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THE PRINCIPLES AND PRACTICE OF THE
LOCALIZATION OF FOREIGN BODIES

BY X RAYS.

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[WITH SPECIAL PLATE.]

SOME recent experiences have led me to realize that sufficient attention is not always paid to the methods which must be followed by the surgeon in order to interpret correctly the information which *x* rays, properly applied, can afford with regard to the precise position of a foreign body. At the present time, when such large numbers of wounded are returning from the seat of war with bullets, fragments of shrapnel, etc., embedded in their tissues, it seems advisable that the writer, who has had many years of experience in *x*-ray localization, should put on record certain methods which are likely to be of some special service in existing circumstances.

THE MISLEADING SINGLE RADIOGRAPH.

At the risk of being too elementary, it may be remarked, what sometimes appears to be forgotten, that space has three dimensions, and that an *x*-ray picture on the fluorescent screen or an *x*-ray photograph is merely a shadow or silhouette. This single shadow-picture tells us little more than that a foreign body is present, and gives us no certain knowledge about its relation to the surrounding structures. Indeed, if these limitations are not realized, the *x*-ray method becomes a positive danger to the patient as well as to the surgeon. Almost every surgeon has experienced the annoyance and disappointment brought about by failure to find, even after a prolonged search, the bullet or needle which was shown to him so clearly in a single *x*-ray photograph. Quite recently the writer had brought to his notice the case of an officer who had undergone an operation of nearly three hours' duration for the extraction of a shrapnel bullet, which even at the end of that time could not be found. It had been photographed several times, and was supposed to have been localized by a layman. When, however, the case had recovered from this quite unnecessarily prolonged operation and the bullet was again localized—this time properly and precisely—the same surgeon cut down upon it, and removed it through a small incision in a space of time not longer than three minutes.

A very simple illustration may be given of the different kind of *x*-ray picture which may be produced showing, say, the relation of a bullet to the femur, by a shift in the position of the tube. The femur, for the purposes of this illustration, is supposed to be maintained in an upright position, and behind it, a little removed, is suspended a bullet. The bone is held close to a sheet of opal glass, or against a white wall, and an ordinary candle or a small electric lamp may be used to cast a shadow of these objects, this light representing the *x*-ray tube. If, now, the candle is held horizontally, level with the bullet, and a little to the left, the bullet may be made to appear as in Fig. 1, *a*. If the candle be

lowered in position, then the bullet appears as in Fig. 1, *b*, and if the source of illumination be moved to the right, we get the picture shown in Fig. 1, *c*. Now, these apparent positions of the bullet in relation to the bone, all of them different, do not show, even approximately, the actual position which the bullet occupied in relation to the femur. This seems so simple and obvious that one feels diffident to describe it, and yet many times I have seen my colleagues, on looking at an *x*-ray photograph, imagine that they see at once exactly where the foreign body is situated, at the same time describing what is only its apparent position. Having said so much as to the misleading inferences which are liable to be drawn from the study of a single *x*-ray photograph, it becomes necessary to describe some methods of overcoming the difficulty, and to demonstrate what very precise and useful information may be obtained if only sufficient care and attention are bestowed upon the subject.

In a recent paper on "The Wounded in War,"¹ Mr. D'Arcy Power, after pointing out the difficulty which arises from the fact that the patients are strong muscular men, adds: "The shadow only gives an approximate idea of the position and depth of the projectile." Again, in a recent clinical lecture² Sir John Bland-Sutton relates a case in which an *x*-ray examination revealed a bullet lying in relation with the internal condyle of the left femur. "It required several plates to determine accurately whether the bullet was lying in front of or at the back of the bone. . . . When the parts were exposed in the course of an operation the bullet was found firmly embedded in the condyle near the adductor tubercle." With the adoption of a precise system of localization, such as has been in vogue for many years, the idea furnished with regard to the position and depth of the shadow would not have been approximate but exact, nor would it have been necessary to use "several plates" to determine accurately whether the bullet was lying at the front of or at the back of the femur.

The general subject of *x*-ray localization is too wide for the limits of this paper, and only the most sketchy description of the method can be given. At the present time, when so many wounded have to be examined, it is essential that the method employed should be as speedy as possible compatible with accuracy. Unnecessary refinements, therefore, shall be eliminated in the course of this description, and the attempt shall be made to fix attention upon the points which are really essential. Nothing need be said about the *x*-ray apparatus such as coil, tube, and interrupter, as these remarks are intended for those who are already familiar with the electrical installation.

Fig. 1.

THE X-RAY COUCH.

Whatever method is adopted the first essential is to have some means of determining the exact position of the point of emergence of x rays from the tube in relation to the patient's body. The most convenient plan, when dealing with large numbers of wounded, is to have some form of couch or stretcher on trestles which enables the tube to be placed below the patient. In this way a screen examination can be made conveniently; the photographic plate also, being placed upon the patient, is not subject to the damage which might occur from pressure if the plate were placed below the patient and the tube suspended above. The details of the couch can be varied, of course, according to the means and the desire of the worker, but, generally speaking, I should advise some arrangement of rails running below the couch for its whole length and upon the carrier, some short rails at right angles to the others, which would allow the holder or box supporting or containing the x -ray tube to be moved from side to side. By this arrangement the tube can be moved readily up and down and also crosswise, and thus brought into any desired position beneath the patient. The vertical position of the x -ray anode may be determined most conveniently by means of an attachment consisting of some form of upright to the tube holder or box, so that they move together. This upright, which may project 3 ft. or 4 ft. above the couch, is furnished with a horizontal arm, and a slot and thumbscrew provide for its adjustment on the top of the upright.

One of the simplest methods for carrying out the whole of this arrangement takes the form of a structure such as can be made by any carpenter. At the top of each of two trestles a couple of V-shaped notches may be cut so as to admit the poles of an ordinary army canvas stretcher. This stretcher being placed upon the trestles, we have the rudiments of the x -ray couch. Two thin pieces of wood, sufficiently long to stretch between the bases of the trestles, are then placed on the floor below, each of them having a raised V-shaped ridge which forms a line of rails. A flat board, having along its under surface a couple of indentations so as to fit upon the V-shaped rails, is then placed upon these parallel pieces of wood and made to slide up and down, thus corresponding with the length of the couch above. The use of French chalk makes the sliding very easy and smooth. Upon this board two other lines of V-shaped rails, this time horizontal, carry the tube-holder or box at right angles to the long axis of the couch. By this arrangement of ridges and grooves, and both a lengthwise and a crosswise movement, the tube can readily be placed at any desired spot under the patient. If the top of the couch is movable, a plumb-bob, dependent from the arm of the upright, can always be arranged so as to be vertically above the anode, and as the upright above and the tube below have a single movement, this device is quite close enough for the ordinary localization of large foreign bodies.

If, however, it is desired to be very accurate, one can have cross wires arranged horizontally across a small celluloid vessel, like a powder box, and suspend a small plumb-bob from the intersection of the wires. It is convenient to put a little paraffin or glycerine at the bottom of this vessel so as to steady the plumb-bob very quickly. If this is placed upon the couch, with a small fluorescent screen on the top of it, and the tube is excited, it is a matter of a few seconds to move it into position so that the shadow of the plumb-bob comes to be vertically below the intersection of the cross wires. It is then left in this position, and the plumb-bob attachment from above the couch adjusted to be vertically over the cross wires. Such an adjustment having once been made, it remains constant unless disturbed. With the couch more or less on a level surface the plumb-bob invariably indicates the path of the vertical ray passing through from the x -ray tube beneath. Once a couch of this sort is obtained, it is extraordinarily useful in a variety of ways to enable the position of foreign bodies, etc., to be ascertained with extreme accuracy.

STEREOSCOPY.

The enormous advantage of stereoscopic x -ray photographs is that they give a realistic view of the true and relative positions of all the parts concerned in the picture.

The method of taking a stereoscopic picture with a couch such as has been described is exceedingly simple. Having decided the point of view from which the x -ray picture is to be taken, one brings the plumb-bob vertically over the spot, places a photographic plate (in its cassette or black envelope) upon the patient's body in such a way that the edge of the plate is parallel with the side of the couch, marks with a skin pencil the outline of the plate upon the patient's body, and makes the one exposure. The tube is then displaced for the stereoscopic distance; it is of no consequence whether the displacement takes place on the length or on the breadth of the couch, the matter being one purely of point of view. A simple plan adopted by the writer is to place a little block of wood, exactly 6 cm. in length, against the carrier, then to hold up against its edge another block of wood, remove the first and slide the carrier up against the second, which is held firmly by the hand. This ensures an accurate displacement of 6 cm. Another plate is then placed in exactly the same position on the patient as was the first, and an exposure made. These two plates are developed, and the combined image is truly stereoscopic.

Various methods are available for viewing the stereoscopic result. One of the most convenient is the examination of the plates in a Wheatstone stereoscope, but if there is time it is much more satisfactory to have them reduced to the ordinary stereoscopic slide size ($6\frac{3}{4} \times 3\frac{1}{4}$ in.), and the slide can then be viewed in an ordinary lenticular stereoscope. In this form it is very convenient for the surgeon to look at it during the operation if he wishes to do so. For purposes of localization, an additional advantage is obtained by placing fine fuse-wire on any part of the skin, say on the wound of entrance of a bullet, or on a scar; or in some cases bismuth compound can be applied to the skin as an ointment, which has the effect of making it visible, and by this device the relations of the skin markings to the deeper parts can be readily seen, and the surgeon's work facilitated.

PRECISE LOCALIZATION.

For more precise localization in which exact measurements can be obtained, it becomes necessary, of course, to make certain special arrangements. If the maximum amount of accuracy and information is desired, the method which the writer devised and described seventeen years ago³ will meet the case. It depends upon the use of cross wires. Having decided what part of the body has to be examined, one places upon the skin of the patient as he lies on the couch a frame carrying thin cross wires at right angles to each other. One of these wires runs parallel to the length of the couch and the other to the breadth. The position of these wires is traced on the skin with nitrate of silver, so that the position they occupy leaves a permanent mark, then the distance of the anode to the plane of the cross wires is accurately ascertained and noted. This can be done with ordinary inspection by means of a foot-rule, one end of the foot-rule being placed on a level with the central point of the anode of the tube, and the height of the cross wires above this point being read off. Sometimes it may be more convenient to fasten the wires on the patient's skin with plaster. The next procedure is to adjust the plumb-bob carefully so that it falls upon the intersection of the cross wires, and, as a further assistance, fuse wire in the shape of an arrow can be placed upon the wound of entrance, or a wire circle placed upon the wound of exit, or a similar indication upon any landmark one may wish to note. The plate is then laid upon the top of the cross wires and a photograph taken, care being taken in the meantime that the patient does not move in the slightest degree. The tube is displaced in the manner already described when dealing with the purely stereoscopic aspect of the subject, and the displacement is of the same extent—namely, 6 cm. from the former position, either along the couch or across the couch. It is advisable in the notes of the case to record in which direction the displacement was made.

When these photographs are developed, each of them shows white lines corresponding to the position of the wires. As these were closely in contact with the plate, they suffer no displacement—that is, there is no effect of parallax—but all other objects, in accordance with their distance from the plate, do suffer more or less displacement. It should be pointed out, in the first place, that

SIR J. MACKENZIE DAVIDSON: LOCALIZATION OF FOREIGN BODIES BY X RAYS.

FIG. 5.—Captain D., wounded by a shrapnel bullet in the right arm. The loop in the looped wire marks the wound of entrance. The length of this looped wire indicates the length of the incision the surgeon made in order to extract the bullet. The bullet was considered to be embedded in the humerus. The x ray (photograph A) is one of a pair of stereoscopic plates which showed the bullet to be far back behind and quite outside the humerus. To confirm this the patient's arm was abducted and another stereoscopic pair of x-ray pictures taken. One of these is reproduced (B), a single wire being placed on the scar of the operation wound to mark its position. It was obvious that the bullet was in the axilla. It has since been extracted.

The skiagrams well illustrate the misleading appearances that result from a single x-ray picture. The bullet appears larger in A than in B, because in A the plate was placed in front and the tube behind the patient; the bullet being further away from the plate produced a larger shadow than in B, where the plate was placed behind and the tube in front.

FIG. 6.—Skiagram of a case in which a German rifle bullet entered at a point marked by the lower point of the wire (X), and lodged on the inner side of the bone point downwards. This is one of a stereoscopic pair which clearly showed the position of the bullet in relation to the bone and teeth.

SIR J. MACKENZIE DAVIDSON: LOCALIZATION OF FOREIGN BODIES BY X RAYS.

FIG. 7.—Stereoscopic skiagram of a case in which a shrapnel bullet entered at the back of the neck below the left mastoid. The position of the wound of entrance is marked by wire. The bullet lodged between the vertebrae and pharynx. The patient could only swallow fluids, and these only with much difficulty. The bullet was precisely localized, and removed by Sir William Bennett. The patient is now quite well. Viewed in the stereoscope the plate shows the position of the bullet in relation to the bones.

FIG. 8.—Stereoscopic skiagram showing a shrapnel bullet lodged near the left hip-joint. It was precisely localized, and was removed by Mr. English, who was assisted by the use of a telephone attachment to his instruments. Viewed in the stereoscope the plate shows a picture in relief.

these negatives are stereoscopic, and when viewed stereoscopically they show the cross indicating the level of the skin, and all the other parts in their true relation to it. But, apart from this, it is very simple to ascertain by measurement the exact position of any foreign body or bodies, and also the size of the foreign body, the direction or angle in which it is lying in the tissues, and its distance from the skin, and from each cross wire, and from any other points which may be required.

The method of interpreting these negatives may now be briefly described. A tracing paper, or tracing sheet of gelatine, has cross lines drawn upon it. One of these negatives is held up against a light source, and the tracing sheet is placed preferably upon the glass side of the negative, with the cross lines in accurate register with the white image of the cross lines on the negative. This position can be maintained with little pieces of rubber plaster while the bullet or other object is traced with pencil. A similar procedure, on the same tracing paper, is carried out with the other negative, and it is convenient to use black pencil for the tracings in one instance, and red pencil in the other. In this way one obtains on the tracing sheet a single cross with duplicate tracings of the bullet, the outlines being displaced as between the two negatives, in accordance with the direction of previous displacement of the tube.

THE CROSS-THREAD LOCALIZER.

In order to enable measurements to be made by reconstructing geometrically the conditions of the exposure, an instrument devised by the writer, and called the cross-thread localizer, is employed.

The principles upon which it depends are illustrated in the accompanying diagrams, reproduced from my paper published in the issue of the JOURNAL for January 1st, 1893. The negative is placed under exactly the same conditions as it occupied when it was being taken, and the part of the x rays which produced the negative is ascertained in the following way: In Fig. 2 the negative is seen lying on a table with its glass side uppermost; above the table is fixed a scale at a height equal to that at which the anode was when the negative was taken. Silk threads are introduced into notches in the scale 6 cm. apart, and kept taut in the notches by small weights. The other ends of the threads are threaded into fine needles weighted by being fixed into small lead weights in shape resembling a mouse (m , m , Fig. 2).

Fig. 2.

Now these threads can be used to show the path of the x rays which produced the negative. Suppose we are dealing with a needle in some part of the body. On looking down on the negative we find two needles, and it is not difficult to see that as the Crooke's tube was displaced horizontally in a line running right and left, the shadow of the needle to the left was produced by the tube when displaced to the right, and *vice versa*. Thus, if we place one of the threads on the point of the needle in one shadow correctly, it will indicate the path of the x ray that produced the shadow of the needle point (P, Fig. 2). Now, if the other thread is placed on the corresponding point of the other needle shadow (P', Fig. 2), then it must follow

C

that the position actually occupied by the point of the needle in question is precisely where the two threads cross at *c*, in Fig. 2.

If we can measure the perpendicular distance of a point from three planes which are at right angles to each other—in short, if we can get the x , y , and z , we then know all about the position of the point in question. This we can do at once for the point c in Fig. 2. First, the vertical distance from the negative to where the threads cross each other is measured. This is the distance of the point of the needle beneath the skin (of the patient), which rested on the photographic plate. We can measure this with an ordinary pair of compasses, or with a surface gauge. The small arrow (Fig. 2) indicates the marked quadrant, and 1, 2, 3, 4 mark the corners of the negative.

We next measure the vertical distances from the two vertical planes represented by the shadows of the cross wires to the

Fig. 3.

point where the threads cross. An upright square is placed with its edge coincident with the shadow of one of the wires, and the perpendicular distance is measured with compasses from it to the point where the threads intersect. We have now obtained our x , y , and z of the point of the needle, and we note the result down as shown in Fig. 3. The arrows in Fig. 3 indicate the direction of the displacements of the Crookes's tube. We then proceed in a similar manner to ascertain the position of the eye of the needle (c' in Fig. 2), and the distance between c and c' in Fig. 2 gives the direction and actual length of the needle.

From the measurements jotted down, as shown in Fig. 3, we can mark a line on the patient's skin in the same plane as the needle, and give the surgeon the exact depth at which each of its extremities can be reached by a vertical puncture.

The apparatus I now use consists of a small flat table surface, which again has the two black lines drawn upon it at right angles to each other. From the middle of one of the sides of this table there rises a sliding upright, with clamp, which can be used at any desired height. This is really a T-piece, and the arm reaches above the middle of the table. A central notch on this arm is adjusted so as to be exactly above the point where the two lines intersect below, and on either side, at distances of 3 cm. from this central notch, are two other notches, which in their distance from each other represent the distance of the tube displacement. The tracing is placed flat upon the table, with its cross lines in register with those already marked on the table, and the central notch of the T-piece is adjusted by means of a plumb-line to be exactly the same distance from the intersecting point below as was the anode of the tube from the centre of the cross wires when the photographs were taken.

As x rays travel in straight lines from their point of origin to their destination, the path of any ray can be conveniently traced by means of a stretched thread. Accordingly two slightly weighted silk threads are passed in the little side notches on the T-piece, 6 cm. apart, and are attached to weighted needles on the stage below. In this way they can be used to trace any ray as desired. To take an example, one of the simplest cases is that of a round bullet, represented on the tracing paper by a couple of outlines side by side. It is evident that the outline to the left must have been produced by the tube when it occupied the right-hand position, and vice versa. The thread from the right notch, therefore, is brought down to a point on the tracing which represents the left-hand shadow, and the thread from the left notch to a corresponding point on the tracing which represents the right-hand shadow. It follows that the foreign body, or

the part of it thus indicated, must have occupied a position corresponding to some point along the line of these threads, and the actual position is immediately denoted by the point where the threads intersect. The distance from the tracing below to this point of intersection above furnishes us with the precise depth of the bullet below the skin.

The cross lines may now be looked upon as the bases of vertical planes, just as the lines marked out on a building site indicate the walls which presently will be laid upon them. A millimetre scale, attached to a base so that it can stand vertically, is brought into register with one of these cross lines, and by means of a pair of compasses the distance of the point of intersection of the threads from this vertical plane is measured. The same procedure is followed in the case of the vertical plane corresponding to the other cross line. Furnished with these distances of the two vertical planes from the point of intersection of the threads, one is enabled to measure on the skin of the patient, from the marks that have been left upon it, the distances from the planes at which the foreign body is situated, and once this point in relation to the planes represented by the cross wires is found on the surface, one knows that the bullet is situated at a distance vertically below this point corresponding exactly to the distance between the intersection of the threads and that of the cross lines marked on the table. An important precaution is to have some means of identifying one of the quadrants formed by the cross wires; this can be afforded by means of a mark made on the skin at the time of exposure, corresponding to the shadow of a fragment of lead on the plate. This precaution is necessary in order to avoid the possibility of mistaking the quadrant owing to the effect of reversal.

This method, while apparently elaborate, is simple, and gives the maximum amount of detail. A saving of time can be effected by making the two exposures on a single plate and thereby avoiding the tracing. Should a diagrammatic stereoscopic picture be desired when the two exposures have been taken on the one plate, it can be obtained by making a tracing of each image on separate pieces of glass or tracing material, and these, when combined by the stereoscopic method, give a faithful diagram of the relation of the foreign body to the cross wires. For cases where the screen is available a very speedy and

Fig. 4.—A B, Distance of x-ray tube from screen or photographic plate; A C, distance between the two positions of the x-ray tube; D B, distance between two shadows of bullet; X, distance or depth below skin of the bullet. To ascertain x by similar triangles the formula is:

$$D B : X :: A C : (A B - x)$$

$$D B (A B - x) = A C \times x$$

$$X = \frac{D B}{A C} (A B - x)$$

The method of cross-thread localization has been applied, with more precise and rigid apparatus, to the localization of the minutest foreign bodies in the eye, and in the course of an experience covering some years

it has been found to give the most astonishingly accurate results.

SURGICAL PRECAUTIONS.

Thus far I have dealt with the information which the x-ray worker can place at the disposal of the surgeon. I now venture to make some remarks on the proper precautions which ought to be observed by the surgeon in dealing with these foreign bodies. In the first place, he should be careful to take the trouble to place the patient in precisely the same position as he occupied at the time the x-ray photograph was taken. In the second place, he should be very careful to ascertain the exact position occupied by the foreign body which he proposes to remove. If the cross lines and their markings made at the time of the x-ray examination have been carefully preserved on the patient's skin, this information can be given to the surgeon with the minutest accuracy, and at the same time the result is stereoscopic, and, reduced to the stereoscopic size, can be viewed by the surgeon during operation.

As an adjunct to the operative measures, I should like to mention a method which I have recently adopted with considerable success. It consists in the use of a telephone—preferably one with double receivers—such as is used in wireless telegraphy. One end of the telephone wire is attached to a small piece of platinum. This is placed upon any part of the patient's skin, which has first been moistened in the usual way with salt water. Plaster or bandage is used for holding the small disc of platinum in position. The other end of the telephone wire should be in the form of a disinfected thread of silver (preferably), because this can be readily attached to any of the surgeon's instruments—knife, probe, needle, or forceps. The only precaution necessary is that the attachment of the terminating wire to the instrument shall be firm. If the surgeon then attaches the telephone receiver to his ear, and begins to use his instrument upon the patient's tissues, he may possibly distinguish some slight sound on first making contact, but this is so faint as to be negligible. What he will hear with great distinctness, however, is the characteristic microphonic rattle the instant his instrument touches any metal embedded in the patient's tissues. The convenience of this adjunct to the operative instruments of the surgeon, when used carefully and intelligently, is not easy to over-estimate. One of the most regrettable habits of many distinguished surgeons is that of searching the wound with their fingers; this is the more regrettable because the use of the modern rubber gloves makes their tactile impressions rather imperfect. The writer's experience is that it is extremely difficult for him to persuade the surgeon to take great pains in going directly to the position at which the foreign body is situated. Almost the moment after the incision the surgeon invariably begins to search about in the same old way as he would have done if no information as to the position of the foreign body had been placed at his disposal at all. On several occasions these manipulations have actually resulted in pushing the foreign body out of the position which it had occupied and in which it had been carefully localized. Perhaps this criticism from one who for many years had a large operative experience in the removal of foreign bodies from the eye and orbit may be pardoned, and the use of the telephone attachment to surgical instruments, combined with precise measurements of the position of the foreign body may be a means of preventing the large incisions one often sees made, and the great disturbance of tissue and loss of time involved in extracting comparatively small foreign bodies which results.

Some cases illustrated by skiagrams are given on a Special Plate, Fig. 5 (A and B), Fig. 6, and Figs. 7 and 8, but before concluding I should like to state my firm conviction that a great many bullets are removed, sometimes from difficult positions, which, if they had been left alone, would have given no trouble whatever. As an example of the tolerance of foreign bodies, even in very movable parts of the human frame, one need only instance the great number of people who are known to have small shot in their orbits, sometimes very close to the eye, which remain there absolutely unnoticed for the remainder of their lifetime. There seems to be an impression abroad among officers that their chance of employment is diminished if they are known to have a bullet embedded somewhere in

their bodies. If this is so, the sooner this erroneous idea is removed the better.

REFERENCES.

¹ *Lancet*, November 7th, 1914, p. 1084. ² *BRITISH MEDICAL JOURNAL*, December 5th, 1914, p. 953. ³ *BRITISH MEDICAL JOURNAL*, January 1st and December 3rd, 1898.

SOME PRACTICAL HINTS ON THE LOCALIZATION OF BULLETS AND SHELL FRAGMENTS.

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SINCE the publication of my short note on a method of bullet localization,¹ I have received numerous letters asking for further information on the subject, and referring to various practical difficulties met with in the course of such work. These difficulties are mainly the result of two causes: inability to get the limbs into the position desired, and the presence of large suppurating wounds. Pain may prevent a limb being flattened out on the couch-top, preparatory to obtaining the vertical line. For example, it may be possible to straighten a knee only to within 30 to 40 degrees of full extension. The limb may, however, be held in position and two marks, one beneath the other, obtained; these will form a perfectly good guide to the surgeon, provided that the knee be operated on at the same angle. The lateral marks are, of course, obtained as usual.

Again, the patient's wounds or general condition may prevent him from being rolled on to his side so as to get lateral markings. This difficulty may be got over by using a second tube in an upright stand, so arranged that its normal ray is at right angles to that of the one beneath the couch. The procedure is exactly as before, the only inconvenience being that the tube is not so readily manoeuvred into position as in the case of one resting on a carriage with universal movement (Fig. 1).

Fig. 1.—T, Tube under couch; B, bullet; A and C, first markings; T₂, tube in adjustable stand, with diaphragm; D and E, cross markings; X Y, position of screen while obtaining the latter.

The use of a second tube has, however, one small advantage. The "cross markings" are made without the limb having been moved. When a patient is shifted so as to obtain a lateral view, care should be taken that the muscles of the limb are not thrown into action. If a bullet is lodged in the belly of a muscle, it may move relatively to the skin mark when the muscle contracts. Therefore the patient should always be instructed to remain absolutely passive; he must be rolled over, not allowed to turn over himself.

Patients with large suppurating wounds near the parts where the skiagrams must be taken may be prepared by having the limb wrapped in sterile gauze, covered by a layer of thin waterproof material, the whole being secured by a well-fitting bandage. Localization marks are made on the bandage. Afterwards the bandage is snipped with scissors at the points indicated, and nitrate of silver marks are made on the skin. It may be that one of the markings is directly over an open wound. The surgeon will then have to be content with three points only.

The discharge from some of these wounds is so copious that unless very stringent precautions are taken some of it is apt to escape. The screen, couch, and localizer are soiled, and infection may be transferred to other cases. A localizer made entirely of metal is undoubtedly an

advantage, as it can be boiled after each case. If, in addition, a square of sterilized waterproof is spread on the couch, and another is interposed between the screen and the limb, the precautions are complete.

In numerous instances localization can only be carried out properly under an anaesthetic. By arrangement with the surgeon and the anaesthetist the patient is anaesthetized on the x-ray couch, and the operation is performed immediately afterwards. As the localization can be carried out before surgical anaesthesia has been reached, this procedure does not prolong the operation. It is necessary to have the room in darkness only for a few seconds at a time, but if the anaesthetist is troubled by this, a fluoroscope may be used in all but very difficult cases.

Those cases in which bullets or shell fragments have lodged in the neighbourhood of the hip-joints, pelvis, and shoulder girdle, require special consideration. Where powerful apparatus is at hand, where the bullet is of full size and the patient thin, cross markings may be obtained in these regions, but they cannot be counted on as a rule. The vertical line, on the other hand, can always be ascertained, and various means are employed to ascertain the distance of the bullet below the surface along this line.

In the region of the hip and shoulder stereoscopy is very valuable. The vertical line of the bullet should, however, be found in the usual manner. The diaphragm is then opened, and the plates taken by moving the tube 3 cm. on either side of the original position. If this plan is followed, the true vertical relationship of bullet and bony landmarks will be seen in the stereoscope. For instance, if the bullet appears to be directly over the middle of the acetabulum, this represents what will actually be found at operation. Some people have an idea that because a stereoscopic image gives an appearance of solidity therefore the exact position of the tube does not matter. That this is a mistaken view a very little thought will show. Suppose, for instance, we desire to centre an x-ray tube which has no plummet over any particular part of the body. It is necessary to get into a position from which one can look directly down on the desired spot, as it is not possible to be sure of the correct centering of the bulb from any other view-point.

Where cross markings cannot be obtained, and where it is desired to localize without the necessity of taking plates, or to gain information additional to what is given by the stereoscope, some modification of the well-known method of triangulation must be employed. Of such modifications there are

several, and the choice between them must be largely a matter of personal preference. For my own use I have designed a simple apparatus which I call a "depth indicator," shown in the appended rough diagrammatic sketch (Fig. 2), which, however, makes no pretensions to exact scale.

To ascertain the depth at which a bullet lies, the tube is, as usual, manoeuvred into a position vertically below the

Fig. 2.—A board, 36 in. high, 18 in. wide, and $\frac{1}{2}$ in. in thickness, is screwed to the wall of the x-ray room. On it, in the position shown, is drawn a vertical scale, 26 in. in length. Of this the portion E C represents the distance between the anticathode and the top of couch. Five inches to the left is a parallel scale, E F, 10 in. long. E B is a scale running to the right, perpendicular to E D; it is 3 in. long. G H is a rigid arm, 32 in. long, pivoted at G. The pivot G can be moved vertically between E and F, and clamped in any desired position. The lever is steadied at the top by the bar L M, behind which it can move freely except when clamped by a screw at M.