used as follows:† "The essential features of this apparatus and the method of employing it are shown in the illustration (Fig. 650). An adjustable arm carries two ball-pointed rods which are at a known dis-

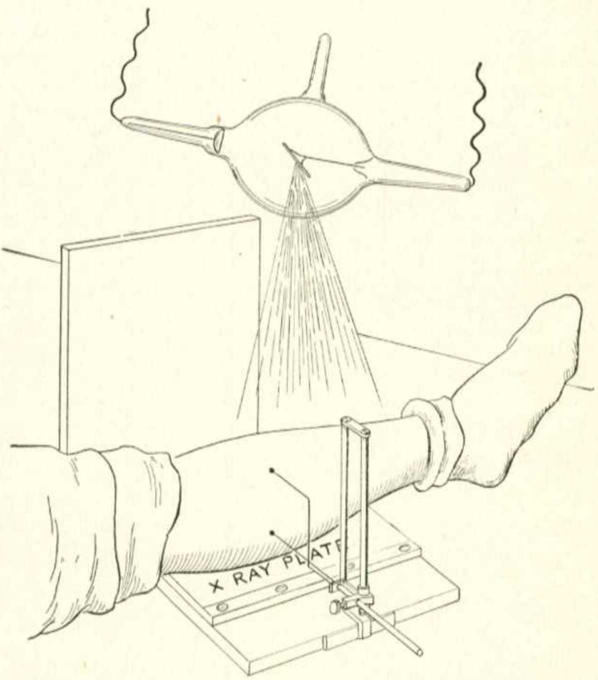

Fig. 650.—W. M. Sweet's *x*-ray apparatus for locating foreign bodies.

tance apart, and are parallel with each other and with the photographic plate, while the balls are perpendicular to each other and the plate.

"When the skiagraphs are made, one of the indicator-balls rests against the skin at any point in the neighborhood of the foreign body, while the second indicator is toward the plate. The spot on the skin at which one of the indicator-balls rests is marked with silver nitrate, as the position of the foreign body is measured from this point.

"Two skiagraphs are made to give different relations of the shadows of the two indicators and the bullet, one exposure with the tube horizontal, or nearly so, with the plane of the indicators, and a second exposure with the tube at any distance above or below this plane. Since the shadow of the

* Battle's case in Lancet, Feb. 29, 1896.
† W. W. Keen, in Phila. Med. Jour., Jan. 6, 1900.

A

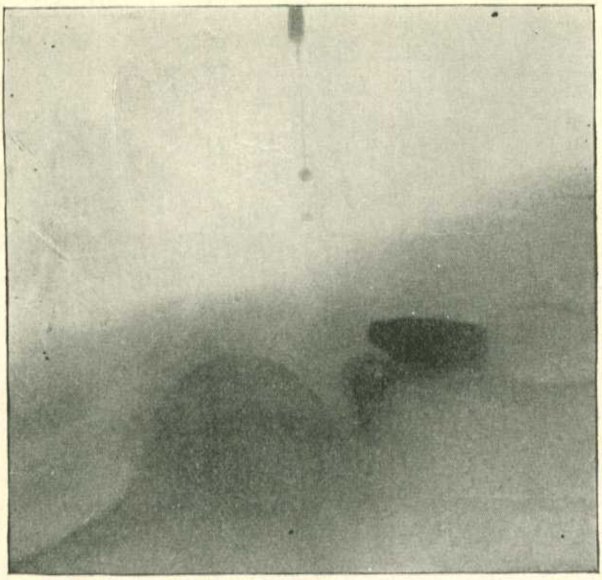

Fig. 651.—Skiagraph made with tube horizontal to plane of indicators. The bullet is well seen. Opposite *A* are seen the two balls at the ends of the rods.

A B

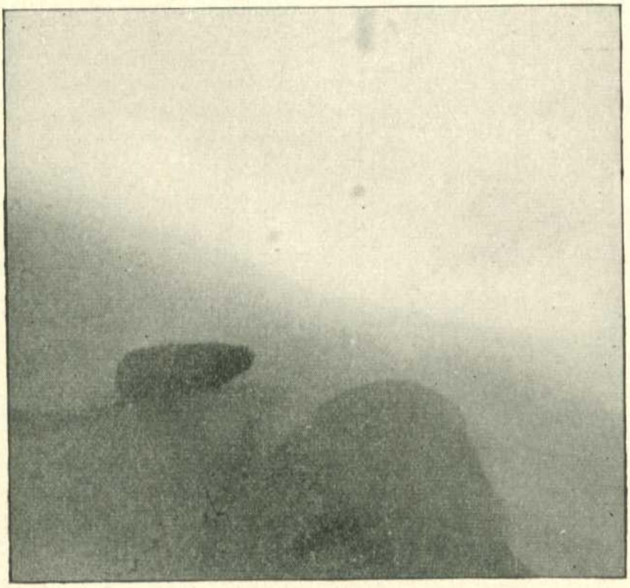

Fig. 652.—Skiagraph made with tube above horizontal plane of indicators. The bullet is well shown. Opposite *A* and *B* are seen the two balls at the ends of the rods.

foreign body preserves at all times a fixed relation with respect to the shadows of the two indicator-balls in whatever position the tube is placed, and since the situation of the two balls is known, the location of the foreign body in the tissues is readily determined from a study of the planes of shadow at the two exposures.

"When the skiagraphs of the case here reported were made, the anterior surface of the leg was placed upon the bottom of the right-angle support of the apparatus, the plate to the inner side of the knee, one indicator-ball resting on the skin nearly in the center of the popliteal space. The skiagraph made with the tube horizontal with the plane of the indicators is shown in Fig. 651, and the second skiagraph with the tube a short distance above the first position is seen in Fig. 652. Both negatives show the leg as viewed from the outer side, with the posterior surface of the leg uppermost.

"In determining the position of the bullet a spot is made upon paper to indicate the point on the skin at which one of the indicator-balls rested at the time of the exposure, a second spot being made two inches from the first, to represent the fixed distance between the two balls. These are shown at *A* and *B*, upper diagram, Fig. 653. The first negative is now taken. The distance the shadow of the bullet is below the shadow of each of the two indicators is measured, and this distance entered below the spots representing the two balls when the exposure was made (*C* and *D*). A line drawn through these points indicates the plane of shadow of the bullet when the first skiagraph was made. Similar measurements are made from the second negative and marked below the spots *A* and *B*, the line through the spots (*F* and *H*) giving the plane of shadow when the second negative was made. Where these two planes of shadow cross (*X*) is the position of the bullet as measured below, and to the inner side of the nitrate of silver spot on the skin.

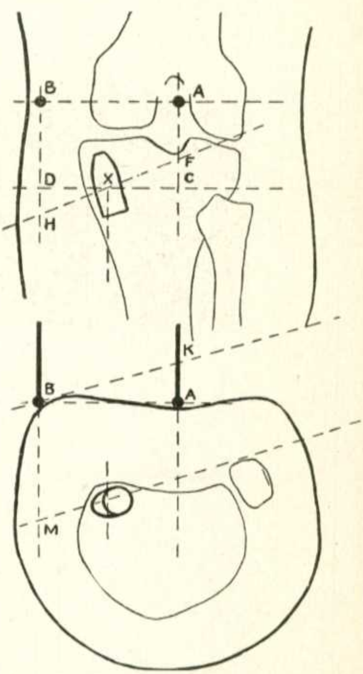

Fig. 653.—Method of indicating location of bullet. Upper diagram, posterior view of leg from above. Lower diagram, cross-section of leg, near knee-joint.

"In determining the depth of the bullet in the tissues, a second diagram is made to indicate the position of the two balls, as viewed from a cross-section of the leg. Since the tube was only twenty-four inches away at the time of the exposure, the convergence of the rays in an object as large as the leg must be allowed for. This is done by measuring the distance the shadow of one ball is behind that of the other, entering this distance (*A K*) on the diagram, and marking on a line through this point, twenty-four inches from the ball resting on the skin, the situation of the tube. If we now measure the distance the shadow of the bullet on the first negative is back of that of the shadow of the ball on the skin, enter this distance in the plane of this indicator (*B M*), and draw a line from the situation of the tube through this point, we obtain the plane of the shadow of the bullet when the exposure was made. Drawing a line from the position of the bullet as previously found on the first diagram, the intersection of this line with the plane of shadow upon the second diagram gives the situation of the bullet from a cross-section view of the leg. For purposes of greater clearness, outlines of the leg have been shown in the two diagrams, although this is unnecessary in practice, since the position of the foreign body in respect to a known point upon the integument is all that is required. The position of the bullet was shown to be one inch toward the inner side of the spot on the skin at which one of the indicator-balls rested, one and a quarter inches below this spot, toward the ankle, and embedded in the tissues to the depth of one and a half inches. Both skiagraphs show the bullet close to the bone, but, owing to the false projection, so common in all *x*-ray pictures, it is impossible to say whether the bullet was embedded in the bone or not." Morris tells us to be somewhat skeptical in accepting unreservedly the evidence offered by a skiagraph, as slight carelessness in taking the picture may mean great distortion and consequent error.

In detecting fractures and dislocations the Röntgen rays are of great value, especially when there is much swelling, when there is little displacement, and when the fracture is in or about a joint. The rays enable us to determine the nature of the injury, the amount of splintering, the existence of impaction, the question whether or not the fragments are in contact and can be brought into contact; the direction of the line of fracture, the variety of deformity, the existence of more than one fracture, the presence of epiphyseal separation or dislocation alone or with a fracture, the existence of an ununited fracture, and the question if the splints are holding the fragments in accurate apposition. Fractures of the skull, if involving both tables of the vault, may be recognized; it is possible that fractures of the inner table may be found; fractures of the base can be seen, but with difficulty. Fractures of the spine can be skiagraphed, but never show very clearly. To take a picture of a fractured rib, first limit chest-motion by bandaging (White). The *x*-rays may be of value in enabling the surgeon to recognize rheumatoid arthritis; bone- and joint-tuberculosis (the tuberculous area being lighter than the sound bone); the amount of acetabular rim present in congenital dislocation of the hip-joint (Rowland); the state of the bones in a crushed limb (J. Hall Edwards); bone deformity; osseous tumors; bone displacement (as in Morton's foot); osteomyelitis; caries; necrosis; and osteosarcoma. By skiagraphy we are enabled to decide on the proper situation to perform osteotomy, and if a deformity of the foot can be amended without operation (Willard). The position of the fetus in utero can be definitely made out.

Applied to the soft parts, the new process has obtained interesting but not as yet many practically useful results. Fibrous tumors can be seen, but malignant tumors, unless they contain calcareous or fibrous elements, cannot be definitely made out; loose bodies in a joint can often be detected. The shadow of the heart can be made out, and the outlines of the diaphragm, kidney, and liver can be thrown upon the screen. If the stomach is distended with gas, it shows as a light area upon a dark background (Hedley). If food is eaten after being mixed with subnitrate of bismuth, the outline of the viscus becomes fairly distinct. Thickened pleura, pleural effusion, pulmonary consolidation, abscess of the lung, pericardial effusion, aortic aneurysm; cavities in the lungs, and atheromatous blood-vessels may be made out with more or less distinctness. If a sinus is injected with iodoform emulsion, a picture of it can be taken, because the emulsion casts a shadow when placed in the path of the *x*-rays (J. Hall Edwards).

The X-rays in Malignant Disease.—Of late the surprising fact has been demonstrated that *x*-rays may alleviate, or even, it may be, cure, malignant disease. So far it does not seem likely that internal cancer can be notably affected, although even in these cases the rays seem to lessen pain. Surface epitheliomata may entirely disappear and enlarged lymphatic glands associated with epitheliomata sometimes shrink up and pass away. In two dreadful cases of inoperable and recurrent cancer of the face with extensive lymphatic involvement in which the rays were used I have seen apparent cure result. Unfortunately, the cure is more apparent than real, and in every case which I have watched the growth has begun again after weeks of apparent immunity and has progressed with fearful speed. Nevertheless, it is most important to know that we have a remedy which relieves pain even in advanced cases, lessens bleeding and discharge, and which will often for a time arrest the ravages of this fearful malady, prolong life, and add to comfort when nothing else is of avail. It may be that with increase of knowledge we may learn that an apparently cured case can be kept well by the continued use of the rays from time to time. Francis H. Williams says that for this work a good-sized static machine or coil is needed and the spark-gap should be adjustable. If the growth is superficial, a tube of low resistance is used; if it is deeper, one of high resistance is employed. The tube is placed in a holder, the interior of which is painted with white lead. A screen of lead is used to reduce the cone of the rays to a size but little larger than that of the area to be treated. If cavities are to be treated, the rays are passed through a cylindrical speculum of glass, which is surrounded by a sheet-tin shield.

At each sitting the exposure is from five to ten minutes in the beginning, but later it may be increased to twenty minutes or more. Three or four exposures a week are given. Williams points out that a rapidly growing tumor should receive an exposure of not more than five minutes; and that if, a day or two later, there is pricking and slight irritation, these signs should be regarded as distinctly favorable (Dr. Francis H. Williams, before the New York Academy of Medicine, March 6, 1902; reported in the "Med. Record," March 15, 1902).

It may be very quickly determined whether the *x*-rays will help the patient or not. For instance, if an epithelioma is going to be benefited, it will begin to show improvement within two weeks.

Some observers have maintained that the beneficial effects are due to burning with the *x*-rays. Dr. Carl Beck thinks that they are obtained only when the integument alone is involved. Dr. A. G. Ellis ("Amer. Jour. of Med. Sciences"), from a series of studies made in the laboratories of the Jefferson Medical College, has reached the conclusion that endarteritis is induced by the *x*-rays; but that, as the accompanying tissue-necrosis is out of proportion to the vascular changes, it is possible that the necrosis does not result from the vascular changes, but that each condition results from the same influence. He has further concluded that the *x*-rays do not possess any definite germicidal power. Some observers attribute to actinic action the tissue-changes wrought by the *x*-rays; others, to phagocytosis and leukocytosis. It is certain that the *x*-rays are irritant and tend to produce inflammation. In an inflamed area stasis occurs and about an inflamed area leukocytes gather. Hence, degeneration may occur or actual sloughing take place. The embryonal cells of cancer are acted upon more strongly than normal tissue-cells. Sarcoma is not so apt to be benefited as carcinoma.