Fractures of the Acetabulum: Classification and Surgical Approaches for Open Reduction: PRELIMINARY REPORT

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Fractures of the Acetabulum: Classification and Surgical Approaches for Open Reduction

PRELIMINARY REPORT

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It appears that frequency of fractures of the acetabulum is increasing with the number of automobiles on our roads. In the past ten years, several important studies concerning this subject were published, notably those of Cauchoix and Truchet, Knight and Smith, Stewart and Milford, and Waller.

Since 1954, we have paid particular attention to the study of fractures of the acetabulum[4]. Because we were so disappointed with the results of closed treatment of these fractures, we decided to try open reduction. Our series includes 173 patients, of whom 129 were treated surgically. One hundred and eight were operated on primarily (within twenty days after injury) and twenty-one at a later date. Based on these experiences, we wish to describe the mechanism of injury and the roentgenographic and pathological findings in these acetabular fractures and to outline a plan of treatment.

Of the 173 patients in the series, 118 were male and fifty-five were female. The age distribution was fairly uniform—between twenty and sixty years.

Surgical Anatomy of the Acetabulum

In our study of these fractures the roentgenographic and operative findings were compared. Surgical treatment helped us to understand and to explain the roentgenographic findings. It is necessary to review the normal anatomy of the acetabulum if we are to understand the pathological changes. The surgeon's concept of the acetabulum must not be limited to the socket but should take into consideration the osseous masses that limit and support the acetabulum. It is to these masses that the internal-fixation devices must be attached to restore and maintain the shape of the socket.

We consider the acetabulum to be located in the concavity of an arch formed by two columns of bone, one anterior and the other posterior. These columns converge and meet in a thick and compact zone of bone which is always spared by fractures of the acetabulum. This zone is situated below and in front of the iliac articular surface of the sacro-iliac joint.

The posterior or ilioischial column (Fig. 1-A), which is voluminous and thick, descends caudad as far as the ischial tuberosity. This column is composed of the vertical portion of the ischium and of that portion of the ilium immediately above

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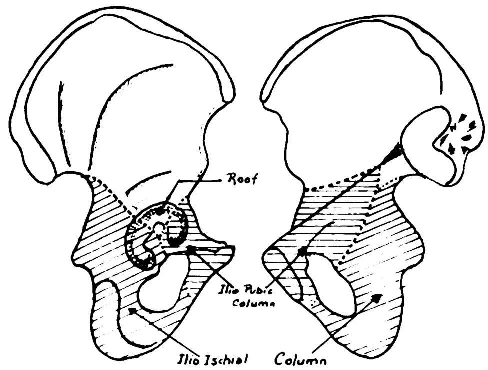

FIG. 1-A

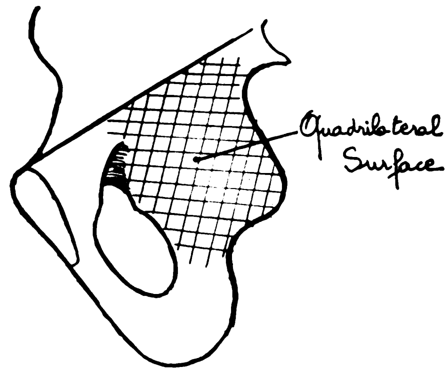

FIG. 1-B

Fig. 1-A: Medial (right) and lateral (left) views of the columns of the acetabulum.
Fig. 1-B: Medial view showing the quadrilateral surface.

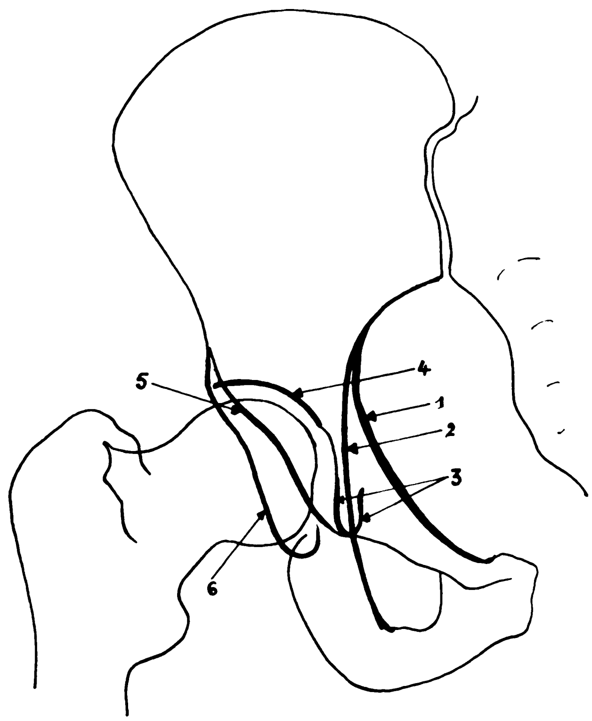

FIG. 2

Diagram of a standard anteroposterior roentgenogram of the hip showing significant landmarks: *1*, superior channel, the arcuate (iliopectineal) line; *2*, ilioischial roentgenographic line; *3*, roentgenographic U; *4*, roof of the acetabulum; *5*, anterior lip of the acetabulum; and *6*, posterior lip of the acetabulum.

the ischium. On the anterolateral surface of the column lies the posterior part of the articular surface of the acetabulum, the posterior acetabular rim. On the medial surface of this column is the quadrilateral surface (Fig. 1-B).

The anterior or iliopubic column runs obliquely downward, inward, and anteriorly, making an angle of about 60 degrees with the posterior column. The anterior column consists of a short segment of the ilium and of the pubis and extends up as far as the anterior inferior spine of the ilium. On the posterolateral surface of this column is the anterior portion of the articular surface of the acetabulum, the anterior acetabular rim. These two columns form an arch in which the superior angle or keystone is formed by a rounded plate of compact iliac bone, the roof of the acetabulum.

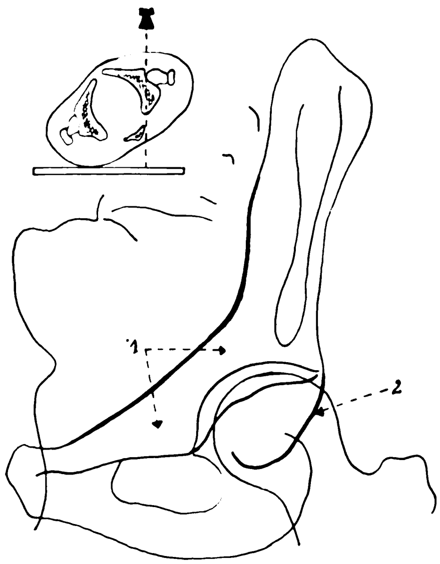

FIG. 3-A

FIG. 3-B

Figs. 3-A and 3-B: Three-quarter internal oblique view of the hip (patient supine and rotated 45 degrees away from the injured side): *1*, iliopubic column; *2*, posterior lip of the acetabulum.

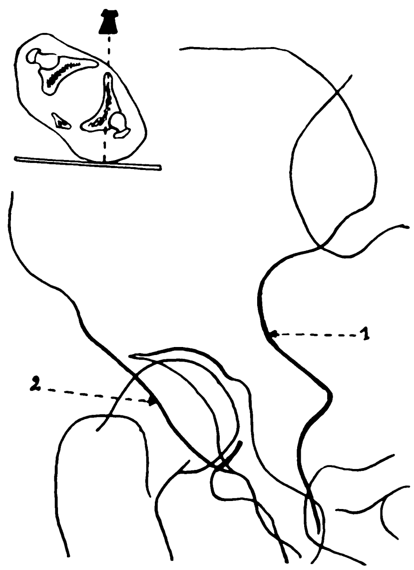

FIG. 4-A

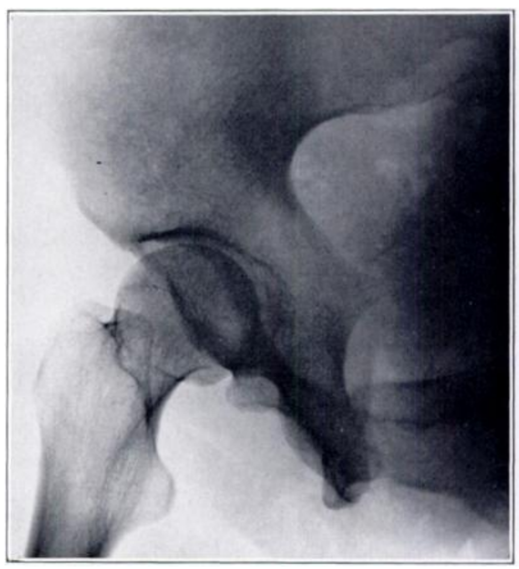

FIG. 4-B

Figs. 4-A and 4-B: Three-quarter oblique view of the hip (patient supine and rotated 45 degrees toward the injured side): *1*, posterior lip of the ilium; *2*, anterior lip of the acetabulum.

The anatomical variations of the acetabular fractures in this series have been carefully studied on roentgenograms. To do this, it is essential to have several views. A standard anteroposterior roentgenogram of the pelvis should be obtained as well as one of the injured hip. This is necessary because of the occurrence of bilateral fractures. These views invariably enable us to see the fracture but are never sufficient to make an accurate anatomical diagnosis; therefore, oblique views are a necessity.

On the anteroposterior roentgenograms of the hip we are interested in six landmarks (Fig. 2): (1) the superior channel, a roentgenographic line corresponding to the arcuate line which begins at the superior edge of the greater sciatic notch

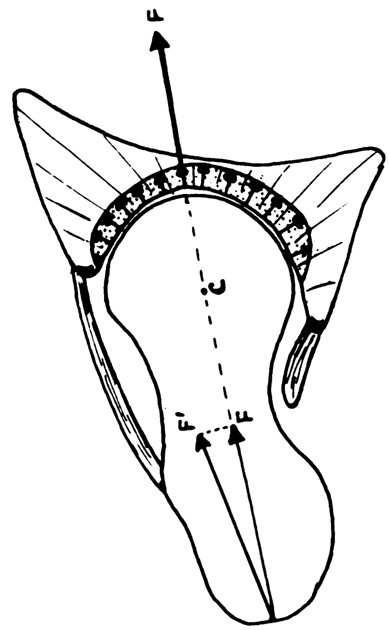

FIG. 5-A

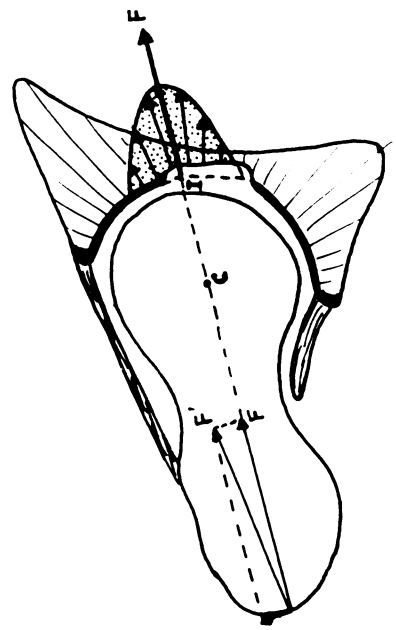

FIG. 5-B

Figs. 5-A and 5-B: Horizontal sections through an abducted hip joint demonstrate the distribution in the acetabulum of a force applied to the greater trochanter (see text).

Fig. 5-A: If the hip was a perfectly congruous enarthrosis without cartilaginous pads, the force would be distributed equally throughout.

Fig. 5-B: In the real hip with a double cartilaginous pad interposed between the bones, the force is concentrated as shown. In fact, the head should be in perfect contact with the acetabulum on all its surface.

and extends downward to the pubic tubercle (a break in this line indicates fracture of the iliopubic column); (2) the ilioischial roentgenographic line formed by the posterior four-fifths of the quadrilateral surface of the iliac bone; (3) the roentgenographic U, composed laterally of the most inferior and anterior portion of the acetabular fossa and medially of the anterior flat part of the quadrilateral surface of the iliac bone (normally, the U and the ilioischial line intersect or are tangential); (4) the roof of the acetabulum, which is prolonged in a lateral-to-medial direction to end on the lateral branch of the U; (5) the edge of the anterior lip of the acetabulum; and (6) the edge of the posterior lip of the acetabulum.

The three-quarter internal and three-quarter external oblique views of the affected hip are necessary to define these fractures further.

The three-quarter internal oblique view (Figs. 3-A and 3-B) shows the entire iliopubic column (Fig. 3-A, *1*) in profile, whereas the wing of the ilium is perpendicular to the film and viewed on edge. This projection also enables one to follow the posterior lip of the acetabulum prolonged by the curve of the posterior horn of the acetabular articular surface (Fig. 3-A, *2*).

The three-quarter external oblique view (Figs. 4-A and 4-B) spreads out the iliac wing and the quadrilateral surface, allowing us to study the posterior edge of the iliac bone (Fig. 4-A, *1*) and the anterior lip of the acetabulum (Fig. 4-A, *2*).

Thus, there are four basic roentgenographic views. In some instances it is also helpful to obtain the axial view of the acetabulum on a lateral roentgenogram of the hip [2]. This gives a tangential view of the acetabulum and the two columns which limit it.

Systematic study of the roentgenograms should enable one to envisage the site and direction of the main fracture lines, the number, size, and location of the fracture fragments, and the orientation of the dislocation of the head of the femur. With

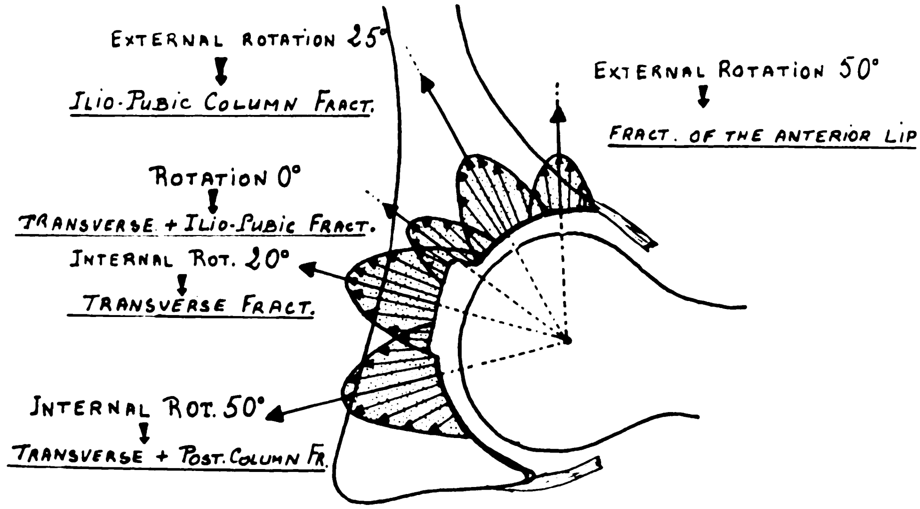

FIG. 6

Horizontal section shows the distribution of force in relationship to external and internal rotation of the femur and the lesions produced in the different degrees of femoral rotation.

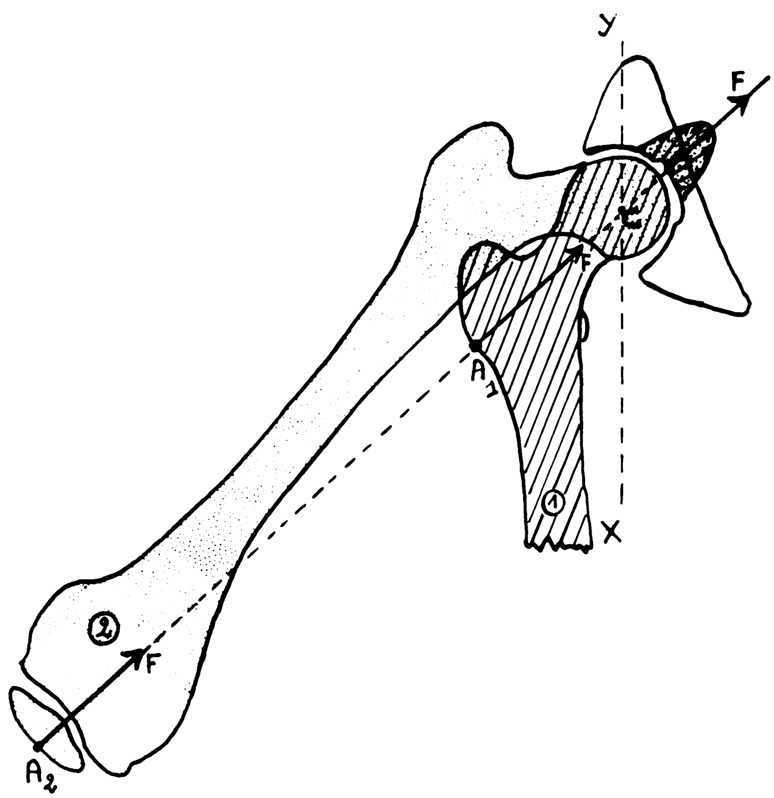

FIG. 7

Horizontal section of the hip. The broken line Y-X is the axis of the limb with the hip in neutral position. In position 1 (flexion, 90 degrees; abduction, 0 degree; internal rotation, 20 degrees), the angle of abduction of the femoral neck A_1CX is 45 degrees. In position 2 (flexion, 90 degrees; abduction, 45 degrees), the angle of abduction of the femur A_2CX is 45 degrees. The same force F applied to the greater trochanter in position 1 and to the flexed knee in position 2 will produce the same acetabular fracture. The location and direction of the force transmitted to the acetabulum and hence the location of the transverse fracture will vary according to the amount of abduction or adduction of the hip at the time of injury.

this information we can "know" the fracture, can classify it anatomically, and can approach it surgically.

TABLE I

Cause of Injury	No. of Patients
Automobile	123
Motor scooter	5
Direct blow on greater trochanter	22
Fall from height	8
Blow on posterior aspect of pelvis	1
	159

TABLE II

Anatomical Classification	No. of Patients	No. of Early Open Reductions	
Posterior-lip fracture	57	32	
Fracture of posterior horn of the articular surface (1)			
Fracture of posterior lip (3)			
Fracture of posterior rim, posterior dislocation (45)			
Fracture of posterosuperior portion of the rim, posterosuperior dislocation (8)			
Fracture of the ilioischial column	9	6	
Transverse fracture	74	47	
Transverse fracture, posterior-lip fracture, posterior dislocation (23)			(22)
Transverse fracture, posterior-lip or posterosuperior fracture, central dislocation (10)			(6)
Transverse fracture, central dislocation (25)			(8)
T fracture, central dislocation (3)			
Transverse fracture, ilioischial-column fracture (6)			(5)
Transverse fracture, iliopubic-column fracture (7)			(6)
Fracture of iliopubic column	17	7	
Anterior-ridge fracture (1)			
Iliopubic-column fracture (16)			
Associated fracture of both columns	16	16	
Totals	173	108	

Anatomical Classification

A useful classification of fractures of the acetabulum must be simple and the identification of a fracture must be based on the elementary lesions of the acetabulum, whether they be isolated or in combination.

There are four elementary or simple acetabular fractures: (1) fracture of the posterior lip (Figs. 11-A through 11-C); (2) fracture of the ilioischial column (Figs. 13-A, 13-B, and 13-C); (3) transverse fracture (Figs. 16-A and 16-B); and (4) fracture of the iliopubic column (Figs. 19-A through 19-D). These elementary fracture types are the most frequent (111 of 173 cases in our series). In the other cases there were also associated fracture lines. For example, we observed a transverse fracture with an associated fracture of the posterior lip and either a central or posterior dislocation of the femoral head. Frequently, one sees a transverse fracture associated with a fracture of either the ilioischial or the iliopubic column. At times, both columns of the acetabulum are fractured.

In fact, our series constitutes a continuous spectrum of the elementary fractures with all the intermediate and associated fracture lines between an isolated posterior-lip fracture on the one hand and a simple avulsion fracture of the anterior ridge of the iliopubic column on the other (Table II). The mechanism of injury is responsible for the type of fracture and explains the different anatomical varieties observed and enables us to understand the perfect unity of all acetabular fractures.

In addition to the fracture, there is, in this injury, another important and inherent element which must be remembered—dislocation of the femoral head. This dislocation, which is either posterior or central with variable degrees of displacement, is a second anatomical lesion and one of prime importance in prognosis since we believe it is the dislocation that is primarily responsible for avascular necrosis of the femoral head, one of the worst complications of these injuries.

Mechanism of the Fracture

The acetabulum is fractured by the femoral head, which transmits force received on the greater trochanter, knee, or foot. More rarely fracture occurs when the head of the femur acts as an anvil on which the acetabulum with the hip in flexion

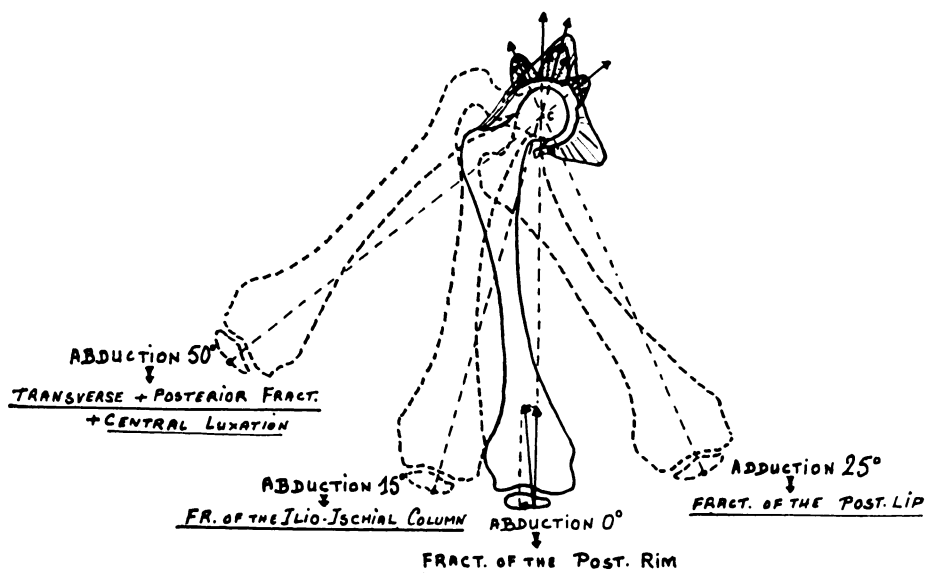

FIG. 8

Horizontal section through the hip and femur with the hip flexed to 90 degrees. When a blow is applied to the flexed knee, the resulting lesions and distribution of force in the acetabulum in relation to adduction and abduction of the femur are as shown.

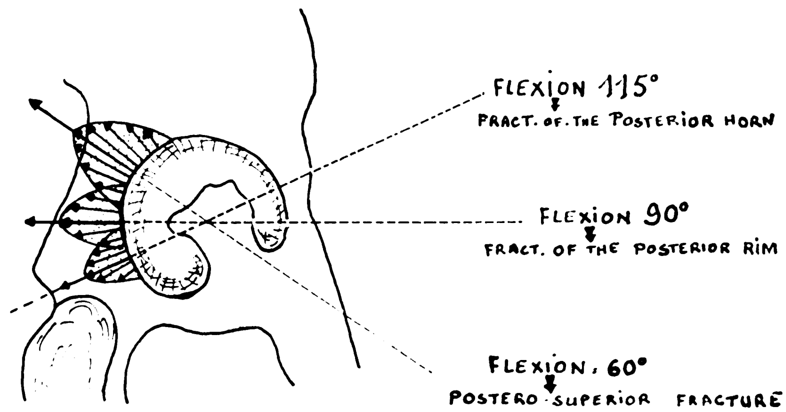

FIG. 9

External view of the acetabulum shows how the force distribution and resulting lesions vary with the amount of flexion of the hip when the force of impact is received on the flexed knee.

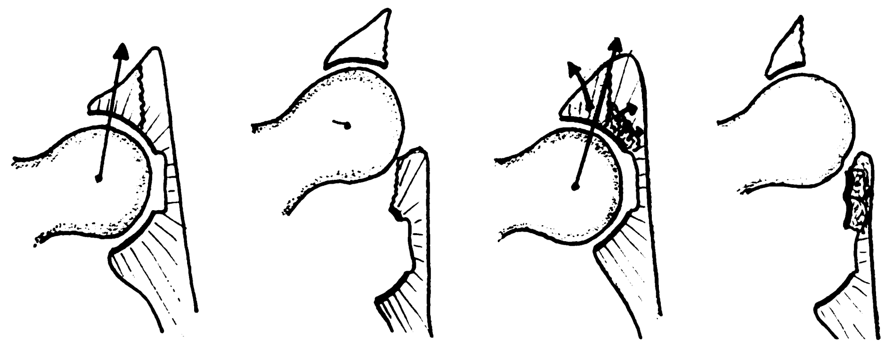

FIG. 10-A FIG. 10-B FIG. 10-C FIG. 10-D

Figs. 10-A through 10-D: The two types of posterior-rim fractures showing direction of force (Figs. 10-A and 10-C) and final displacement (Figs. 10-B and 10-D).
Figs. 10-A and 10-B: Simple fracture with displacement of the rim.
Figs. 10-C and 10-D: Mixed type with displacement of the outer part and impaction and comminution of the inner part of the posterior rim.

is broken by a violent blow applied from behind. There was one such case in our series.

As illustrated in Figure 5-A, we believe that, when a force F' is applied to a point on the femur, only the force F is transmitted to the acetabulum along the axis joining the point of application of F' and the center of the femoral head C. This axis intersects the acetabular surface at the point of head-acetabulum impact (Fig. 5-B, I).

If the hip were a perfect ball-and-socket joint, the force applied to the femur and transmitted by the head to the acetabulum would be shared almost equally by the whole articular crescent (Fig. 5-A). However, because of the interposition of a double elastic cartilaginous pad, the force is transmitted to a limited area of the acetabulum (Fig. 5-B). The effect is maximum at the point of impact (I) along the axis FCF and diminished progressively from this point, as indicated by the hemielliptical force diagram.

The height, width, and location of the hemiellipse representing the distribution of the transmitted force are functions of the direction and magnitude of the force transmitted to the acetabulum. The observed damage to the bone of the acetabulum and the displacement of the fragments can be related to these force diagrams, indicating how the position of the femur at the time of impact influences the resultant lesion (Figs. 6, 7, 8, and 9.)

Description of the Types of Fracture

The anatomical and roentgenographic characteristics of the principal varieties of acetabular fracture are:

Posterior Fracture

The simple posterior fracture detaches more or less of the posterior lip of the acetabulum (Figs. 10-A through 10-D). At times, the fragment may take with it a part or all of the acetabular roof, thus producing a posterosuperior fracture and dislocation (Figs. 12-A and 12-B). We have seen forty-nine simple posterior fractures which spared the roof of the acetabulum and eight posterosuperior fractures which involved this area, the weight-bearing portion of the acetabulum.

Two types of fracture may occur. The more frequent type is a simple separation of a fragment (Figs. 10-A and 10-B). Less commonly, in addition to this lesion, there is comminution and impaction of the adjacent articular surface into the underlying cancellous bone of the posterior column (Figs. 10-C and 10-D). In the

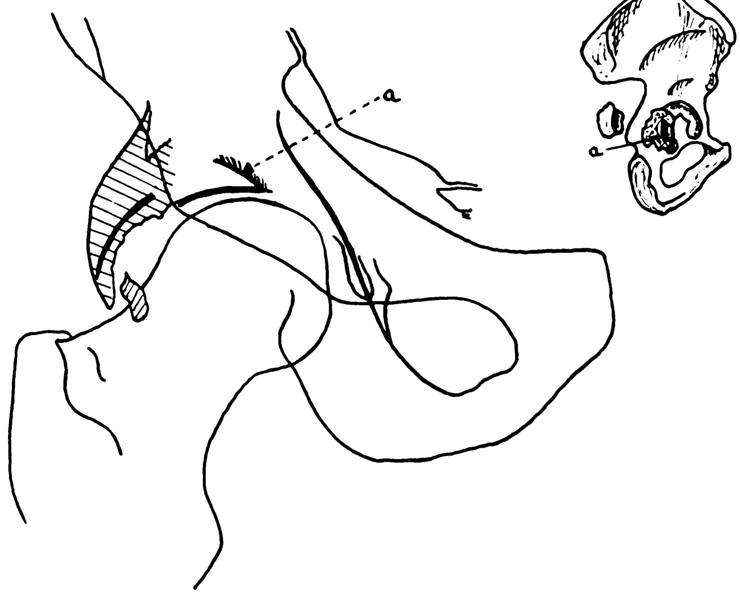

FIG. 11-A

Posterior-rim fracture (mixed type). Note the displaced and comminuted posterior rim: *a* is the inner part of the posterior articular surface impacted into the underlying cancellous bone of the posterior column.

FIG. 11-B

FIG. 11-C

Fig. 11-B: Before open reduction.
Fig. 11-C: After open reduction and internal fixation through a posterior approach (see text).

second type it is important to dislodge and replace the fragments into their normal location in contact with the femoral head.

Roentgenographically, posterior fractures are easy to recognize on the anteroposterior view, which shows the posteriorly dislocated head of the femur with the displaced fragments above it. To determine the size and number of the fragments it is necessary to obtain the other views because usually the anteroposterior view shows the shortest diameter of the fragments. On this view the posterior lip is absent except for its more inferior portion and the other anatomical landmarks are intact. The anterior lip appears more prominent because of the missing underlying posterior surface of the acetabulum (Figs. 11-A and 11-B).

Posterosuperior fractures (Figs. 12-A and 12-B) are distinguished by the displacement of the lateral part of the acetabular roof or by displacement of the whole roof. The three-quarter internal oblique view always reveals these fragments clearly.

This type of acetabular fracture is usually produced by direct trauma on the anterior aspect of the flexed knee with the hip flexed to 90 degrees and in slight or no abduction. The size of the posterior fragment varies directly with the amount of abduction. Thus, if the hip is adducted, simple dislocation occurs. This type of injury sometimes occurs as a result of trauma to the posterior aspect of the sacrum, when the hip is fixed at 90 degrees of flexion.

There were nine instances of sciatic paralysis associated with the fifty-seven posterior-lip fractures in our series.

Simple Fracture of the Ilioischial Column

Nine simple fractures of the ilioischial column occurred in our series; six of

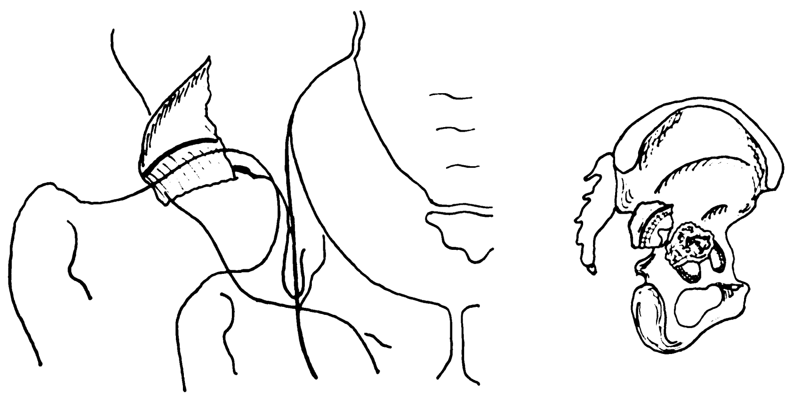

Fig. 12-A

Figs. 12-A and 12-B: Posterosuperior-rim fracture.

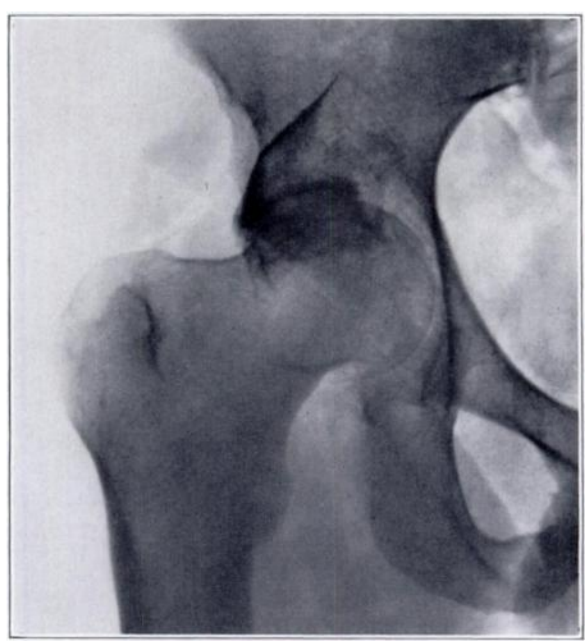

Fig. 12-B

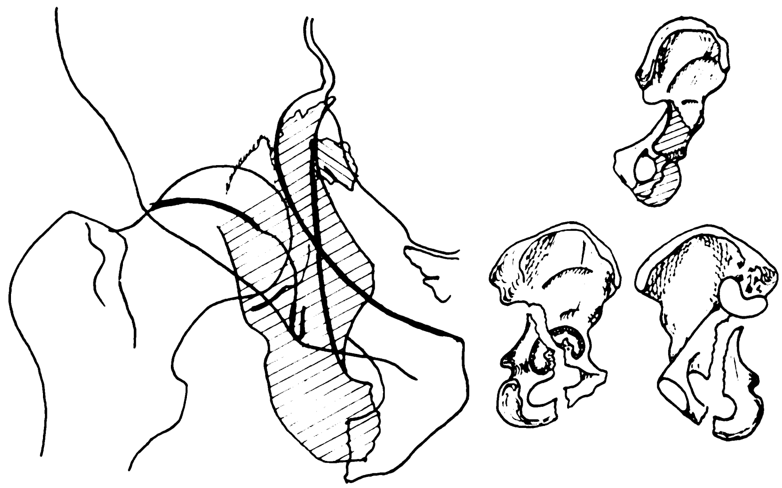

FIG. 13-A

Figs. 13-A, 13-B, and 13-C: Complete fracture of the ilioischial column.
Fig. 13-A: The ilioischial line is displaced medially, its upper half appears inside the superior channel, and its lower part is separated from the roentgenographic U, its faithful companion.

FIG. 13-B

FIG. 13-C

Fig. 13-B: Before open reduction.
Fig. 13-C: Nine years after open reduction through the posterior approach. Avascular necrosis of the femoral head had occurred, but at this time the condition of the head was stabilized and there was very good function (the patient was able to play tennis).

these were treated surgically. The fracture line usually begins close to the apex of the sciatic notch and extends obliquely down and forward to enter the acetabulum just behind its roof; it then passes through the posterosuperior quadrant of the acetabulum and descends caudally through the acetabular notch to the ischiopubic junction. The displaced fragment, therefore, consists of the whole posterior column of the innominate bone (primarily the ischium and a small part of the ilium).

On the anteroposterior roentgenogram there is a large medially displaced fragment, and the head of the femur is centrally dislocated in company with this fragment. The integrity of the superior channel, the abnormally prominent anterior lip of the acetabulum, and the appearance of the roentgenographic U in or at the right place confirm the continuity of the anterior column (Figs. 13-A, 13-B and 13-C). The roof of the acetabulum is in the right place and no transverse fracture is seen.

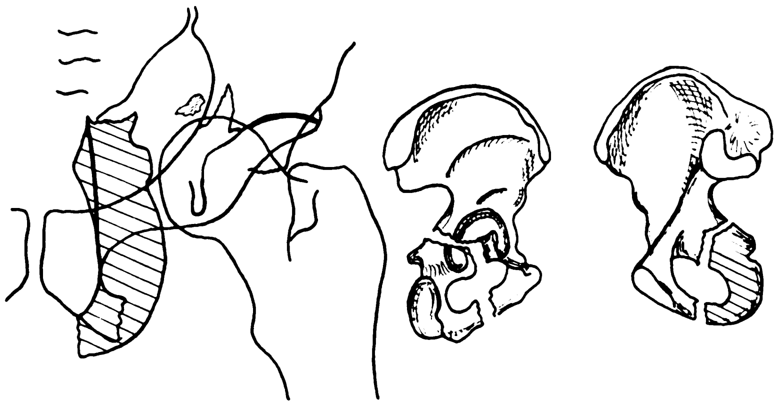

FIG. 14-A

Fracture of the inferior half of the ilioischial column.

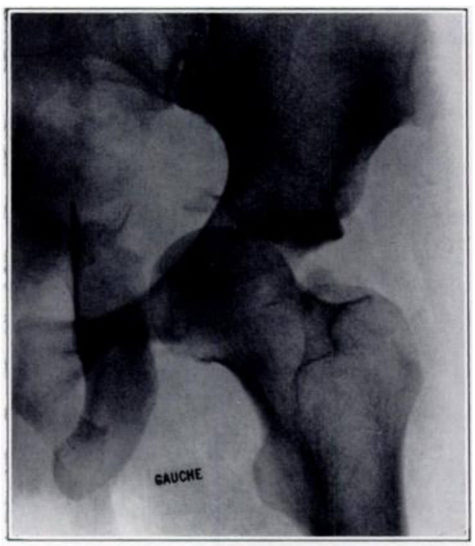

FIG. 14-B

FIG. 14-C

Fig. 14-B: Before open reduction.

Fig. 14-C: Three years after open reduction and fixation with a plate and screws, using the posterior approach.

On the displaced fragment the ilioischial line is perfect but it is displaced inside and separated from the roentgenographic U, its faithful companion.

The three-quarter internal oblique view shows the intact state of the anterior column. The three-quarter external oblique view discloses the medial displacement of the posterior column.

Only part of the posterior column may be detached (Figs. 14-A and 14-B). The mechanism of injury is a posteriorly directed blow on the anterior aspect of the knee, the thigh being abducted 10 to 15 degrees and flexed 95 to 100 degrees.

This fracture also places the sciatic nerve in danger. Injury to the nerve occurred in one of five patients who had complete detachment of the posterior column.

Simple Transverse Fracture of the Acetabulum

Transverse fractures separate the innominate bone, including the acetabulum, into two segments—a superior iliac and an inferior ischiopubic.

The fracture line which cuts across the acetabular ridge horizontally or obliquely is often higher anteriorly than posteriorly. There were twenty-five

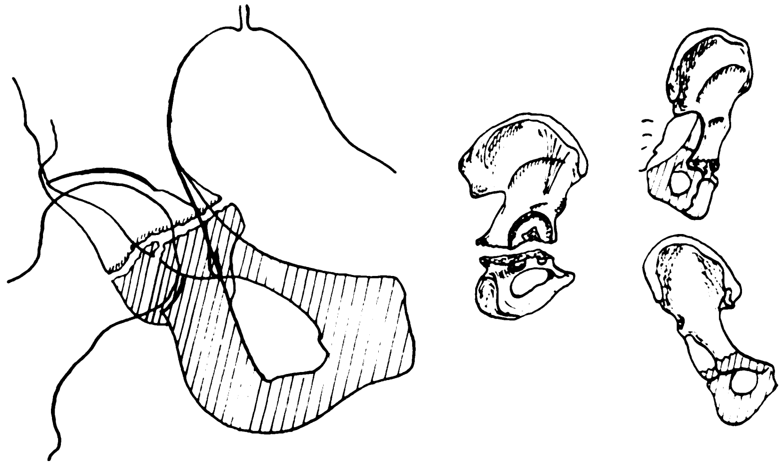

FIG. 15-A

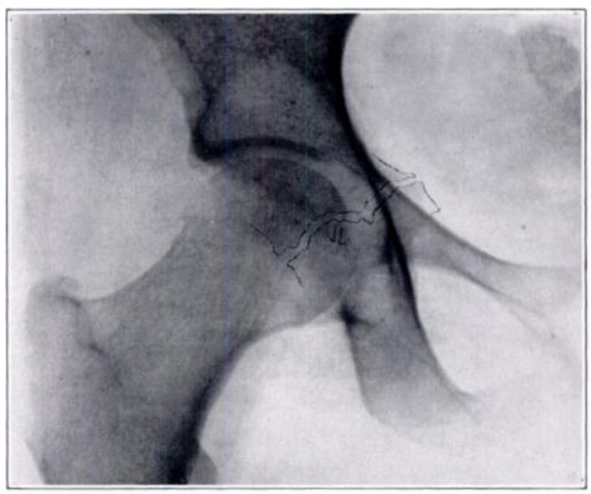

FIG. 15-B

Figs. 15-A and 15-B: Simple low transverse fracture without displacement. The fracture line splits the ischial spine.

patients with this type of fracture in our series; eight had early surgical treatment.

The transverse fracture line passed through the inferior part of the acetabulum ten times (often splitting the sciatic spine) (Figs. 15-A and 15-B); at the level of the junction of the acetabular roof and fossa, ten times (Figs. 16-A and 16-B); and through the roof of the acetabulum, five times (Figs. 17-A and 17-B).

In these fractures, the ischiopubic fragment is shifted medially and the head of the femur usually follows it, producing a central dislocation.

Roentgenographically, the superior channel, the ilioischial line, and the anterior and posterior lips of the acetabulum are all crossed by a fracture line clearly visible on the anteroposterior view. The roof may not be affected. The inferior portion of the ilioischial line and the U are clearly visible on the inferior fragment, with their normal mutual relationship retained. There may be some rotation of the inferior fragment. The three-quarter oblique views show that the fracture line crosses both lips of the acetabulum and the posterior ridge of the innominate bone.

These fractures are caused by a blow either on the lateral aspect of the greater trochanter or on the posterior aspect of the pelvis while the hip is flexed. When a trochanteric blow produces the fracture, the femur is internally rotated 15 to 20

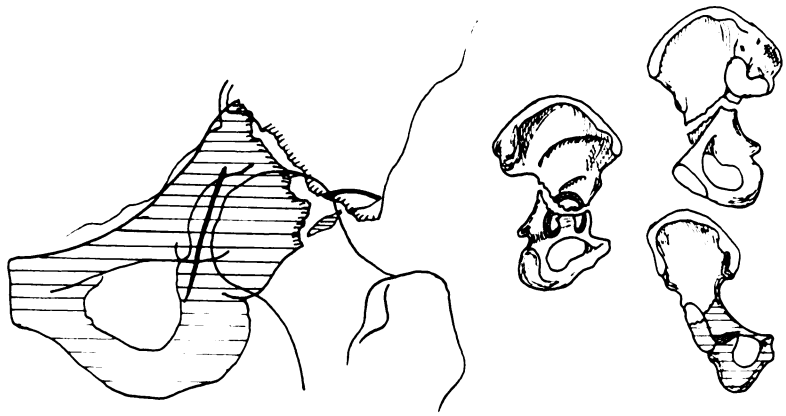

FIG. 16-A

FIG. 16-B

Figs. 16-A and 16-B: Simple transverse fracture at the level of the junction of the acetabular roof and the fossa.

degrees, with a variable amount of abduction. When a pelvic blow does the damage, the lower extremity is abducted. In our series there was one instance of this latter mechanism.

In T fractures, a transverse fracture is combined with a vertical fracture line. These two fractures separate the inferior acetabulum into pubic and ischial fragments and the pubis and ischium from the rest of the pelvis. As the separation of the fragments is usually slight, the ilioischial line and U are not separated (Figs. 18-A and 18-B). This type of transverse fracture is rare; there were only three in our series.

Simple Fracture of the Iliopubic Column

In our series there were sixteen patients with simple fractures of the iliopubic column. Seven were operated on early and one, in a late stage, after traumatic arthritis had developed.

These fractures separate the anterior column from the rest of the innominate bone (Figs. 19-A through 19-D). The fracture line usually begins in the region of the groove of the iliopsoas muscle, or at the level of the notch just above the

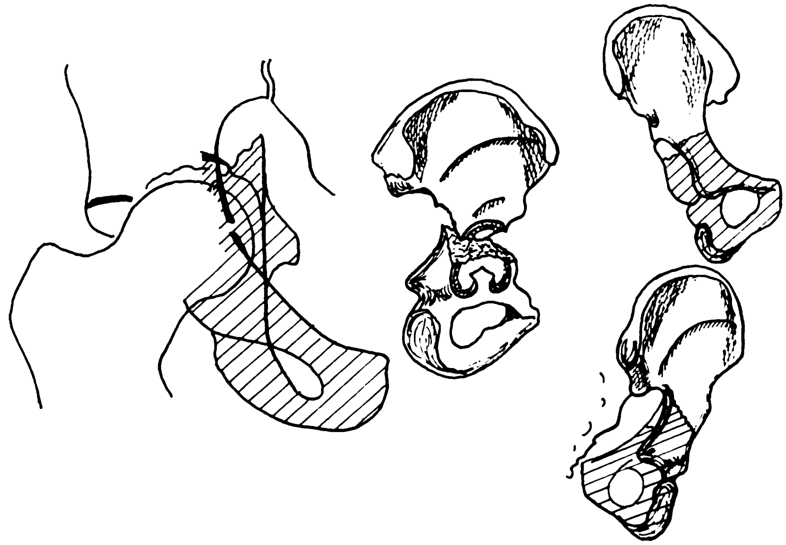

FIG. 17-A

FIG. 17-B

Figs. 17-A and 17-B: Simple transverse fracture through the roof of the acetabulum.

anterior inferior iliac spine (Figs. 20-A and 20-B). On the inner aspect of the ilium the fracture line follows either a straight or curved course upward and posteriorly almost to the sacro-iliac joint and crosses the superior channel. From here, the fracture runs for a short distance along the inferior side of the superior channel and then descends almost vertically in the anterior part of the quadrilateral surface. There may be secondary fracture lines in the quadrilateral surface which demarcate a fragment attached by a posterior hinge (Figs. 20-A and 20-B).

On the outer aspect of the pelvis, when the separated fragment of the anterior column includes the anterior inferior iliac spine it also includes the anterior portion of the roof of the acetabulum (Figs. 20-A and 20-B). On the roentgenogram the portion of the acetabular roof may appear to be a separate fragment but, in fact, it is all part of the iliopubic fragment and it is reduced with the iliopubic fragment at operation. When the fracture line starts from the groove of the psoas, it crosses the acetabulum through the anterosuperior quadrant of the articular surface and

Fig. 18-A

Fig. 18-B
Figs. 18-A and 18-B: T fracture.

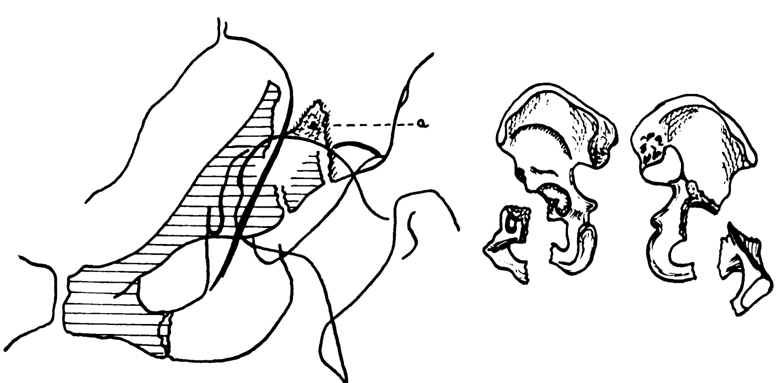

Fig. 19-A

FIG. 19-B

Figs. 19-A through 19-D: Simple fracture of the iliopubic column extending down the groove for the psoas muscle.

Figs. 19-A and 19-B: Anteroposterior view: *a* is the zone in the ilium from which the upper end of the iliopubic column was wrenched when the fracture occurred.

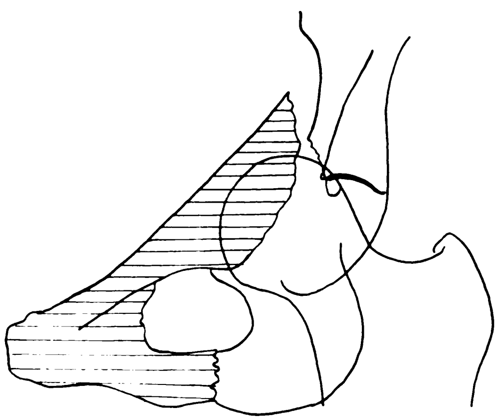

FIG. 19-C

FIG. 19-D

Figs. 19-C and 19-D: Three-quarter internal oblique view.

passes caudally through the fossa; therefore, the roof is intact on the anteroposterior view. Anteriorly, the column may be separated from the rest of the pelvis at three places: (1) the superior ramus of the pubis, (2) the anterior part of the pubis close to the symphysis, or (3) the inferior ischiopubic junction.

On the roentgenogram, this fracture at first may appear to be transverse but, with careful evaluation of the landmarks and study of the oblique views, its true nature can be identified.

The iliac portion of the superior channel is detached at its junction with the ilioischial line. The anterior lip of the acetabulum is fractured. The appearance of the roentgenographic U and its relationship with the superior channel are normal, but the U is separated from the ilioischial line, which lies lateral to it. This indicates that the anterior part of the quadrilateral surface is a part of the fragment. The zone from which the upper end of the displaced anterior column was torn by the injury is always visible (Fig. 19-A,*a*). On the other hand, the posterior ridge of the

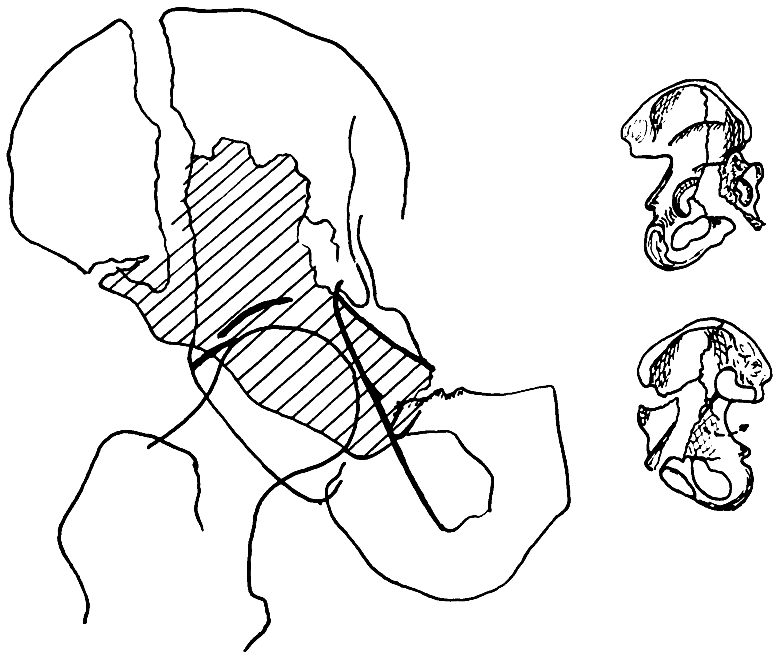

Fig. 20-A

Fig. 20-B

Figs. 20-A through 20-G: Simple fracture of the iliopubic column with the fracture line starting in the notch above the anterior inferior iliac spine and running through the acetabulum and the superior pubic ramus.

Figs. 20-A and 20-B: Anteroposterior view shows supplementary fracture line which detaches the anterior part of the iliac wing. The shaded area and the arrow in the lower insert indicate a fragment from the quadrilateral surface turned inward on a posterior hinge.

acetabulum, which is intact as the ilioischial line, confirms the integrity of the posterior column.

All of these findings demonstrate that the fracture involves the anterior part of the ilium, which is displaced inward along with the centrally dislocated femoral head. The hip is in marked external rotation.

The internal oblique view clearly shows the detached column and the integrity

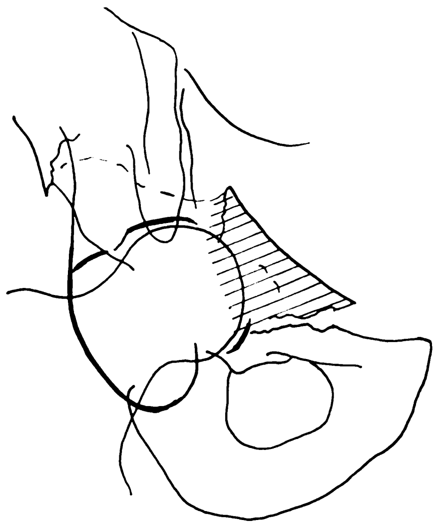

Fig. 20-C

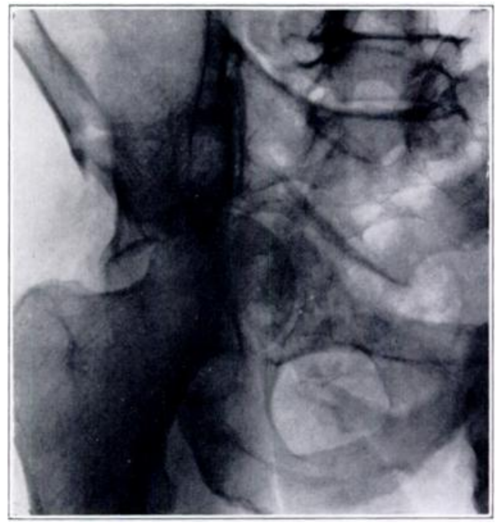

Fig. 20-D

Figs. 20-C and 20-D: Three-quarter internal oblique view shows that the posterior lip of the acetabulum is intact. The fracture of the iliopubic column is easy to study in this view.

of the posterior acetabular lip (Figs. 19-C and 19-D). The external oblique view demonstrates the integrity of the posterior aspect of the iliac bone.

This fracture is caused by a blow on the lateral aspect of the greater trochanter with the hip externally rotated at least 30 degrees.

The four elementary types of fracture of the acetabulum just described accounted for 111 of the 173 fractures in our series. The remainder had at least two associated elementary fractures.

Thirty-three patients had a transverse fracture associated with a posterior-rim fracture; in twenty-three there was an associated posterosuperior dislocation of the femoral head. Twenty-two of these posterior dislocations were treated surgically.

Roentgenograms of these patients demonstrated the characteristic findings of both types of elementary fractures (Figs. 21-A through 21-E). These fractures with posterior dislocation of the femoral head are caused by a blow received on the flexed knee or on the foot, the hip being flexed to about 90 degrees and abducted 20 to 25 degrees (Fig. 8).

Ten of the thirty-three patients had a transverse fracture of the acetabulum, an associated posterior or posterosuperior fracture, and a central dislocation of the femoral head (Figs. 22-A and 22-B).

The mechanism of these fractures with central dislocation of the femoral head is either a blow on the lateral aspect of the greater trochanter with the hip in 30 to 50 degrees of internal rotation (Fig. 6) and in variable amounts of abduction or a proximally directed blow on the flexed knee with the hip flexed to about 90 degrees and abducted to 40 to 50 degrees (Fig. 8).

Six of our patients had transverse fractures of the acetabulum with an associated fracture of the ilioischial column. In two the dislocation of the head of the femur was posterior (Figs. 23-A and 23-B) and in four, central. Seven patients had transverse fractures with an associated iliopubic-column fragment. In these the dislocation of the femoral head was always central and the limb was in external rotation (Figs. 24-A, 24-B, and 24-C). Six of the seven fractures were treated by open reduction.

The mechanism of injury in these cases was a blow on the lateral aspect of the greater trochanter with the limb in neutral or slight external rotation.

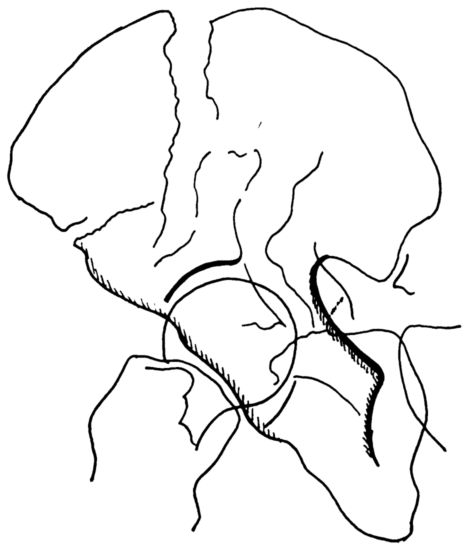

FIG. 20-E

FIG. 20-F

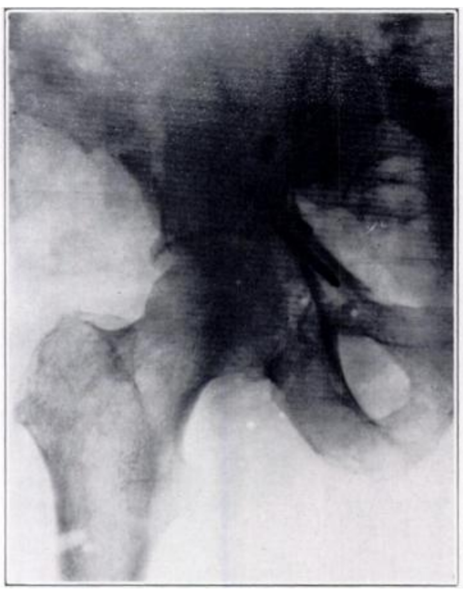

FIG. 20-G

Figs. 20-E and 20-F: Three-quarter external oblique view. On the quadrilateral surface there is an associated incomplete fracture which outlines a fragment turned inward on a posterior hinge. The posterior edge of the innominate bone is intact.

Fig. 20-G: After open reduction and fixation with three screws through the anterior approach.

Sixteen patients had fractures of both columns. Some of these fractures separated the columns from each other and from the ilium; others had additional minor fractures such as a posterior-lip fracture or a split of the anterior column (Figs. 25-A through 25-G). All of these sixteen patients were operated on.

Anatomically, in these cases, the posterior column is separated from the ilium by a fracture line which starts just above the apex of the greater sciatic notch and, on the outer aspect of the innominate bone, proceeds inferiorly along the junction of the posterior lip with the roof. From here the fracture descends vertically across the acetabular fossa, sometimes after running along the superior edge of the fossa separating the ischiopubic junction. Then, across the "obturator hole," it divides the ischiopubic inferior junction in the middle or, characteristically, it cuts across the anterior part of the pubis close to the symphysis (ten of sixteen cases).

The fracture that separates the anterior column from the ilium takes origin

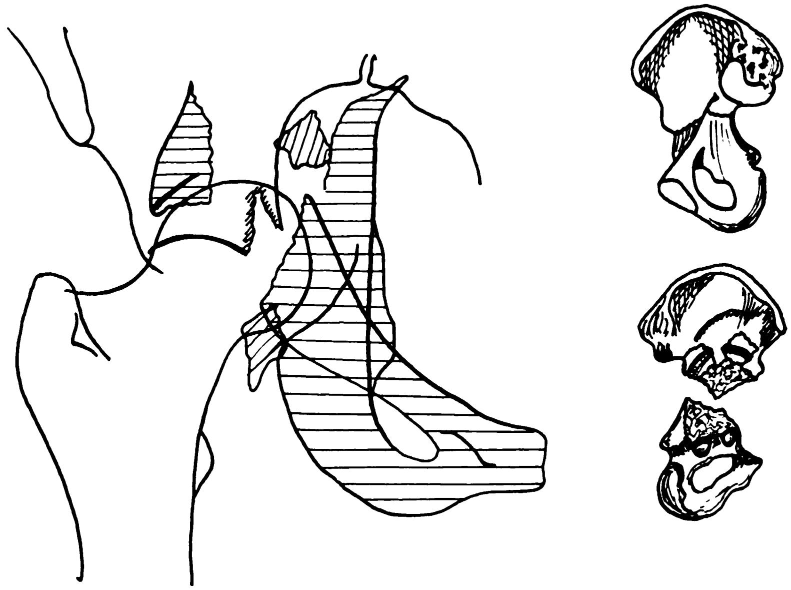

FIG. 21-A

FIG. 21-B

Figs. 21-A through 21-E: Transverse fracture associated with a posterior-rim fracture and a posterosuperior dislocation of the femoral head.
Figs. 21-A and 21-B: Anteroposterior view.

from the different points on the previously described fracture line at the level of the posterior iliac surface (Figs. 25-A, 25-B, 26-A, and 26-B). It may run two or three centimeters above the acetabulum, ending just above the anterior inferior iliac spine, as it did in nine of sixteen fractures of this type, or it may diverge obliquely upward and anteriorly to just behind the middle of the anterior half of the iliac crest. When the fracture line ends just above the inferior iliac spine there is often a separate fracture line that separates a portion of the roof of the acetabulum, whereas when the fracture line ends in the iliac crest there is often a transverse fracture line that divides the large anterior-column fragment into two parts.

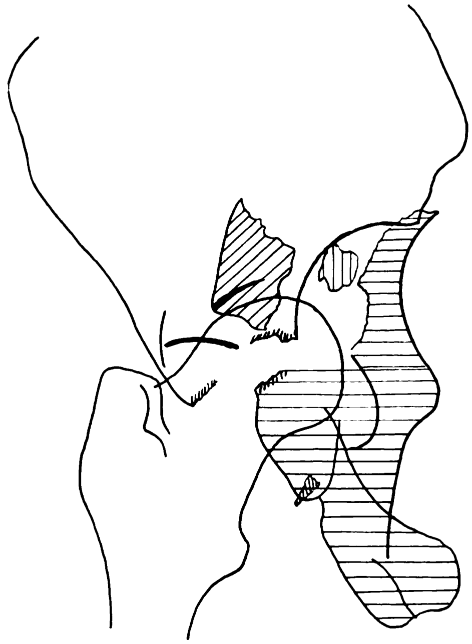

Fig. 21-C

Figs. 21-C and 21-D: Three-quarter external oblique view.

Fig. 21-D

Fig. 21-E

Fig. 21-E: Four years after open reduction and fixation with four screws through a posterior approach.

A central dislocation of the femoral head was associated with all of these sixteen fractures.

On roentgenograms, fractures of this type seem to be comminuted, and the fragmented acetabulum may appear to surround the centrally displaced femoral head perfectly, but this is only a roentgenographic finding.

The anteroposterior view suggests the presence of a transverse fracture of the acetabulum but no such fracture exists; instead, there is a large and displaced ilioischial fragment. However, the roentgenographic U and the ilioischial line are rarely separated.

The roof of the acetabulum is displaced medially, accompanying the head of the

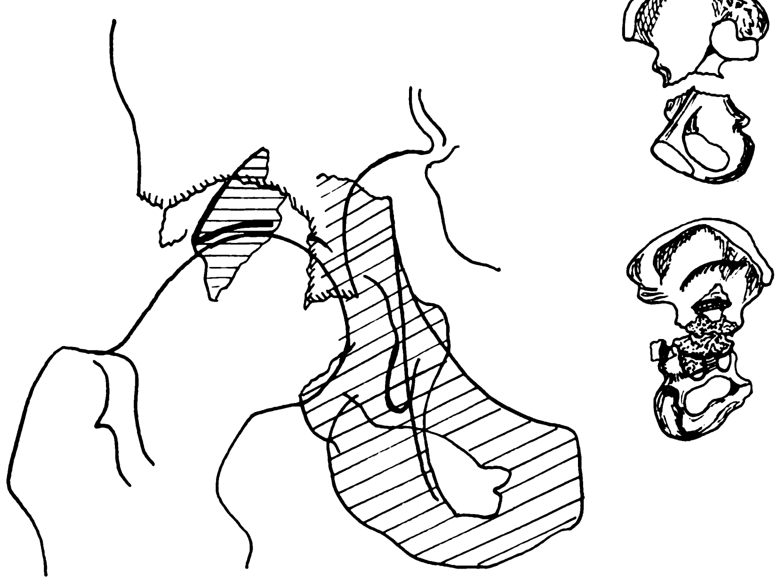

FIG. 22-A

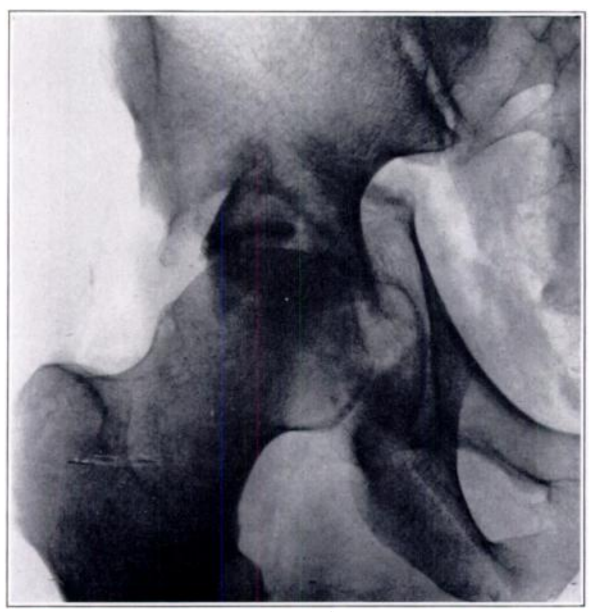

FIG. 22-B

Figs. 22-A and 22-B: Transverse fracture associated with a posterosuperior fracture and a central dislocation of the femoral head.

femur as it is dislocated medially. The roof of the displaced acetabulum is attached either to the anterior inferior iliac spine or to a large segment of the wing of the ilium.

The presence of a fracture of the anterior column is demonstrated roentgenographically by the breaking of the superior channel.

Oblique views are indispensable. The internal oblique roentgenogram shows the fracture of the anterior column with or without a fracture line through the anterior portion of the acetabulum. The anterior fracture line through the external aspect of the wing of the ilium can be seen better on this view, and one can appreciate the shift of the whole roof and anterior column. The external oblique roentgenogram

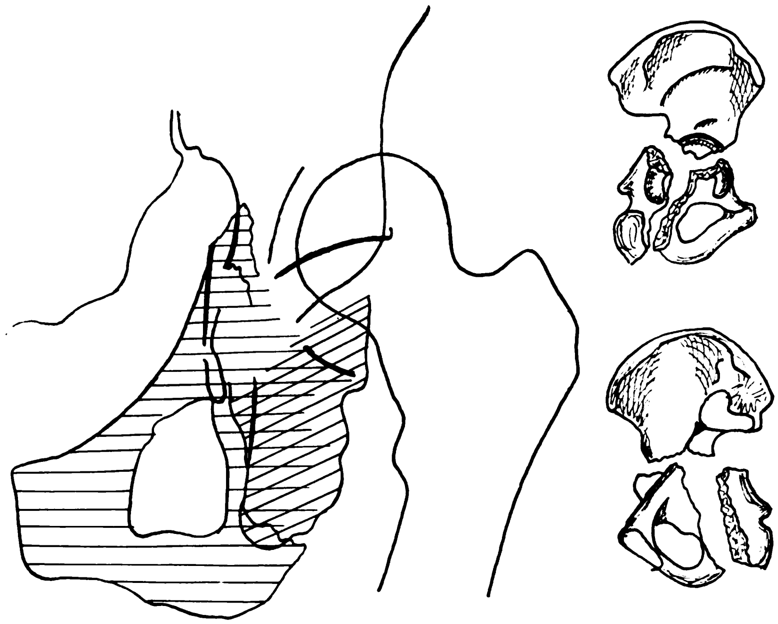

Fig. 23-A

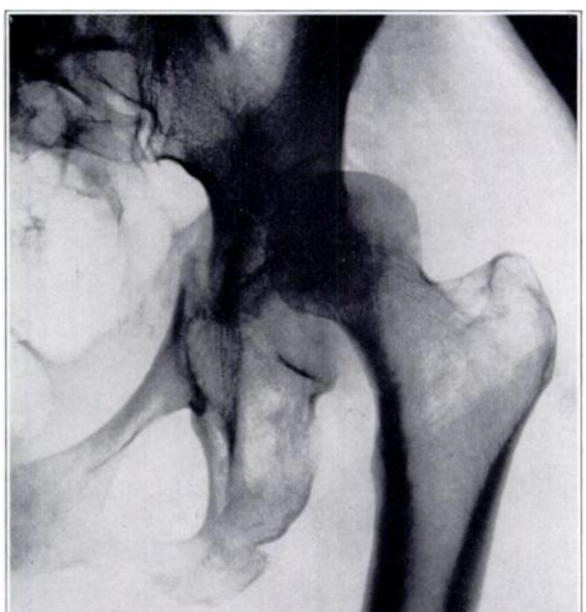

Fig. 23-B

Figs. 23-A and 23-B: Transverse fracture with associated fracture of the ilioischial column and posterior dislocation of the femoral head.

(Figs. 26-C and 26-D) demonstrates the large ilioischial fragment and shows the superior fracture line of this fragment well. The vertical line between the two columns through the quadrilateral surface is sometimes visualized, and the segment of the ilium containing the iliac crest and the roof of the acetabulum is easy to study on this view.

One must be careful not to classify these fractures as comminuted and not suitable for open reduction. We believe that they can and must be reduced as suggested for the other types of fracture.

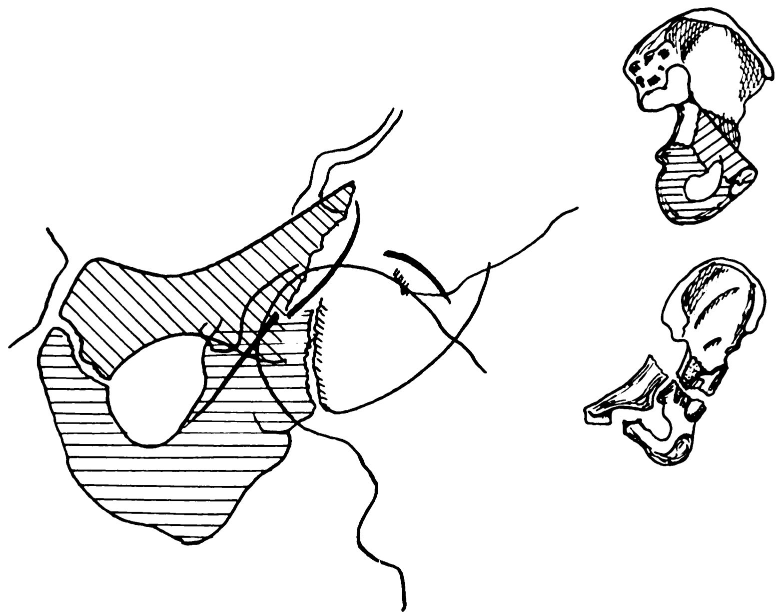

FIG. 24-A

Figs. 24-A and 24-B: Transverse fracture with associated fracture of the iliopubic column.

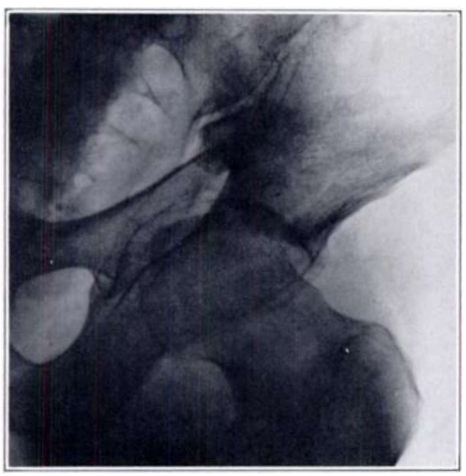

FIG. 24-B

FIG. 24-C

Fig. 24-C: Poor reduction was obtained because of mistaken evaluation of the fracture. A posterior approach was used, but an anterior approach should have been selected.

Treatment

In our experience the unsatisfactory results of non-operative treatment of fractures of the acetabulum with displacement are usually not due to failure to reduce the dislocation of the femoral head but, rather, to the inability to reduce the acetabular fractures.

Reduction of the dislocation of the head by traction, closed reduction, or both is usually easy, but exact restoration of the fractured acetabulum is, generally speaking, impossible.

Undoubtedly, it is because the surgical approach to the acetabulum is difficult that the so-called golden rule of treatment of articular fractures—anatomical restoration—has been violated. One cannot expect surgical treatment to correct

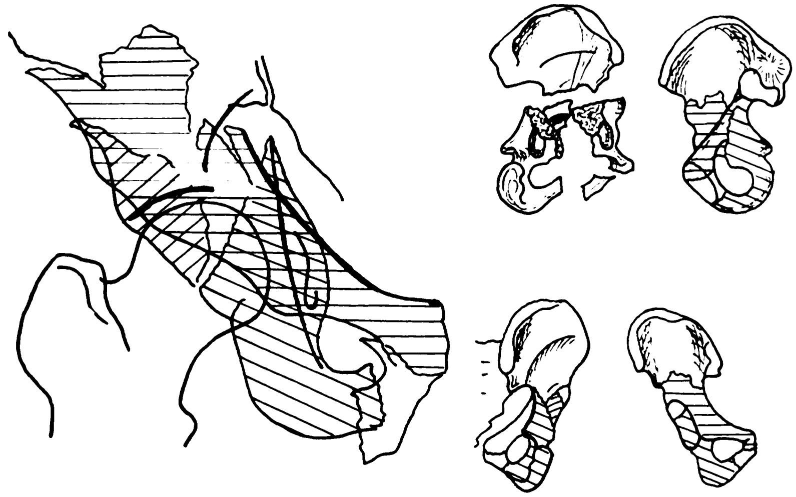

FIG. 25-A

FIG. 25-B

Figs. 25-A through 25-G: Associated fractures of both columns with a posterosuperior-rim fragment as well. The fracture line through the top of the anterior column runs along the upper margin of the acetabulum.
Figs. 25-A and 25-B: Anteroposterior view.

the vascular damage to the femoral head caused by the original trauma, but accurate reduction can prevent mechanical aggravation of the vascular damage and reduce or eliminate the mechanical element in the genesis of the post-traumatic arthrosis.

We recommend open reduction and reconstruction of fractures of the acetabulum, except when there is no displacement. We treat undisplaced fractures with complete bed rest and gentle, passive, range-of-motion exercises and massage for the first forty-five days. One must constantly be aware of the possibility of secondary displacement of these fractures. Crutch-walking without bearing weight on the involved limb is instituted for the next forty-five days and then gradual weight-bearing is permitted.

Displaced fractures are treated surgically by either an anterior or a posterior approach. The latter is used more frequently.

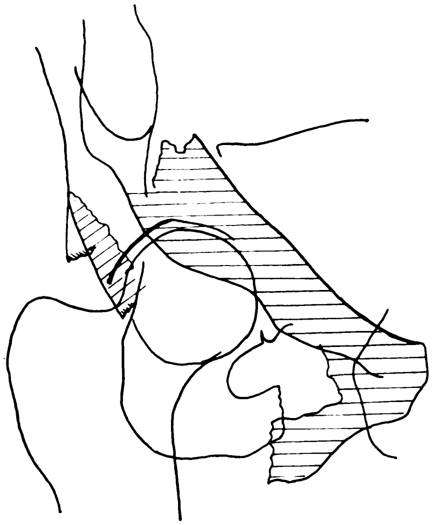

FIG. 25-C

FIG. 25-D

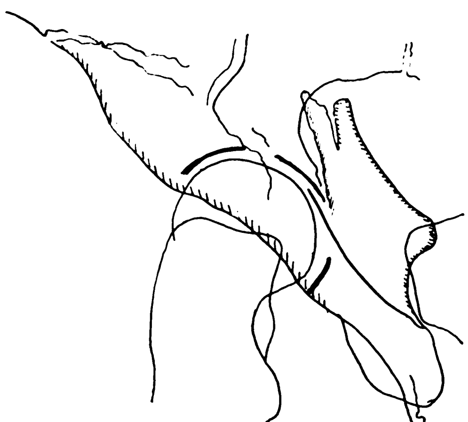

FIG. 25-E

FIG. 25-F

FIG. 25-G

Figs. 25-C and 25-D: Three-quarter internal oblique view.
Figs. 25-E and 25-F. Three-quarter external oblique view.
Fig. 25-G: After open reduction and fixation with screws and plates, using the posterior approach.

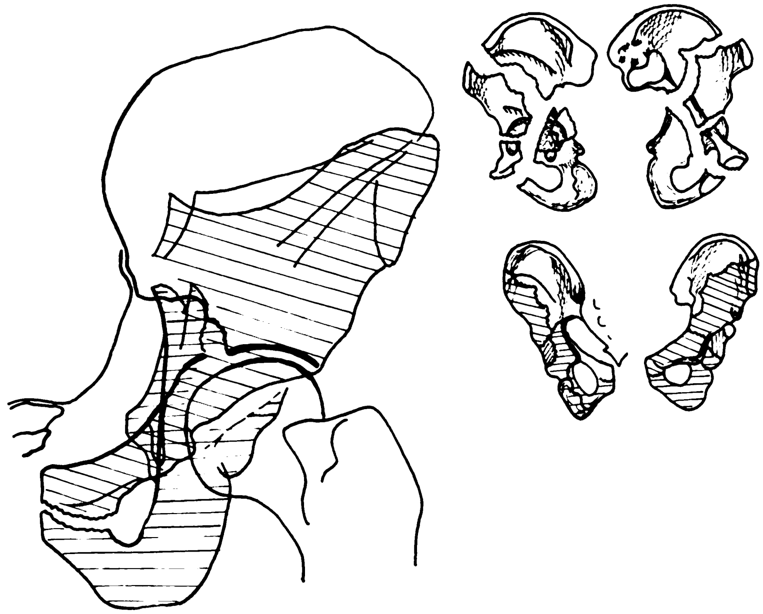

Fig. 26-A

Fig. 26-B

Figs. 26-A through 26-E: Associated fractures of both columns and of the posterior rim without dislocation. The fracture line at the top of the anterior column goes obliquely upward and forward to the anterior part of the iliac crest.
Figs. 26-A and 26-B: Anteroposterior view.

We utilize a posterior approach that is a combination of the approaches described by Langenbeck and Kocher (Figs. 27-A, 27-B, and 27-C). The patient is placed upon the orthopaedic table in the prone position. Transcondylar Steinmann-pin traction fixes the limb to the table, the leg being placed at almost a right angle to relax the sciatic nerve. The center of the incision is over the superior portion of the greater trochanter. The proximal limb is directed toward the posterosuperior iliac spine, and through this the fibers of the gluteus maximus are separated to expose the posterior aspect of the hip joint. The inferior part of the incision descends vertically along the lateral side of the trochanter, dividing the fascia lata.

The incision must extend as far as the posterosuperior spine and be sufficiently long to permit visualization of the acetabulum. The sciatic nerve is identified. The tendon of the piriformis is cut to gain a better view of the sciatic notch and the emerging sciatic nerve. The obturators and the gemelli are also divided at a distance from the greater trochanter to spare the blood supply to the neck and head of the femur.

If necessary, the lower portion of the external iliac fossa can be exposed subperiosteally and, with the sciatic nerve isolated, an instrument may be slipped into the greater sciatic notch. By cutting the sciatic spine at its base, as suggested by Virenque [6], a remarkable exposure of the quadrilateral surface can be obtained, sufficient to operate on the internal aspect of the acetabulum. This approach was used in eighty-eight of our 108 patients who were operated on early.

To reach the anterior aspect of the acetabulum we used an iliocrural approach. This approach extends along the anterior half of the crest of the ilium as far as the anterosuperior iliac spine (Figs. 28-A, 28-B, and 28-C) and then runs obliquely anteriorly and medially along the lateral aspect of the sartorius muscle for about fifteen centimeters.

The external aspect of the ilium is not stripped of the gluteal muscles. The medial aspect is superiosteally exposed by detaching the abdominal muscles, the crural arch, and the sartorius from the iliac crest, with care to preserve the inner-

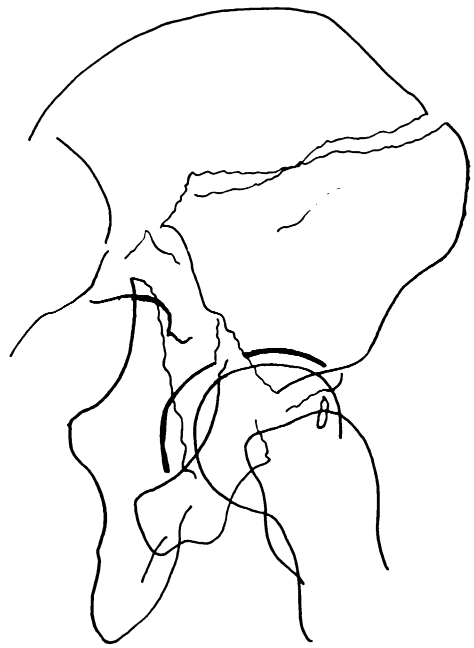

FIG. 26-C

FIG. 26-D

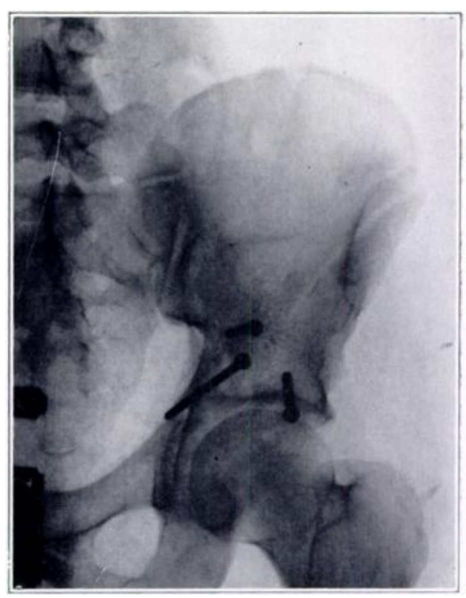

FIG. 26-E

Figs. 26-C and 26-D: Three-quarter external oblique view.

Fig. 26-E: One year after open reduction and fixation with three screws through the posterior approach.

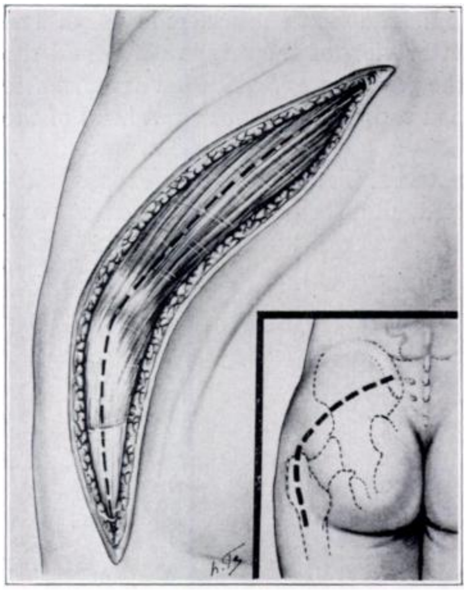

FIG. 27-A

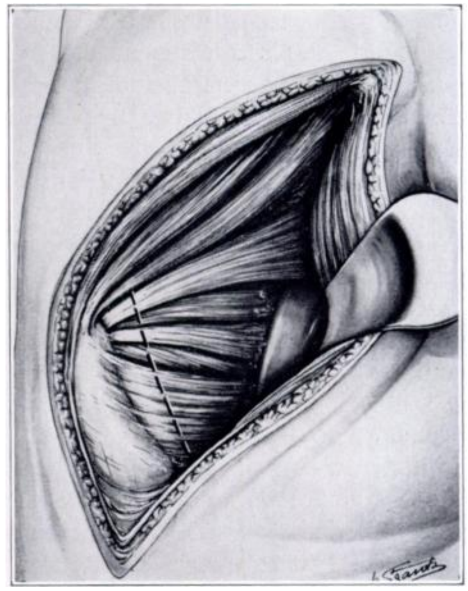

FIG. 27-B

Figs. 27-A, 27-B, and 27-C: Our posterior approach is a combination of the Langenbeck approach and the Kocher approach.

Fig. 27-A: Incision.

Fig. 27-B: After splitting the gluteus maximus and the fascia lata. The broken line indicates the location of the incision through the piriformis, gemelli, and obturator internus. The sciatic nerve is deep to the tip of the retractor.

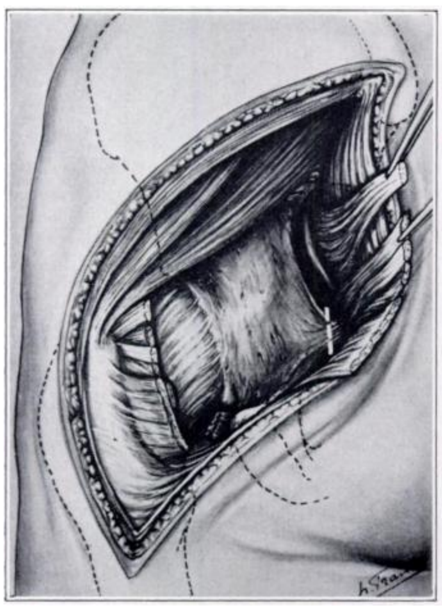

FIG. 27-C

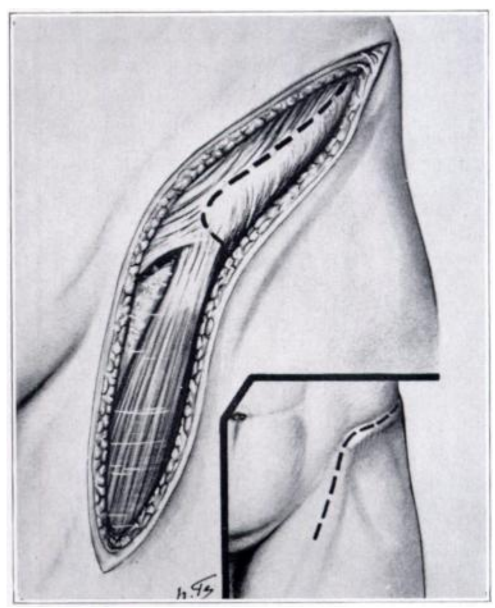

FIG. 28-A

Fig. 27-C: After section of the short rotator muscles. The broken white line indicates the line of osteotomy of the ischial spine used to gain access to the quadrilateral surface and medial aspect of the acetabulum.

Figs. 28-A, 28-B, and 28-C: Anterior approach.

Fig. 28-A: The skin incision. The broken black line on the iliac crest shows the line of subperiosteal exposure of the inner aspect of the ilium.

vation of the sartorius. Through this approach the internal iliac fossa can be exposed easily from the sacro-iliac joint to the iliopectinate protuberance.

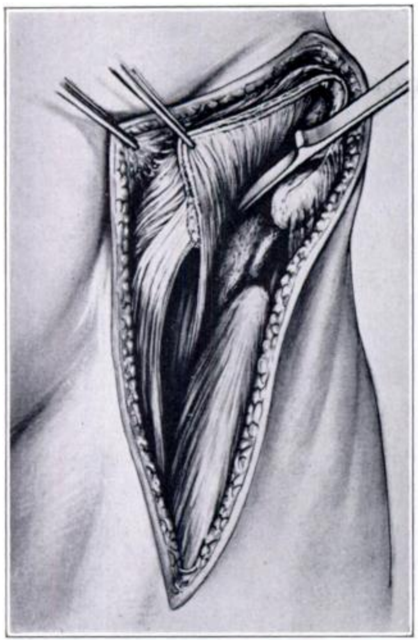

FIG. 28-B

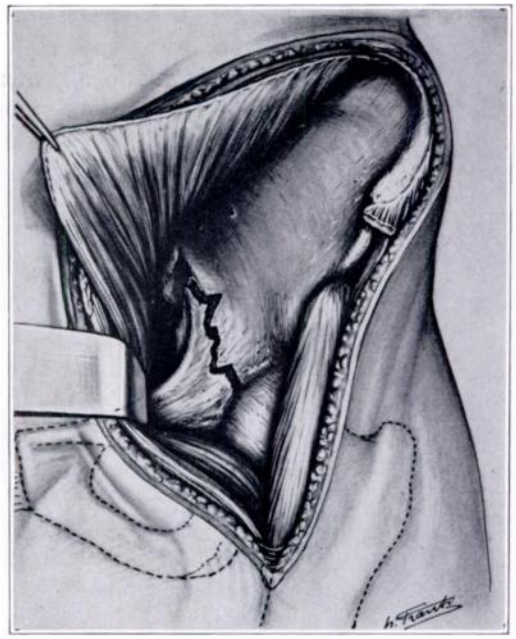

FIG. 28-C

Fig. 28-B: Reflection of the abdominal muscles, crural arch, sartorius, and iliacus to expose the internal iliac fossa.
Fig. 28-C: The superior channel and iliopubic columns are exposed.

Flexing the thigh facilitates release of the lateral edge and the deep surface of the iliopsoas muscle to give access to the horizontal ramus of the pubis.

This approach does not endanger the crural nerve provided the thigh is flexed. If the dissection is subperiosteal, the femoral vessels are easily avoided. The only problem is the femoral cutaneous nerve, which is often cut in the Smith-Petersen incision. If great care is taken to keep the dissection on the medial side of the ilium subperiosteal and if the femoral cutaneous nerve is preserved at this level and its gluteal branch is sacrificed, two femoral branches that follow the lateral margin of the sartorius can be spared and the nerve can be displaced medially inside the ilium.

If the patient is not too stout, this approach affords an excellent view of the iliopubic column, particularly its anterolateral aspect. It is possible to work on the quadrilateral surface by elevating the obturator internus after cutting its aponeurosis. As this is done one must take care to avoid injury to the obturator vessels and nerve.

The choice of approach is sometimes easy. In posterior-lip (Fig. 11-C) or posterior-column fractures (Figs. 13-C and 14-C), the posterior approach is obviously best. Similarly, fractures of the anterior column are best treated through the anterior approach (Fig. 20-G).

With transverse fractures, the decision is not so easy. The ideal approach would be one that allows the surgeon to work at both ends of the fracture line. Theoretically, the Ollier approach should be ideal. We used it on two occasions but it did not give the expected view and we have given it up. For simple transverse fractures of the acetabulum we now use the posterior approach, which provides good access to the posterior column and to the inner aspect of the pelvis. The thick and solid bone of this column provides good purchase for internal-fixation devices. Similarly, transverse fractures that have an associated posterior-lip or ilioischial-column fracture are better approached posteriorly (Fig. 21-E).

On the other hand, for a transverse fracture with an associated fracture of the anterior column, the anterior approach is the one to choose (Fig. 24-C).

Associated fractures of the two columns have all been approached posteriorly, aided by exposure of the lower portion of the wing of the ilium (Figs. 25-F, 25-G, and 26-E). In a few cases the two approaches were used in the same operative session, beginning with the posterior approach.

Vitallium screws, screws and plates, and now and then staples were used for internal fixation. Our most frequent choice now is Vitallium plates, shaped exactly to the contour of the bone at the moment of use, and Vitallium screws. We have found that crossed plates with a screw through the common central screw hole are a good, valuable type of fixation.

Early operation is advocated, ideally as an emergency procedure. Unfortunately, the general condition of the injured patient and the associated lesions often do not permit a major surgical procedure of this type for several days.

It is essential that the dislocation be reduced as soon as possible, even if complete treatment is not possible. A posterior dislocation is usually easy to reduce. The centrally dislocated femoral head should be brought back under the acetabular roof or what is left of it. The reduction is performed under general anesthesia and continuous traction is applied by skeletal traction, using either a tibial or transcondylar femoral pin. The limb is placed in external rotation to avoid recurrence of the posterior dislocation. Generally, our patients were operated on between five and seventeen days after injury, but, in fact, the time of operation is dependent on the date of arrival of the injured patient at the orthopaedic center.

Postoperative care varied, depending on the solidity of the fixation. When screws and plates were used, the fractures were treated by simply keeping the patients in bed. The patients are allowed sitting in bed, and some gentle, passive mobilization of the joints is done every day. Static contraction of all muscles is ordered. Some of the patients were immobilized in a plaster hip spica; others were placed in continuous traction. The choice of postoperative immobilization was often related to the stoutness of the patient and the quality of the skin.

When immobilization in a plaster spica was necessary, it was maintained for forty-five to seventy-five days, depending on the extent of the damage and the adequacy of the internal fixation.

Subsequently, patients were permitted to walk with crutches but they were not allowed to bear weight on the involved limb until 120 days after operation.

Results

There were three postoperative deaths, two caused by pulmonary embolism and one by multiple injuries, and one wound infection.

It is too early to assess the final end results as many of the patients in this series were operated on less than two years ago. However, our over-all impression after ten years of using our surgical approach to acetabular fractures is that we can trust this operation.

At the time of writing there were two cases of definite avascular necrosis of the femoral head, two of degenerative arthritis, and one of ankylosis secondary to infection. There were also five poor reductions which are likely to result in degenerative changes.

We observed very few hips with sclerosis of the femoral head. The limitation of motion of the joint is never of an important degree; usually, function of the hip is very good and its roentgenographic appearance is normal or nearly normal. On the whole, the immediate results are much better than with closed treatment and it seems that the late results are better too.

Long-term follow-up of this group of patients will be presented in the future.

(References are on page 1675)

began to disappear in the head as early as elsewhere, or earlier. Most often the last portion to be replaced was the middle third. The speed of absorption did not seem to be related to the speed of union or the incidence of avascular necrosis.

This study is not yet conclusive. It is being continued under the same conditions except that the grafts are of fresh-frozen bank bone rather than of autogenous origin and a two-hole sideplate is used to prevent retraction of the nail. The results will be reported later when long-term roentgenographic studies are completed. I am now using this method of treatment in most displaced fractures of the femoral neck in which the patients are under eighty and too healthy to warrant use of a replacement prosthesis.

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