The Classic

Epiphyseal Coxa Vara or Displacement of the Capital Epiphysis of the Femur in Adolescence

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Abstract This Classic Article is a redacted reprint of the original work by J.A. Key, “Epiphyseal coxa vara or displacement of the capital epiphysis of the femur in adolescence.” (Note the case reports and associated figures were deleted but are available in the supplemental reprint of the original article available online.) An accompanying biographical sketch of J.A. Key is available at DOI [10.1007/s11999-013-2907-9](https://doi.org/10.1007/s11999-013-2907-9). The classic article is reprinted courtesy of The Journal of Bone and Joint Surgery from Key JA. *J Bone Joint Surg.* 1926;8:53–117.

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Introduction

The head of the femur is so firmly fixed on the neck and the hip joint is so well protected by muscles and ligaments that traumatic separation of this epiphysis is unusual and for a long time was considered an impossibility. Poland [1] states that the first authentic case of traumatic separation of the upper epiphysis of the femur was that reported by Brousseau [2] in 1867. This was in a boy aged fifteen who was severely injured by the passage of the wheel of a heavy cart over the left hip. Death ensued within a few hours and post-mortem examination revealed a complete separation of the capital epiphysis of the femur. This case definitely established the possibility of the lesion, and from this time on an occasional specimen was recovered and a few cases were reported in the clinical literature. Poland in his extensive monograph published in 1898 was able to collect thirty-one cases from the literature. He ranks this epiphysis as being the third most frequent site of epiphyseal separation. In his book is to be found an adequate review of the subject up to 1898.

Epiphyseal or adolescent coxa vara of non-traumatic origin as a clinical entity is of still more recent date. Fiorani [3] in 1881 reported fifteen cases of adduction deformity of the hip in children. He regarded the deformity as a bending of the upper femur from localized rickets. His paper is inaccessible to me and in the abstract the cases are not described, but it is highly probable that some of them were epiphyseal coxa vara.

In 1886 Monks [4] reported a case of an unusual deformity of both hips in a boy of sixteen years of age. The typical history and characteristic physical findings in this case enable one to classify it as a case of bilateral epiphyseal coxa vara. Monks diagnosed the condition as arthritis deformans affecting both hips and causing softening of the bones with deformity from weight-bearing. His pathology was at fault, but subsequent years and a voluminous literature have added little to his clinical description of the condition.

In 1888 Keetley [5] reported a case in a girl of twenty years of age. He regarded the condition as adolescent rickets with a bending downward of the femoral neck.

He corrected the adduction deformity by subtrochanteric osteotomy of the femur and myotomy of the adductors, thus being the first to institute this surgical procedure for the condition.

Muller [6] in 1888 reported four cases from Brans' clinic. In one of these cases a resection of the head and neck of the femur was performed, the pre-operative diagnosis being tuberculosis of the hip. From the data obtained from the excised specimen and the study of the four cases, Muller introduced a new clinical entity into surgical literature. He termed the condition *Schenkelhalsverbiegungen im Jungesalter* or bending of the neck of the femur in adolescence, and is generally credited as being the discoverer of epiphyseal coxa vara. However, as will be pointed out later on in this paper, Muller's conception of the nature of the condition was erroneous.

Following Muller's report a number of the leading German surgeons became interested in the bending of the neck of the femur in early life. In 1894 Hofmeister [7] and Kocher [8] independently and almost simultaneously suggested the term coxa vara for the condition. The term became popular and was applied to various conditions in which an adduction deformity of the hip was present, and was assumed to be due to a bending downward of the neck of the femur. There was much controversy as to the cause of the bending in the idiopathic coxa vara of adolescence. In 1898 Sprengel [9], on the basis of two resection preparations, showed conclusively that the clinical picture of adolescent coxa vara could result from traumatic separation of the capital epiphysis of the femur. He also showed that this separation could result from a relatively mild trauma. This, of course, added to the controversy. Joachimsthal [10] states that in 1898 twenty-two papers on coxa vara were published in the German literature alone. The subject coxa vara was prominent in surgical literature up to about 1912, and since that time relatively little has been written on the subject. General reviews of the subject are given by Zesas [11], Drehmann [12], Hofmeister [13], de Quervain [14], Perrin [15], and Elmslie [16].

Definition and Classification of Coxa Vara

As was stated above, the term coxa vara was proposed by Hofmeister and Kocher as a substitute for Muller's *Schenkelhalsverbiegungen im Jungesalter*. These two surgeons were, however, somewhat at variance in their definition of coxa vara. Hofmeister [7] used the term to signify a skeletal deformity of the hip in which the angle of the neck with the shaft of the femur was diminished and the extremity maintained in a position of abnormal adduction. Kocher [8], on the other hand, on the basis of a specimen which he obtained by excision, used the term coxa vara

to describe a triple deformity of the neck of the femur. The neck was bowed upward, it was bowed forward, and it was twisted so that the distal extremity was hyperextended on the head of the femur. In Kocher's sense in coxa vara the limb must be in adduction, external rotation, and hyperextension. As the term came into more general use a wide variety of clinical conditions were described as coxa vara and it gradually was accepted in its anatomical sense (Alsberg [17]), and is now regarded as being synonymous with depression of the neck on the femur. This conception of coxa vara is a relic of old pre-roentgenologic days, when it was regarded as being due to a softening and bending of the neck of the femur. We now know that in the condition to which the term was first applied the femoral neck is not bent, but the deformity is due to a displacement of the epiphysis, and the relation of the neck with the shaft of the femur is for a long time unchanged. For this reason it is perhaps in order to define coxa vara as distinguished from an adduction deformity of the hip.

The term coxa vara should be limited to conditions in which the neck of the femur is intact and the head of the femur is in the acetabulum and not firmly ankylosed. In such a hip, when the extremity is maintained in a position of adduction or when the normal range of abduction is limited by bony deformity of the femur, coxa vara may be said to exist. The deformity may be in the head, epiphyseal line, neck, or trochanteric region of the femur.

As the term coxa vara became accepted in its anatomic sense clinical classifications were in order. The most widely accepted are those of Alsberg [18], Helbing [19], Hofmeister [13], and Drehmann [20]. All are based on etiology. Now that the X-ray is so generally available it is possible to classify our cases anatomically as well as etiologically.

Such a classification is the following:

- A. Capital Coxa Vara.
 1. Legg-Calvé-Perthes disease (osteochondritis juvenilis), (coxa plana).
 2. Arthritis (hypertrophic, atrophic, or malum coxae senilis).
 3. Destructive disease (tuberculosis, pyogenic, Charcot's disease, etc.).
- B. Epiphyseal Coxa Vara.
 1. Idiopathic.
 2. Traumatic.
- C. Cervical Coxa Vara.
 1. Congenital deformity.
 2. Congenital deformity in old reduced congenital dislocation.

3. Developmental or constitutional disease (rickets, achondroplasia, osteopsathyrosis, cretinism, osteogenesis imperfecta, osteitis deformans, osteomalacia, etc.).
 4. Destructive disease (tuberculosis, osteomyelitis, syphilis neoplasms, cysts, osteoporosis, osteitis fibrosa, etc.).
 5. Fracture with malunion.
- D. Trochanteric Coxa Vara.
1. Destructive disease as in C.
 2. Fracture with malunion.

In the above classification coxa vara is used purely in the anatomic sense. When used as a diagnosis the term coxa vara should be preceded by the adjective locating the chief deformity and followed by the etiology, as: cervical coxa vara due to rickets; or, trochanteric coxa vara due to old osteomyelitis, etc.

Incidence

Epiphyseal coxa vara is not a common condition, yet it is probably the most frequent cause of disability in the hip, which begins in the adolescent period. I was able to obtain data upon twenty-four cases which were seen at the Massachusetts General Hospital during a period of eighteen years (August 10, 1904 to January 28, 1922, inclusive). It is these cases which form the basis for this study of the condition. The cases were reviewed by me in 1921 and 1922 while working in the orthopaedic clinic. At that time Dr. Osgood was chief of the service and I am indebted to him not only for permission to study the material, but also for encouragement and stimulation to complete this analysis of the present status of the condition.

In Table I is given a summary of our cases. It is noticeable that epiphyseal coxa vara is being seen more frequently at the Massachusetts General Hospital in recent years. This is probably because we are recognizing the condition when it is presented to us. A fair average in a large orthopaedic clinic is from two to five cases of epiphyseal coxa vara a year.

From the literature it is difficult to judge how frequently the condition actually occurs. Schanz [21], in an analysis of one thousand private orthopaedic cases, encountered twelve cases of coxa vara. Among one thousand orthopaedic cases in Steindler's [22] clinic epiphyseal coxa vara occurred ten times. Whitman [23] in 1919 had seen seventy-two cases of coxa vara, and forty of these occurred in adolescents. Kleinfelter [24] remarked that he had seen nine cases in a year's time. Helbing [19] reports seventy-seven cases of coxa vara from Hoffa's clinic. Only twenty of these cases were of the epiphyseal type and they

occurred among ten thousand orthopaedic cases. Hofmeister [25] in Bruns' clinic encountered forty-five cases of coxa vara in a period of three years (1894–97). During this time twenty-one thousand cases (probably all types of surgery) passed through the clinic. In a period of ten years Hofmeister had seen eighty cases of coxa vara. Of the first forty, thirty-two were of the epiphyseal type. In Bruns' clinic he noted twenty-two cases of coxa vara to forty-seven cases of genu valgum.

If we compare epiphyseal coxa vara with tuberculosis of the hip, the former is much less common. Hofmeister noted twenty-two cases of coxa vara to three hundred and ninety cases of tuberculosis of the hip. But less than ten per cent, of the cases of tuberculosis of the hip begin during adolescence. Whitman [23] in one thousand cases of tuberculosis of the hip found ninety-five cases in which the disease began between the eleventh and nineteenth years of life. As bone tuberculosis seems to be steadily decreasing epiphyseal coxa vara is at present probably a more frequent cause of lameness in the hip beginning in adolescence than is tuberculosis. The condition occurs more often in males. In our series there were seventeen males and seven females. In a series of two hundred and fifty cases reported in the literature by various surgeons there are one hundred and ninety-two males to fifty-eight females. For reasons pointed out in a previous paper (Key [26]) the condition is limited to adolescent life. In Table I it is seen that in our series the youngest patient was ten years of age and the oldest patient was seventeen years of age when the epiphyseal coxa vara began. It is to be remarked that it tends to begin earlier in the female. In our series the average age at onset in six girls was 11.3 years and in seventeen boys it was 14.3 years. In the cases from the literature the ages given varied from nine to nineteen years; and the average for the girls was 13.5 years and the average for the boys was 15.4 years. Not infrequently the condition is bilateral. In our series of twenty-four cases four were bilateral. Hofmeister found one-third of his cases to be bilateral. In the cases in the literature thirty-eight, or 15.2 per cent., were bilateral. The left hip is affected more frequently than the right. In our series the ratio is seventeen left to fourteen right hips. Manz [27] found forty-eight left to twenty right hips affected. In one hundred unilateral cases from the literature there were sixty-three left and thirty-seven right hips affected.

Clinical Pictures

The histories of any large group of cases of epiphyseal coxa vara can be roughly divided into two classes: non-traumatic and traumatic. In the non-traumatic or so-called idiopathic type there is nearly always a history of pain.

Table 1. Summary of cases of epiphyseal coxa vara from the Massachusetts General Hospital

Initials	Sex	Age at Onset	Duration of Symptoms	Constitutional Type	Side affected	Shortening in Inches	Onset	Condition on Admission	Treatment	Admitted	Last Treated	Last Note
1 W. R.	M	15	2 months	Normal	R		Gradual	Hip flexed and everted. No motion permitted.	Traction and spica 5 months.	8-10-04	10-17-05	½ inch shortening. Walks with marked limp. Some pain. Motion good. (?)
2 H. G.	F	12	3 years	Normal	R	1	Trauma	Hip flexed, adducted, and everted. Not painful.	Intertrochanteric osteotomy. Spica 20 months.	12-1-08	1-29-15	Lame since operation. ¾ inch shortening. Motion limited.
3 J. W. A.	M	12	1½–2½ yrs.	Normal	R-L	¾	Gradual	No pain. Flex. 30, Abd. limit. Int. R. limited.	Subtrochanteric osteotomy.	5-7-09	5-30-09	Secondary hemorrhage and death.
4 B. C.	F	11	10 months	Fat	L	1¼	Trauma	No pain. Flex. 75, Abd. 10. Int. R. 0.	Right wound infected.	10-12-09	5-27-11	No pain. ¾ inch shortening. Hyperextension and Int. Rot. limited. Flex. to 90°, Abd. to 10°.
5 G. W.	M	14	2 months	Normal	R	½	Trauma	Flex. to 45, Abd. and Int. R. limited.	Manipulated. Spica 2 months. Crutches.	11-4-09	9-25-10	No pain, deformity, shortening, or limitation of motion.
6 R. T. M.	M	15	2 months	Feminine	R	¾	Trauma	Abd. 20, Int. R. 0. Flex. limited.	Manipulated. Spica 2 months. Crutches.	10-9-11	2-29-12	Hip stiff. No pain. 1 inch shortening. Flex. 115°, Abd. 25°, Int. Rot. 0°.
7 M. A. M.	F	13	5 months	Normal	R	1	Trauma	Acute pain. Fixed in Flex. 30, Abd. 20, and Ext. R. 30.	Manipulated. Spica 4½ months.	3-21-17	1-5-20	No pain. Hip practically ankylosed in 30° Flex. and 20° Add. 1 inch short.
8 V. R.	F	12	16 months	Fat	L	1	Gradual	Acute hip adducted and Ext. R. Flex. 90.	Obesity diet and pituitary extract. Manip. twice. Spica 11 months.	10-8-17	1-30-19	No pain. Flex. 90° Int. Rot. 0°, Abd. 15° Ext. Rot. 35°. 1 inch short.
9 N. T.	M	12	1 year	Slight Rachitis	L	2	Gradual	Abd. 20 and Int. R. limited.	Manip. twice. Spica 6 months.	3-26-19	10-26-19	In Spica. Did not return. Last ½ inch short.
10 F. R.	M	16	6 months	Slender Normal	L	½	Gradual	Acute epiph. sep. Hip extended. Add. and Ext. R.	Manip. unsuccessfully then open replacement of epiph.	12-1-21	4-15-22	Wilson's Case I.
11 M. C.	F	10	3 years	Slight obese	L	1	Gradual	Acute hip. Flex. 25, Add. 20, and Ext. R.	Spica 8 months.	10-23-18	4-11-21	Flex. to 65°, Abd. 15°, Int. Rot. 0°. 1 inch short.
12 S. L.	M	14	1 year	Normal	L	VA	Sudden	Flex. 90, Abd. 0, Int. R. 5.	Spica 6 weeks. Brace 8 months.	3-13-20	1-28-22	Flex. 75°, Abd. 10°, Int. Rot. 0°. 1½ inch short.
13 E. B. C.	M	16	3 years	Normal	L	1	Gradual	Flex. 55, Abd. 10, Int. R. 0.	Operation refused. Corrective only.	3-28-21	4-28-22	Perm. Flex. 20°, Flex. to 85°, Int. Rot. 0°. ¾ inch short.
14 G. B.	M	14	2 months	Normal	L	½	Trauma	Flex. 60, Abd. 0, Int. R. 0.	Spica 4 months. Corrective exercises 1 year.	1-29-21	4-11-22	Flex. 40°, Abd. 30°, Ad. 15%, Int. Rot. 0°½ inch short.

Table I. continued

Initials	Sex	Age at Onset	Duration of Symptoms	Constitutional Type	Side affected	Shortening in Inches	Onset	Condition on Admission	Treatment	Admitted	Last Treated	Last Note
15 T. J. D.	M	12	33 years	Normal	L	1	Trauma	Abd. and Int. R. limited.	Exostosis on grt. trochanter removed. Crutches 1 month.	4-4-11	8-9-21	Occasional pain. Flex. 130°, Abd. 0°, Int. Rot. 0°. Perm. Flex. 15°. ¾ inch short.
16 S. R.	F	?	?	Normal	R	¾	?	Pain in right hip.	Rest and ½ inch lift on left heel.	11-15-06	1-28-22	Mod. pain. Flex. 80°, Abd. 30°, Int. Rot. 0° ½ inch short.
17 F. K.	M	15	4 months	Normal	R-L	1	Gradual Gradual	Abd. Flex. and Int. R. limited.	Operation and bone removed from ant. part. Spica 1 month.	4-26-22	4-26-22	Rt. Flex. 45°, Abd. 0°. Int. Rot. 15°. 1 inch short. L. Flex. 135°, Abd. 20°, Int. Rot. 25°.
18 K. M.	F	10	2 years	Fat	R	1	Trauma	Flex. 90, Abd. 15, Int. R. 0.	Manip. Spica 5 months. Brace 6 years.	4-15-12	4-12-21	In splint. No motion. Flex. 20°, Abd. 0°, Int. Rot. 0°. 1 inch short in hip. Neurotic.
19 A. F.	M	13	9 months	Fat	R-L		Gradual	Flex. 0. Abd. 10. Int. R. 0.	Obesity diet and pituitrin.	7-24-16	3-22-22	Rt. Flex. 30°, Abd. 10°, Int. Rot. 10°. L. Flex. 120°, Abd. 25°, Int. Rot. 0°.
20 J. B.	M	16	6 months	Normal	L	½	Gradual	Flex. normal. Abd. normal, Int. R. 15.	Manip. Spica 7 months.	10-18-18	2-13-22	Flex. 90°, Abd. 5°, Int. Rot. 0° ½ inch short.
21 H.C.	M	15	1 year	Adolescent	R-L		Gradual	Flex. 60, Abd. 20, Int. R. 0.	Manipulated. Spica 9 months.	3-7-21	3-30-22	Rt. Flex. 60°, Abd. 5°. Int. Rot. 10°. L. Flex. 15°, Abd. 15°, Int. Rot. 20° ½ inch short.
22 J. E. C.	M	17	9 months	Slender Normal	L	5/8	Trauma	Flex. 45, Abd. 20, Int. R. 0.	Brace 8 months.	11-15-19	3-27-22	Perm. Flex. 15°, Flex. 20°, Abd. 10°. Int. Rot. 0°. 1 inch short.
23 M. K.	M	13	1 year	Normal	L	¾	Gradual	Acute hip. Flex. to 50. Abd. to 20. Int. R. limited.	Manipulated. Spica 1 month. Brace 5 months.	10-4-19 1	9-12-21	Flex. 50° Abd. 10° Int. Rot. 0° ½ inch short.
24 F. A. D.	M	13	10 months	Normal	L	¾	Gradual	Acute hip add. Ext. rot. in 45 Flex.	Manipulated. Spica 4 months.	5-6-21	3-6-22	Flex. 120°, Abd. 10°. Int. Rot. 5°. 1 inch short.

The pain may be confined to the hip, but usually radiates to the lower thigh and knee. In one of our cases the patient's only complaint was a limp and pain at the inner side of the knee, and the first impression was that this patient had a strain of the internal lateral ligament of the knee. In some instances the pain is referred to the leg or foot, and in other cases it is felt in the groin.

As a rule the pain is not severe in character and it is not constantly present. A very common history is that some months previously the patient began to tire easily and that after walking or standing more than usual he had some pain in one or more of the regions mentioned above. This condition existed for a few days or weeks and then disappeared for a short time, only to reappear and become somewhat more severe in character. By the time the patient consulted a physician there may have been several such attacks. In the early stages the pain is always relieved by rest and the patient is not troubled at night unless perchance he lies for some time on the affected side, when a dull ache may develop in the hip or extremity. The pain is accompanied by a limp which is noted by the parents. As the condition progresses the limp persists even when the pain is not present. The patient may have noted that the affected extremity was becoming shorter and smaller than that of the unaffected side. He may also state that the limb tends to turn outward, is restricted in movements at the hip, and is weaker than normal. In rare instances such as that of Whitman [28] and our Case 19, there may be absolutely no history of pain. On the other hand, when first seen by the physician the patient may be bedridden by severe pain in the hip which is accentuated by the least movement. As a rule there is no history of any preceding or accompanying illness or constitutional disturbance. Both hips may be affected. In the bilateral cases there is usually an interval of some months after the beginning of the trouble before the onset of symptoms in the second hip.

The above is what might be termed a pure non-traumatic history. More frequently the patient ascribes his trouble to some injury. He may have had a slight fall or received a blow upon the hip, or the trauma may have been severe. As a rule, however, the injury which the patient regards as the cause of his difficulty is a rather trivial one and not of sufficient severity to cause serious trouble in the hip of the average normal adolescent. In many of these so-called traumatic cases the physician can by questioning elicit the fact that the patient had had some mild pain in the hip before the injury occurred, and that the accident only served to enhance a pre-existing condition.

The immediate effect of the trauma varies in different cases. In some cases after a fall on the hip there is a dull ache with very little disability, while in others a similar fall may result in severe pain and immediate total inability to use the affected extremity. There is no relation between the

severity of the injury and the extent of the disability. In some instances one obtains a history of series of minor accidents, each followed by a period of pain and disability from which the patient recovered. In cases of this type the recovery from each trauma is apt to be more slow and less complete than was the recovery from the preceding one.

An occasional case of epiphyseal separation is seen in which there was a violent injury quite severe enough to cause a fracture of the neck of the femur in a normal person. The history is that of a fracture of the femur. All gradations exist between this type and the non-traumatic cases with gradual onset.

Just as there is a wide variation in the subjective symptoms, so is there wide variation in the objective findings. As the condition tends to continue active over a period varying from one to three years, the physical findings naturally vary considerably at the different stages of the process. One patient when examined may present a hip with little or no abnormality in appearance or measurements, while in another patient the hip is markedly deformed with considerable atrophy and definite shortening of the extremity. In either of the above cases the hip may be painless and freely movable within the range permitted by the deformity, or exquisitely sensitive and fixed by muscle spasm.

As will be noted in the discussion of the etiology, there is an abnormal condition present in the femur before the epiphysis is displaced. Theoretically, in the cases with gradual onset there is nearly always some pain before there is any atrophy or displacement of the epiphysis. Dr. Osgood [29] made the diagnosis in one instance before any displacement of the epiphysis had occurred. The patient, an obese girl of fourteen years, stubbed her toe in leaving his office and abruptly slipped the epiphysis. The diagnosis was made on the persistent mild pain in the hip, accentuated by standing and relieved by rest, occurring in an obese adolescent. The physical examination showed a slightly sensitive hip with some pain on abduction and internal rotation. The roentgenogram showed a slight broadening of the epiphyseal line and nothing else abnormal. Vieullet's [30] Case 1 is a similar instance and Schanz [31] reported five cases of early coxa vara, only two of which, however, were definitely of the epiphyseal type.

Opportunity to make an early diagnosis in epiphyseal coxa vara is unusual, as these cases do not as a rule seek medical attention until after the condition has been going on for some time and the deformity is definitely established. In our series (Table I) the duration of symptoms is recorded. It is seen that the earliest case entered the clinic two months after the onset of symptoms. There were four such cases and all gave a history of trauma. Excluding the two adult cases (Nos. 15 and 16) the average duration of

symptoms in our twenty-two cases was 14.6 months when they entered the clinic.

The typical unilateral case, then, as seen by us is a patient with the deformity well developed and not in the extremely acute stage. The patient walks with a slight limp in which the body sways to the affected side, and there is a tendency for the pelvis to sag on the unaffected side when the weight is borne upon the affected extremity (positive Trendelenberg). Walking may or may not be painful. The patient stands with the affected leg rotated outward and slightly adducted (Fig. 1). The normal lumbar lordosis may be decreased, increased, or unaffected (Fig. 1).

On inspection from behind, with the patient in the erect posture (Fig. 1), it is seen that the pelvis is tilted laterally, being slightly lower on the affected side. There is a slight spinal scoliosis with the lumbar curve towards the affected side and the dorsal curve towards the sound side. There may be some permanent rotation of the vertebrae with prominence of the ribs posteriorly on the sound side when the patient bends forward. There appears to be some atrophy of the buttock on the affected side, a definite depression being visible posterior to the trochanter, and the gluteal fold being lower than on the normal side. Viewed from the front the trochanter on the affected side is unusually prominent and there may be a visible fullness in the groin on that side. There is a moderate atrophy of the thigh (one-half to two inches) and there may be slight atrophy of the calf on the affected side. Genu valgum may or may not be present and the feet may or may not be pronated. On palpation a hard mass can often be felt in the groin on the affected side. This moves with the femur, and from its location seems to be the thickened head and neck of the femur. The buttock is flabby and the fingers sink into the depression behind the trochanter. The hip is as a rule not tender, but pressure upon the trochanter or heel may cause dull pain in the hip. The trochanter is higher than on the sound side and its tip is above the Roser-Nélaton line (usually about one-half to one inch). If measured from the mid-line of the body the trochanter on the affected side is often slightly farther from the mid-line than is that of the sound side (one-quarter to three-quarters inch). The affected extremity is shorter than that on the normal side. The shortening, measured from the anterior superior spine to the internal malleolus, is one-half to one and one-half inches (usually about three-quarters inch). This shortening is found to be in the femur.

On manipulation one finds more or less limitation of motion in the affected hip. In my experience the hip has always assumed a position of external rotation and slight adduction when the patient lies on the back. (I have not seen cases as described by Hofmeister [7] in which the hip was either in the neutral position or internally rotated.) The hip is extended, but if the unaffected thigh be fully flexed

Fig. 1 Epiphyseal coxa vara (left) one year after onset following fall from a horse. (Shriner Hospital Case.)

upon the chest, thus flattening the lumbar spine, there is often fifteen or more degrees of permanent flexion to be detected in the affected hip (Fig. 2). Flexion of the affected hip is almost always limited, usually to about eighty to ninety degrees. A very characteristic finding is that as the hip is flexed it passively rotates outward, so that with ninety degrees of flexion the hip is usually permanently rotated outward about forty-five degrees. Adduction is as a rule free, being limited only by the soft parts. Abduction is markedly limited; as a rule not more than ten or fifteen degrees is obtainable. In some cases there is permanent adduction with functional shortening. Rotation is best measured by turning the patient upon the face and having an assistant fix the pelvis. The knees are flexed and the legs serve as guides for determining the amount of motion in the hips. Internal rotation is determined by pushing the feet apart, thus rolling the femora outward from behind, and external rotation by crossing the legs and rolling the femora inward. In the affected hip external rotation is usually more free than normal (sixty to seventy degrees being not uncommon). Internal rotation is always sharply limited, usually only ten to fifteen degrees being obtainable, and there is often some permanent external rotation. Hyperextension of the affected thigh with the patient in the prone posture is usually limited on the affected side.

A rather characteristic point about these subacute or quiescent cases is that the ranges of active and passive motion are about equal. Furthermore, if the patient be examined while anaesthetized the limitations of motion are found to be unchanged.

Fig. 2 Epiphyseal coxa vara (right). Duration two years. Permanent Flexion 35° on entrance. (Shriner Hospital Case.)

As Hofmeister [13] pointed out, most cases of epiphyseal coxa vara at some stage of the process enter an acute phase. At this time the hip is exquisitely painful and is fixed in external rotation and adduction by muscle spasm. Little or no movement is obtainable. If such a patient be anaesthetized and then examined with the muscles relaxed the motions of the hip are found to be similar to those described above, or a few days of rest in bed may attain the same result, especially if extension be applied to the extremity.

A somewhat different picture is that of the recent acutely separated epiphysis. These cases resemble a fresh fracture of the neck of the femur. The position of the limb is as described above and there is the tenderness and swelling as in any other fresh fracture. Some authors have described a soft crepitus as being obtainable in these cases.

In bilateral cases the gait is an awkward, rolling one, with the body swaying from side to side at each step as in a bilateral congenital dislocation of the hip. The examination of the hips is as given above except that both sides are affected, usually unequally, and there is no normal for comparison. These patients are not sick, and the general physical examination is negative except for the frequent occurrence of certain constitutional types, as will be mentioned when the etiology is discussed. Laboratory examinations are negative. Blood counts are normal, the Wassermann is nearly always negative, the tuberculin test may be negative, and the urine is normal. In two of our cases sugar tolerance tests gave normal results. In recent cases at the Massachusetts General Hospital the calcium and phosphorus contents of the blood were normal or slightly increased (Wilson [32]).

Roentgenograms

Not only is epiphyseal coxa vara a progressive condition extending over a period of from one to three years, but after the migration of the epiphysis has ceased the process of adjustment sets in and lasts until early adult life when

growth is completed. Furthermore, during the active stage a slight trauma may cause an abrupt separation of the epiphysis with consequent modifications in the X-ray picture. Under these conditions one is justified in describing six main types of roentgenograms as occurring in epiphyseal coxa vara:

1. Before any displacement of the epiphysis has occurred the hip is essentially normal in appearance. The only abnormality visible in the roentgenogram is a questionable broadening and irregularity of the epiphyseal line.

2. *Early non-traumatic type.* There may be slight rarefaction in the head and in the region of the neck adjacent to the epiphyseal line, but as a rule the bone structure of the femur and the pelvis is normal. The contour of the acetabulum is normal and there is no evidence of any arthritic change in the hip. The joint space is clear and of normal width, there being no evidence of destruction of articular cartilage. The head of the femur is in the acetabulum, but is rotated so that its lower and posterior borders are displaced outward. The head is thinned out and appears to be enlarged in the vertical axis. The thinning of the head is most marked in its upper half. In the roentgenogram the shadow of the head is crescent- or sickle-shaped. Not only is the head changed in contour, but it is displaced slightly on the neck. The lower border of the head projects slightly as a beak-like process, extending down beyond the line of the lower margin of the neck. The upper margin of the head is thinned out and is a short distance from the prominence on the upper border of the neck near the epiphyseal line.

The epiphyseal line is not visible above the upper border of the head. Where the head is in contact with the neck it is vague, irregular, broadened, and almost vertical in direction. The femoral neck is normal in its relation to the shaft of the femur, but its upper border is lengthened and roughly convex upward, while its lower border is shortened and appears to be more sharply curved upward than is normal. The upper border of the neck is really more angulated than curved upward, and the apex of the angle is the prominence referred to above which marks the mesial end of the true upper border of the neck. The lengthening is due to the

displacement of the head, leaving bare the upper portion of the mesial extremity of the neck, which is flattened and inclined downward and inward. The lower border of the neck is buried in the concave epiphyseal surface of the head and thus apparently shortened. Between the lower border of the neck and the overhanging lower margin of the head some new bone formation is to be seen.

3. *Advanced non-traumatic type.* The femoral head is markedly displaced and rotated so that only its upper and anterior half is in the acetabulum. Its articular surface is directed inward, backward, and downward. The projecting lower border of the head curls outward and upward to approach the lower border of the neck. From this point the posterior border of the head can be traced curving upward and inward across the neck to approach the thin upper border of the head. The epiphyseal line is absent above and broad and irregular below where the head is in contact with the neck. It is inclined downward and outward.

The neck is often thickened and its elongated upper border is less angular, though the prominence referred to above is definitely present. Its inner portion is smooth and rounded and is in contact with the acetabulum. The lower border of the neck is sharply bowed upward and markedly shortened. The angle of the neck with the shaft appears to be decreased to about ninety degrees, and the whole neck is apparently bowed upward, the apex of the curve being the prominence marking the original mesial extremity of the upper border. The acetabulum is enlarged in the vertical diameter and the pelvis is slightly deformed on the affected side, the ischium being bent inward as in the ischium varum of Murk Jansen. There is definite alteration of the bone structure of the femur. The head is moderately atrophic, especially in its projecting lower half. There is some rarefaction in the upper portion of the neck and the dense lower border (Adam's bow) is thicker than normal. The joint space is clear and there is no evidence of arthritis.

4. *Early traumatic type.* The head is separated from the neck and lies in the acetabulum. It is rotated obliquely so that its lower and posterior borders are out of the acetabulum and applied to the neck of the femur. The head is normal in contour and its articular surface is directed downward, inward, and backward. The femur is displaced upward and externally rotated, the upper border of the neck being in contact with the acetabulum and the lower border is embedded in the cancellous tissue of the epiphyseal surface of the head. The neck points upward, inward, and forward. There is no bone atrophy. The joint line is apt to be rather hazy from the extravasated blood. Except for the displacement of the head upon the neck, the contour of all the bones is normal.

5. *Late traumatic type* (Fig. 3). The head is firmly fixed in its new position on the neck by callus and new bone. As

time goes on the upper border of the mesial extremity of the neck is rounded off, and with the upper and anterior part of the head enters the acetabulum to form the hip joint. The condition resembles the late non-traumatic epiphyseal coxa vara described above. The only difference between them is that in the traumatic type the head becomes markedly atrophic but retains its normal contour for several years.

6. In adult life the idiopathic and traumatic types are indistinguishable. The epiphyseal line has disappeared and the head and neck appear as a solid mass of bone. The neck may appear elongated and bowed upward with the lower border of the head projecting below as in the left hip of Figure 23. More frequently the neck is thickened and shortened as in the right hip of Figure 23 and in Figures 24 and 25. In this type with the enlarged mushroomed head the radiogram of the hip in adult life resembles that of an old Legg's disease (Fig. 24). The acetabulum is enlarged to accommodate the head of the femur, and in later life arthritic changes develop in the hip (Fig. 25).

In the above description six types of roentgenograms have been mentioned as occurring in epiphyseal coxa vara. It is to be emphasized that this division is purely arbitrary and is made for the purpose of description. There are only two types of epiphyseal coxa vara, namely: the traumatic and the non-traumatic. The roentgenograms of these in the early stages are characteristic. Later, as the condition progresses, they gradually come to resemble one another more and more closely, until in the adult it is impossible to determine from the roentgenograms whether the original condition was traumatic or of gradual onset.

It is also to be noted that all transitions between the early and late stages of each type occur. Furthermore, a non-traumatic type may by trauma be converted into an atypical traumatic type.

Pathology

Our knowledge of the pathology of epiphyseal coxa vara is still inadequate to explain the condition. In the earlier cases an excision of the hip was not infrequently performed in an effort to better the patient's condition. A number of these excised heads and necks were studied and the findings reported. The surgeons reporting them and the number of specimens by each are: Muller (1), Kocher (3), Hofmeister (2), Sprengel (2), Haedke (1), Schlesinger (1), Maydl (2), Helbing (1), Frangenheim (6), Rammstedt (4), Kappis (1), and Grashey described a specimen recovered at a post-mortem examination.

Muller's [6] specimen is described as a simple bending downward of the neck of the femur. The upper border of the neck was about twice the normal length and the lower

Fig. 3 Roentgenogram of hip of case shown in Fig. 1.

border was only 1.5 cm. long and sharply curved. The articular cartilage was normal. On section the epiphyseal line was visible as a narrow strip, but no cartilage was present. The epiphysis was sickle-shaped and capped the diaphysis as though the diaphysis had been driven into the epiphysis by a wedge fracture. The internal architecture of the bone was markedly changed. Adam's bow was thickened (1.5 cm.), and the compact bone extended along the lower border of the neck to the epiphyseal line. The bony lamellae were heavy in the upper and inner part of the neck and thin in the lower and inner part. Microscopic preparations were studied by Ziegler and showed normal bone and marrow. The cartilage of the epiphyseal line was normal but in the adjacent bone the osteoblasts and osteoclasts were more numerous than normal.

Kocher [8] excised three hips in two patients with epiphyseal coxa vara, one of the cases being bilateral. His gross findings differ from those of Muller in that the neck was bent obliquely downward and backward. There was also a torsion of the neck which was especially marked in one case, the head being rotated upon the neck in such a manner that with the head in its normal relationships, the femur was hyperextended. On the part of the head not in contact with the acetabulum the cartilage was atrophic, and in one instance was ravelled and covered with a thin pannus. Microscopic studies made by Langhans showed widening of the marrow spaces with hyperemia and abundance of marrow and fat cells, and a paucity of

osteoblasts and osteoclasts. Areas of calcium free osteoid tissue and lattice figures of von Recklinghausen were present in the bony lamellae in one case and suggested a diagnosis of juvenile osteomalacia. The epiphyseal line was irregular, the cartilage being interrupted by ingrowing spongiosa (Fig. 4).

In Haedke's [33] specimen the articular cartilage was thinned in places with dark spongiosa shining through. The epiphyseal line was very irregular in its upper portion but well formed below. It was broken here and there by dark red young bone. In the upper part of the neck, even under the periosteum, were irregular sized islets of cartilage. The zone of cartilage was broadened. Considerable osteoid tissue was present. Areas of fibrous tissue in the marrow merged into the osteoid tissue of the lamellae. Hofmeister's [7] first specimen was a necrotic head removed from a case which became infected after an osteotomy of the neck. The roentgenogram of the specimen showed a crescent-like head. His second case was a traumatic case of one and one-half years' duration. The roentgenogram showed a head markedly thinned in its lower half.

Both of Sprengel's [9] cases were of traumatic type and fairly recent. In the first case the head was only partially separated and in the second case it was completely displaced and lay with its epiphyseal border parallel with the lower border of the neck. In both cases the head was essentially normal in contour. The specimens (studied by Beneke) showed callus and fibrous tissue binding the head

Fig. 4 Right hip of Kocher's Case 1, anterior and posterior view. Duration one year.

Fig. 5 Left hip of Sprengel's Case 1. Anterior and posterior view and drawing of section. Duration three months. (Traumatic.)

to the neck. Necrotic bits of bone and cartilage and extravasated blood were found in this area. The diagnosis was traumatic separation of the epiphysis with union by callus and fibrous tissue (Fig. 5).

Helbing's [19] specimen in the roentgenogram resembled the second type of Hofmeister [13]. The epiphyseal line was broad and irregular. On microscopic examination the epiphyseal line was broken by bone and osteoid tissue. The columns of cartilage cells were absent and there was no longer any regularity in the arrangement of the cartilage cells. Extravasated blood and fibrous tissue were present in the marrow. Large numbers of cartilage cells were present in the joint capsule.

The case of Hoffa, reported by Schultz [34] and so often quoted as the second specimen described, was definitely of the congenital type and need not be considered here. The two specimens of Maydl [35] resembled those of Kocher. He compared them with specimens of arthritis deformans juvenilis. The specimens reported by Rammstedt [36] were regarded by him as traumatic separation of the epiphysis. They resembled Sprengel's specimens. All showed posterior and downward displacement of the head with the epiphyseal line broken by long trabeculae of bone. The head was bound to the neck in some areas by fibrous connective tissue.

Schlesinger's [37] specimen resembled Kocher's classical specimen with the marked torsion of the neck in addition to the usual displacement of the head. The cartilage on the upper part of the head was normal, but on the

lower part was thin and brittle and in the microscopic sections studied by Benda not a single normal cartilage cell was seen in this region. The epiphyseal line was 0.5 cm. broad and the arrangement of the cartilage was irregular with small islets of cartilage and necrotic cells and nuclei scattered here and there. The lower part of the head showed marked bone atrophy, but Adam's bow was thickened and here the bone was very hard (Fig. 6).

Frangenheim [38, 39] studied six resection preparations which exhibited varying degrees of displacement of the head. Microscopically, the cartilage of the epiphyseal region was more cellular than normal and the cells were irregular in their distribution. The cartilage was vascular, and enchondral ossifications in various stages were present in the netlike cartilage matrix. Cartilage islets of varying size were seen in the neighboring marrow tissue. In one case the head was bound to the under surface of the neck by connective tissue in which extravasated blood lay between the fibres. In this head were sclerotic bone lamellae with empty lacunae (Fig. 7).

In the specimen reported by Kappis [40] the head was bound to the neck by callus. The callus showed irregular fibrosis and hyaline cartilage with much connective tissue covering the surface of the neck and encroaching upon the articular cartilage as a pannus. The cells of the epiphyseal and articular cartilage were living, but the bone of the head was entirely necrotic and the marrow was necrotic in many places. New bone was being formed to replace the necrotic bone of the head.

Fig. 6 Schlesinger's preparation. Anterior view and section. Duration four months. (Traumatic.)

Fig. 7 Frangenheim's three specimens reported in his second paper. Duration: No. 1, two months; No. 2, six months; No. 3, six weeks. No. 1 followed a fall on the hip.

Grashey [41] obtained a post-mortem specimen from a patient who died of peritonitis. The right hip showed the typical deformity well advanced, and the left hip showed a slight deformity of the head and bluish coloration of the articular cartilage. The pelvis was asymmetrical (ischium varum of Murk Jansen or oblique coxalgic pelvis of Hofmeister).

There are then at least twenty-four pathologic specimens of epiphyseal coxa vara described in the literature. They range from cases with little displacement of the head, as in Case 1 of Frangenheim's second communication, to complete separation, as in Sprengel's Case 2. From descriptions of the above specimens and roentgenograms of our own cases it is possible to sum up our present knowledge of the pathology of epiphyseal coxa vara as follows: In an early case before any displacement has occurred we have a normal hip with a normal collodiaphyseal angle of the femur. The head of the femur is in its normal position and is covered by normal articular cartilage. There is no bone atrophy or softening. The only abnormality thus far detected is a slight broadening of the cartilage of the epiphyseal line. At this period some change occurs in the region of the epiphyseal line which causes a weakening of the structures which bind the head to the neck of the femur. The nature of this change is unknown, as no such case has ever been studied pathologically.

The head of the femur being loosened in its attachment, begins to slip downward upon the neck. As the head moves downward the cartilage covering the upper part of the head and the adjacent periosteum is stretched and finally there is a tear, which usually occurs at about the border of the cartilage. Before the tear occurs the cartilage of this region is thinned out slightly and assumes a bluish tint from the

shining through of the underlying cancellous bone. The cartilage of the lower portion of the head is in the early stages normal. The periosteum of the lower portion of the neck may be torn across, but usually remains intact and is stripped up from the neck for a short distance.

As the head slips downward the leg tends to rotate outward, and the head, being fixed in the acetabulum, moves backward upon the neck. The displacement of the head is progressive over a period of from one to three years and naturally varies at different times in the same case as well as in different cases. In some cases there is a torsion of the head upon the neck, the head assuming a position of flexion while the femur moves in the direction of extension. In such cases the periosteum, which usually maintains its attachment to the head in much of its circumference, is slipped upon the mesial portion of the neck and its fibres assume a spiral direction, those upon the front of the neck coursing upward and backward to the epiphyseal line. On section of such a specimen it is found that the epiphyseal cartilage is moving with the head. The epiphyseal line is broad and irregular. Unless there has been considerable disuse there is no appreciable bone atrophy.

Microscopic examination in the early period of displacement reveals an epiphyseal line broadened and more vascular than normal. The cells have lost their orderly arrangement in columns and are scattered irregularly through the cartilage matrix. The bone and marrow of the head and neck are essentially normal. There may be an increase in the number of bone cells, and islets of cartilage may be scattered through the marrow in the vicinity of the epiphyseal line. There is no necrosis. The articular cartilage is normal in structure though thinned out on the upper part of the head.

As the head moves downward and backward it rotates upon the lower and posterior border of the end of the neck which sinks into the cancellous tissue of the head. The projecting lower and posterior borders of the head approach the corresponding surfaces of the neck. The result is an apparent shortening of these surfaces of the neck from the encroachment of the head. The upper and anterior portions of the mesial end of the neck, which are laid bare by the departing head, become covered with fibrous tissue and serve to extend the anterior and upper surfaces of the neck, causing the lengthening of these surfaces.

The head having assumed its final position on the neck, the processes of repair and readjustment set in and continue until adult life when the bones assume their final form. It is to be remarked that the processes of repair and readjustment probably begin soon after the epiphysis begins to move, but are thwarted by the continued migration of the head. The repair consists in the binding of the head firmly to the neck. This is accomplished by the laying down of new bone in the region of the epiphyseal line and in the area between the lower and posterior surfaces of the neck and the overhanging head. There is a certain amount of atrophy of bone in the upper part of the neck and considerable atrophy of bone and articular cartilage in the lower and posterior parts of the head which are no longer in contact with the acetabulum.

In the process of readjustment there occurs a rounding off of the mesial ends of the upper and anterior surfaces of the neck, which are now in contact with the acetabulum, and a remodeling of this surface and of the upper and anterior portions of the head to form the new articular surface of the femur. There is also a remodeling of the acetabulum in an attempt to accommodate this new articular surface. The overhanging lower portion of the head may largely disappear. On section in late cases the head is sickle-shaped and there is considerable change in the internal architecture of the neck. The principal change is the thickening of the compact bone along the lower border of the neck to meet the increased strain due to the lessened mechanical efficiency of the neck of the femur. The pelvis becomes deformed on the affected side (ischium varum) as a result of the altered mechanics of the hip.

Microscopically, in the later stages there is the same disorganization of the epiphyseal cartilage as in the earlier stages. Enchondral ossifications are present and bony lamellae are invading the cartilage. There may be some fibrosis of the marrow with fibrillation of the cartilage matrix. In the lower part of the head there is marked atrophy of bone and there may be more or less necrosis of bone and cartilage cells. In cases in which the head has been suddenly moved a considerable distance by trauma there is the usual hemorrhage into the tissues and joint followed by the laying down of fibrous tissue and callus to

unite the head to the neck in its new position. In such cases there seems to be a tendency to necrosis of the bone and marrow of the head, though the cartilage remains viable. Microscopically, in such cases extravasated blood and necrotic bone and cartilage are described. In the specimen described by Kappis the bone and marrow of the entire head were necrotic. This is unusual. As a rule the head remains viable.

The readjustment occurs in these traumatic cases just as it does in those that progress gradually. The final result is a thick neck with short sharply curved lower and posterior borders and long convex upper and anterior borders, which is capped by a deformed head. The neck appears to be bent downward and backward and the collodiaphyseal angle as measured from the center of the head through the base of the neck is usually about ninety degrees. The neck is bowed upward and anteriorly, and on its elongated upper and anterior borders at about the junction of the middle and inner thirds there is a bony prominence (the original points of attachments of the upper and anterior borders of the head). The deformed head is directed inward, downward, and backward. The acetabulum and pelvis are modified as noted above.

Etiology

Very soon after the condition of epiphyseal coxa vara was accepted as a definite clinical entity its etiology became a subject for controversy. The many theories as to the cause of the condition can be grouped roughly under the three main headings as follows:

- (1) Disease, Including Endocrine Disturbances;
- (2) Static; and (3) Traumatic

1. *Theory That Epiphyseal Coxa Vara is Due to Some Abnormal Weakening of the Bone.* This is the first theory in point of time. Fiorani believed that his cases were due to rachitic softening of the neck of the femur. Kocher's [8] first case was resected in 1883 and at that time diagnosed adhesive arthritis. Monks [4] believed that he was dealing with an unusual case of arthritis deformans. Muller [6] thought that his bending of the neck of the femur was due to adolescent rickets, though no evidence of rickets was found in the excised specimen. Keetley [5] likewise diagnosed his case as adolescent rickets.

The first specimen showing pathology was one of Kocher [8], reported in 1894. In this specimen areas in the neighborhood of the epiphyseal line were regarded as being typical of osteomalacia. Kocher first noted that the deformity occurs in the epiphyseal line, and while he supported

the static theory he believed that in certain cases the femur was weakened by a juvenile osteomalacia localized in the femoral neck. As noted above, adolescent rickets played a prominent part in the theoretical origin of the earlier writers, then it apparently fell into disrepute for some years, though Hofmeister emphasized the adolescent type of Mikulicz [42] as being especially prone to develop coxa vara. In 1902 Haedke [33], in his microscopic studies of a specimen from a typical epiphyseal coxa vara, noted changes in the region of the epiphyseal line which he regarded as being characteristic of rickets. Peltessohn [43] regarded rickets as being the most important etiologic factor, though he admitted the influence of trauma in certain cases.

Later writers have revived the theory of late rickets. Bloch [44], in a rather extensive study of fractures of the neck of the femur in young persons, is impressed with the fact that late rickets is a definite clinical entity and that the pathologic findings in the specimens of epiphyseal coxa vara of earlier writers can be interpreted as rickets. He considers the condition a deformity of adolescent rickets. Fromme [45, 46], in his extensive studies on late rickets (ninety-eight adolescent and five adult cases) as encountered in the population around Gottingen during the recent period of food privation due to the World War, does not hesitate to include epiphyseal coxa vara among the surgical conditions due to late rickets and war osteomalacia. He reports no case in detail but states that two cases of traumatic coxa vara were seen in the clinic and both showed roentgenograph evidence of late rickets. In seven cases of epiphyseal coxa vara treated at the Zurich clinic, Frösch [47] found evidence of rickets in six and the other patient was a woman twenty-eight years old who probably had had late rickets.

Arthritis deformans was suggested by Monks and Charpentier [48] (quoted from Lauper [49]), and Maydl regarded the juvenile type of arthritis deformans as being one of the causes of essential or non-traumatic coxa vara. Freiberg [50] in reporting two cases of epiphyseal coxa vara regarded them as a form of osteoarthritis deformans and did not operate to correct the deformity because he believed the bone to be the seat of trophic disturbances (his first case resembled an old Legg's disease).

Frangenheim [38, 39], on a basis of six resection preparations, definitely differentiated epiphyseal coxa vara from osteoarthritis deformans juvenilis and found no evidence of rickets in any of his specimens. In all of his specimens he noted some abnormality in the epiphyseal cartilage. He interpreted this abnormality as a growth disturbance and classed it as a localized form of chondrodystrophy. Frangenheim [38, 39] considers the adolescent habitus of Mikulicz as being of great importance and states that by one familiar with the clinical picture of adolescent

coxa vara the condition can be diagnosed at a glance. He regarded the epiphysis as slipping on a neck which was already diseased and considered true traumatic separation of the upper femoral epiphysis in a normal adolescent as being a very rare occurrence. A somewhat similar view was held by Schwartz [51], who stated that traumatic separation of the upper epiphysis of a normal femur is not possible and that the condition is always the result of some as yet unknown disease of the cartilage.

The theory that in epiphyseal coxa vara the neck of the femur is the seat of a low grade osteitis due to infection was advanced by Froelich [52, 53] in 1904 after he had obtained cultures of staphylococci from material obtained by boring into the trochanter in two cases of coxa vara. Recently [54] he has recorded a case of Legg's disease which was observed from 1905 to 1917. In 1917 the picture resembled an epiphyseal coxa vara and Froelich concluded that the two conditions are stages in the evolution of a single malady which is an osteitis of the femoral head and is generally due to staphylococci. In his latest paper [55] he recognizes the effect of trauma in causing dislocations of the epiphysis but regards the trauma as being purely incidental in the evolution of the disease, the real cause of which is an epiphysitis. Piatt [56] in a recent review of thirty-four cases of pseudocoxalgia does not mention epiphyseal coxa vara, but five of his cases (24–28 inclusive in Group III) classed by him as arthritis deformans juvenilis coxae, are typical examples of epiphyseal coxa vara. Piatt's conception of the etiology is that the condition is due to an inflammatory lesion in the upper end of the femur, the changes being subchondral in location, the lesion being most probably due to an infection of low virulence carried to the femur by the blood stream. Poncet [57] naturally included epiphyseal coxa vara with genu valgum, flat foot, and scoliosis among the conditions due to his conception of inflammatory tuberculosis (toxic tuberculosis without tubercles and without bacilli in the locus of the lesion). Iselin [58] believes that the epiphyseal line is weakened by a nutritional disturbance similar to that which in his opinion causes Legg's disease.

Hofmeister [7] and others among the earlier authors emphasized the frequent occurrence of the adolescent type of Mikulicz [42] in patients with coxa vara. This is not the typical fat boy but is the overgrown boy or girl with large bones and large epiphyses, with rather flabby, weak skeletal musculature, and rather more subcutaneous fat tissue than is usual. These patients after prolonged standing with the hands at the sides tend to develop cyanosis of the extremities with mottling and coldness of the hands and feet. As was noted by Mikulicz, the type is frequently seen in cases of adolescent genu valgum and flat feet.

With the rise of endocrinology more attention is being paid to the habitus of the adolescents who develop

epiphyseal coxa vara, and recent authors are emphasizing the frequency of its occurrence among fat boys and girls. To many, it is an endocrinopathy or constitutional disease. Stieda [59] noted increased knee jerks and ankle clonus in two cases. The adenoids and tonsils were enlarged and he considered the condition as the result of a lymphatic chlorotic constitution with softening of the bones, especially in the region of the epiphysis, and possibly some disturbance in thyroid function.

Kirmisson [60], formerly the champion of the traumatic theory in France, has recently been impressed with the frequent association of epiphyseal coxa vara with obesity [61, 62] and by the tendency of the condition to be familial. He reports several cases in obese children and he noted four cases in one family and two cases in another family. He states that obesity can cause various bone dystrophies and that this establishes a relation between it and coxa vara. In his cases the sellae were normal but development of the genitalia was retarded. He regards the condition as being due primarily to thyroid insufficiency. Vieullet's [30] five cases all occurred in obese girls. Ridlon [63] was impressed by the frequency with which coxa vara occurred in fat boys of feminine type.

Hass [64] found more or less outspoken constitutional abnormalities in all cases. They were the overgrown eunuchoid or fat types with genital hypoplasia and persistence of epiphyseal lines. To him the genital hypoplasia is the primary cause and trauma seems to be merely incidental. Riedel [65] believes epiphyseal coxa vara to be due to an irregularity of the growth of the bone and cartilage in the epiphyseal line, similar to the process in Legg's disease and possibly of an endocrine or infectious nature. Whitman [23] finds the fat boys especially susceptible to traumatic epiphyseal coxa vara. Four of the seven recent cases at the Massachusetts General Hospital reported by Wilson [32] occurred in excessively fat patients (three boys with feminine habitus and one girl with infantilism). In two cases the basal metabolism was normal and there was no evidence of rickets. Wilson believes that endocrine disturbance, probably of the pituitary, plays a part in the production of the condition.

2. Static Theory. The static theory in its original form explained epiphyseal coxa vara as being the result of a bending of the neck of the femur by superincumbent weight. It stressed the plasticity of growing bone and assumed that in epiphyseal coxa vara the weight borne was out of proportion to the strength of the bone. Muller [6] perhaps, may be regarded as the founder of this theory, but he assumed that the bone was weakened by rickets. So it remained for Hofmeister [7] to first propose the static theory as outlined above and he was its foremost champion for many years, defending it on numerous occasions and never at any time admitting that the affected hip was the

seat of any disease. In later years [13] he admitted traumatic separation of the epiphysis as the cause in a small percentage of the cases, but sharply differentiated these cases from his essential or static coxa vara of adolescence. He emphasized the adolescent type of Mikulicz as occurring frequently among his cases. He also emphasized the effect of prolonged standing, especially with weight-bearing, as being a prominent causative agent. His long series of patients was largely from the laboring class. Manz [27] followed Hofmeister's views very closely. To him epiphyseal coxa vara was largely an occupational disease and might be called "Bauerbein" (farmer's bone), just as genu valgum was often called baker's bone. He explained at length the mechanics of the development of the deformity in field workers.

Hoffa [66] supported the static theory in the non-traumatic cases, and Helbing [19] in reporting the cases from his clinic considered epiphyseal coxa vara as a symptom which often followed excessive strain on growing bone.

Kocher [8] first noted that the deformity is localized in the epiphyseal region, and in one of his cases noted changes suggesting localized osteomalacia. For this reason he is generally credited as holding juvenile osteomalacia as a causative agent in all cases. This is unjust, as his work is really one of the foremost arguments in support of the static theory. Two of his cases occurred in cheese makers and he very carefully pointed out the unusual strain with the pelvis tilted backward, incident to this occupation, and its consequent effect upon the hip in adolescence. Lauper [49] reiterates Kocher's views, holding that the passive fixation of the pelvis offers the best explanation of the classical deformity.

Sudek [67] described a system of oblique bony lamellae in the femoral neck which passed upward and forward. The crest or ridge on the anterosuperior surface of the neck near the epiphyseal line marked the termination of these lamellae. An hypothetical insufficiency of these oblique lamellae permitted the neck to bend down and back with weight-bearing, thus giving the typical deformity without assuming the presence of pathologic changes in the bone. Bahr [68] regarded Sudek's theory of primary insufficiency of the bony bow as untenable on mechanical grounds and stated that the roughness on the anterosuperior surface of the neck had nothing to do with weight-bearing, but was the point of attachment of strong fibres in the capsule. He, nevertheless, considered excess weight-bearing as the causative agent.

Von Blum [69] in four patients who had lost the ability to bear full weight on one leg noted coxa vara in the sound hip. Two of his cases were of old tuberculous hips with coxa vara on the unaffected side. In several museum specimens with unilateral hip disease there was coxa vara on the unaffected side. In most cases there was no bone

disease to explain the condition. He concluded that the weight of the pelvis was sufficient to explain all forms of coxa vara, and that pure congenital and pure traumatic cases without static cause are very rare. A very unusual modification of the static theory is that of Jaboulay [70] and his pupil Picqué [71]. They considered epiphyseal coxa vara as the result of a process of compensation by nature in an effort to correct various asymmetries in the lower extremities, such as inequality in length, genu valgum, and flat feet. Another bizarre theory is that of Böhm [72] who cites the flattening of the neck of the femur in the anthropoid apes and so regards coxa vara as an ancestral rest. To him there are early and late congenital deformities. The late congenital deformities are due to primary morphological developments which under the influence of weight-bearing result in vicious development. Epiphyseal coxa vara is then a congenital deformity which develops during adolescence. Herz [73] takes issue with Böhm and points out that in the higher apes the neck of the femur is not in varus.

Two other modifications of the static theory deserve mention. Whitman [23] holds the static theory for his non-traumatic cases but believes that the coxa vara occurs in those adolescents in whom there is a mechanical predisposition to the deformity. This predisposition is a slight depression of the neck, usually due to early rickets, which subjects the part to increased strain and produces coxa vara in adolescence.

Drehmann [20] takes what he calls a middle ground, considering both statics and trauma as being of importance in producing the deformity. However, he also notes a mechanical predisposition to epiphyseal coxa vara. He studied the unaffected hips of his unilateral cases and found marked anterior torsion of the femoral neck on the sound side. The neck was usually longer and steeper than normal. An abnormal static or traumatic strain on a long, steep neck with anteversion caused an acute or chronic separation of epiphysis of the growing bone.

3. Traumatic Theory. Sprengel [9] first showed that traumatic separation of the upper femoral epiphysis could result in a clinical picture identical with the coxa vara of Kocher and Hofmeister. In both of his cases there was a history of trauma followed by disability. At operation the epiphysis in each case was markedly displaced and reattached to the neck. Microscopic study of the specimens revealed no evidence of disease of bone or cartilage, but the picture of a healing epiphyseal separation. He introduced the term traumatic coxa vara and regarded the traumatic as being much more frequent than the static coxa vara.

Rammstedt [36] in his resection specimen found beginning bony union between the displaced head and the neck and a beginning disappearance of the epiphyseal cartilage line. In order to test the traumatic theory he performed ten experiments upon cadavers of individuals aged

eight to seventeen years. He was not able to produce typical epiphyseal separation, as usually a fragment of the neck was broken off with the head. He concluded that it was possible by trauma to loosen the head but not to displace it, because the strong periosteum bound it firmly to the neck. Epiphyseal coxa vara then was due to trauma, but in many cases the trauma served merely to loosen the head from its attachment to the neck and afterward the continuous strain gradually produced the deformity. In other cases there was a definite acute traumatic displacement.

Schlesinger [37] considered his case to be a purely traumatic separation in a normal femur. He considered the epiphyseal line as the locus minoris resistentiae in normal adolescents, and emphasized the fact that in every case reported the bend was in the epiphyseal line.

Kempf [74] in reporting sixteen cases from Sprengel's clinic found definite trauma in ten and was not able to exclude it in the other six. There was no difference between the two groups and no other pathology was present. To him every painful hip in adolescence was strongly suspicious of coxa vara, and there was no coxa vara except traumatic coxa vara.

In Abrahamsen's [75] series all were considered traumatic and compensated as such. In older cases the trauma was usually direct in character. In some instances the condition was thought to be a summation of the results of repeated slight traumata which develop a pathologic condition in the femoral neck, thus paving the way for the final trauma which results in the displacement.

Fittig [76], on the basis of two cases in which the early radiograms showed a traumatic type of epiphyseal separation and which later exhibited the picture of the typical coxa vara statica of Hofmeister, concluded that the static theory was purely hypothetical but that the traumatic theory was clearly the solution in a great number of cases. Lorenz [77] regarded epiphyseal coxa vara as merely a special form of fracture of the neck of the femur. Grashey [41] considered his case traumatic and Seibs [78] noted trauma in his cases, but often the trauma was of minor character. Hoffa [79], Whitman [23], and Hofmeister [13] recognize trauma as the cause in certain cases. Elmslie [80] considered most cases to be purely traumatic in origin but in certain cases he recognizes a weakness or imperfect ossification similar to that found in the epiphysis in genu valgum. Steindler [22] states that in adolescents nine to sixteen years of age under certain traumata, epiphyseal separation is probable, and that epiphyseal coxa vara is a hazard of adolescent life just as fracture of a neck of the femur is a hazard of senility.

Discussion of The Etiology

We have, then, three main theories to explain epiphyseal coxa vara. Beginning with the simplest, they will be

considered in the order of their complexity, viz: traumatic, static, and disease of the bone.

The traumatic theory assumes that in the normal adolescent the capital epiphysis of the femur may be loosened or separated by trauma, which in many instances is very slight and may even pass without immediate symptoms and be forgotten by the patient. It is not to be denied that trauma often inaugurates the symptoms in epiphyseal coxa vara. The essential point is whether or not the upper end of the femur was normal when the trauma caused the epiphyseal separation. If the degree of trauma encountered in the average case of epiphyseal coxa vara were sufficient to cause epiphyseal separation in the normal adolescent, then epiphyseal coxa vara would be almost universal because the average adolescent suffers a number of such injuries yearly. Lorenz [77] regarded epiphyseal coxa vara as merely a specialized form of fracture of the neck of the femur and saw no reason to assume any predisposing bone pathology to explain the condition. By specialized, he meant that the fracture occurred in the epiphyseal line. There is a more important difference between epiphyseal coxa vara and the traumatic fracture of the neck of the femur. It is that epiphyseal coxa vara is frequently bilateral. In Hofmeister's experience, one-third of the cases were bilateral, and in the two hundred and fifty cases referred to above, many of which were traumatic, fifteen per cent, were bilateral. Fracture of the neck of the femur is relatively much more frequent than epiphyseal coxa vara, yet very few bilateral cases are recorded. There is then some predisposing factor which weakens the attachment of the epiphysis to the neck.

It is probably true that the epiphyseal line is the locus minoris resistentiae in the adolescent hip (Key [26]). This being true, cases of true traumatic separation of the upper epiphysis of a normal femur undoubtedly occur. In these cases the trauma is severe in character. Such cases are very unusual and it is not always possible to differentiate them from the usual cases with slight or no trauma. It is also probable that there are a great many adolescents who pass through a phase in which the epiphyseal line is weaker than normal but in whom epiphyseal coxa vara does not occur, because of lack of adequate trauma at the right time.

The static theory as advanced by most of its adherents infers that growing bone is less able to stand strain than is adult bone and that in many adolescents there is a disproportion between the superincumbent weight and the strength of the femoral neck. Such cases develop coxa vara by gradual bending downward of the neck. In the description of the pathology as given in this paper it has been emphasized that the neck is not actually bent but the epiphysis is displaced and the neck remodeled by absorption and laying down of bone to meet the altered mechanics of the hip. If the static theory were true, practically all cases of epiphyseal

coxa vara should be bilateral, just as cases of rachitic coxa vara are bilateral.

Advocates of the static theory should consider the normal factor of safety in the adolescent femur. I have not been able to find or furnish any data on this subject, but in adult femora the factor of safety in a man running at full speed is five and five-tenths, according to Koch [81]. Dixon [82] found that vertical pressures of eighteen hundred to twenty-five hundred pounds were necessary to cause fracture of the neck in a series of adult femora. As interruptions of continuity in the neck and epiphyseal line are rare in adolescents, and fractures of the neck are fairly common in adults, it is reasonable to assume that the factor of safety in adolescence is at least five or more. This being true, it is difficult to understand the giving way of a normal adolescent femur under the influence of obesity or hard labor. In other words, in epiphyseal coxa vara there is undoubtedly some weakening in the epiphyseal line which is the real primary cause of the condition.

The superincumbent weight is undoubtedly of importance in most cases and with muscle pull determines the direction in which the epiphysis moves, but it must act on a bone of less than normal resistance. Jaboulay's modification of the static theory is obviously speculative. Drehmann's finding of anteversion and an increased angle of the neck and Whitman's suggestion of a slight decrease in the collodiaphyseal angle have not been present in the sound hips in our series. In our series the unaffected hips were normal except that in some instances there appeared to be a broadening of the epiphyseal line. Against the findings of von Blum we have the observations of Hoessly [83] who studied the sound hip in ten patients who were severely crippled on one side. In no instance was coxa vara present in the unaffected hip.

In the discussion thus far it has been emphasized that trauma and static influence are both important factors in the development of epiphyseal coxa vara but that they must act upon a femur in which the head is less firmly attached than normal. This fact has been recognized by numerous observers, and a number of them have tried to explain the weakening by disease. The condition most often incriminated is rickets or rather that vague, and in this country almost unknown clinical picture, adolescent or late rickets. In our cases stigmata of rickets were noted in only one case. This, however, is of rather minor importance as an enthusiast could undoubtedly find some stigmata in almost every adolescent and particularly in those of the type prone to develop coxa vara. What is of much more importance is that in rickets the bones are softened and bend in the diaphysis, while in epiphyseal coxa vara the condition is a displacement, either gradual or sudden, of the epiphysis. This is emphasized below in the differential diagnosis between rachitic coxa vara of children and epiphyseal coxa

vara of adolescence. It is further to be noted that in frankly rachitic children I have never seen a case of separation of any epiphysis, nor have I been able to find a single such case in the literature.

Fromme, dealing with adolescent rickets, states that separation of all growth zones is frequent. His evidence is meager, consisting of three cases of separation of the apophysis of the olecranon which he classed as adolescent rickets. If this is true, then adolescent rickets is a very different condition from the rickets of childhood and should be given another name. The only one of the excised specimens in which the diagnosis of rickets was made was that of Haedke [33] and this need not be taken seriously as all of his objective findings can be explained by purely traumatic separation. In two cases in which blood calcium and phosphorus determinations were done, they were found to be normal or high (Wilson [32]).

Kocher's theory of localized osteomalacia has never been taken seriously as applying to all cases, even by himself. His findings might easily result from traumatic separation with resultant necrosis and atrophy. Frangenheim frankly admits that he is unable to diagnose the condition but that there is something abnormal in the epiphyseal line in all of his cases. He attributes it to a disturbance of growth (chondrodystrophia of unknown nature).

The infectious theory rests solely on two positive cultures of staphylococci obtained at operation by boring into the trochanter (Froelich [52]). So slender is this evidence, that Froelich does not refer to it in his recent paper [55] in which he reports a case of Legg's disease as a precursor of coxa vara of adolescence, although he reiterates that both are due to staphylococci of low virulence. No case has ever suppurated except after operative interference, and in none of the specimens examined was there any suggestion of a reaction to an infection. The infectious theory may be discarded. It would be a very unusual organism which would invariably attack the upper femoral epiphyses.

In regard to the various endocrine theories very little can be said as very little is known. It is undoubtedly true that obese adolescents are more likely to develop epiphyseal coxa vara than are adolescents of the normal or slender type. In our series of twenty-four cases, five were obese and one was a boy of fifteen of the so-called feminine type. In none of them were there symptoms of myxoedema or pituitary disturbances other than the obesity, except in the case mentioned.

What then is the nature of this disturbance which causes a weakening of the epiphysis of one or both hips in certain apparently normal, healthy adolescents? Its pathology is unknown because no case has ever been studied early enough. In all of the specimens reported the original pathology has been obscured by trophic changes in the

epiphysis incident to the disturbance in the blood supply and by nature's attempt to repair the lesion by reattaching the displaced epiphysis.

There are two factors which may have some bearing on the occurrence of the condition and which I have not seen mentioned in a rather extensive study of the literature involving a review of about three hundred papers. The first point is that the difficulty may not be in either the bone or in the epiphyseal cartilage. In childhood and early adolescence the periosteum of the femoral neck is very thick and strong and in places thrown into folds or ridges (the retinaculæ of Weitbrecht). This strong periosteum spans the epiphyseal line and is the chief factor in holding the head in place. Harte [84] states that with the periosteum severed, only one-fifth of the force is necessary to cause epiphyseal separation as when it is intact. In adolescence this periosteum begins to atrophy and approach the adult type, thus tending to produce a point of weakness at the epiphyseal line (Key [26]).

The second point is that in every case that I have ever seen the parents have stated (only after direct questions in regard to the growth of the child, it is true) that during the period in which the lesion began the boy or girl grew very rapidly ("suddenly shot up like a weed" is a very usual answer). Unfortunately we have no measurements to substantiate these statements in regard to rapid growth. We have noted in our roentgenograms that in some instances the epiphyseal line of the opposite hip seemed to be unusually broad and well defined. It is not difficult to imagine that during this period of rapid growth the periosteum spanning the epiphyseal line is stretched, thinned, and consequently weakened, thus permitting the head to be easily loosened. Is this a disease or is it physiological? I do not know, yet it seems to be the most logical explanation of what occurs.

The Mechanics of Epiphyseal Coxa Vara

The epiphysis being loosened, the head of the femur remains in the acetabulum with the ligamentum teres intact, while the diaphysis moves upward, rotates outward, and is usually twisted in the direction of hyperextension. The movement of the diaphysis upward on the head is obviously due to the effect of body weight in the upright position and also to the pull of powerful muscles spanning the joint. The external rotation of the leg is less easily explained. It is in part explained by the imbalance of the rotators of the hip, the external rotators being stronger than the internal rotators. This imbalance is increased by the change in the mechanics of the iliopsoas. This muscle being attached posteriorly on the lesser trochanter acts as an external rotator of the distal fragment when there is an

interruption of continuity between its insertion and the head of the bone. Its action becomes similar to that of the biceps on the forearm. The explanation of Kehl [85] that the iliofemoral ligament is shortened and being attached posteriorly pulls the diaphysis into external rotation is not, I believe, to be accepted without reserve. It is true that this would be the action of postero-inferior fibres of the ligament if the displacement were marked. However, in most cases of epiphyseal coxa vara, the displacement is relatively slight. But even with marked displacement the upper band of the iliofemoral ligament which runs from the anterior inferior spine across the upper and anterior part of the neck to the anterior border of the great trochanter would tend to act as a powerful internal rotator of the shaft and counterbalance the effect of the lower branch of the Y with its posterior insertion. Kocher's theory that in weight-bearing the hips are rotated outward to afford a broad base may perhaps have some foundation, but we feel that the hip is stronger and more stable when in the mid position or slightly internally rotated. His argument that in fatigue the hips are rotated outward, thus permitting the body weight to be borne by the ligaments, is perhaps of more weight but not sufficient to explain the moving forward of the neck on the head.

Harte's [84] theory that the head is pulled into the new position by the contracture of the intact periosteum below and behind the neck is inadequate, as it must be explained why this periosteum is not torn. It seems to me that the logical explanation lies in the normal anteversion of the femoral neck. In the normal femur with the leg in the neutral position the neck of the femur is inclined forward from twelve to fourteen degrees. This being true, with the body in the erect posture the thrust on the femoral head is downward, backward, and outward. The tendency is for the head to slip out of the acetabulum at its upper and anterior portion, just where the two limbs of the Y-ligament unite. The head being firmly held in the acetabulum, the stress is transmitted through the epiphyseal line to the neck. In epiphyseal coxa vara the epiphyseal region is unable to support the strain and the head is moved obliquely downward and backward on the neck.

The torsion of the head on the neck as noted by Kocher is not a constant finding. I am inclined to believe that it occurs only after the head has been displaced downward and backward. Then the head rolls under and behind the neck and only its upper and anterior portions are in contact with the acetabulum. The upper portion of the neck is bare and enters into the formation of the hip joint. The result is that the new joint surface on the femur does not fit the acetabulum. In movement in extension the head is probably locked between the neck and the posterior inferior portion of the acetabulum and the tendency is for the neck to twist on the head, the torsion occurring at the epiphyseal line.

In flexion the head is released and the stump of the neck tends to impinge on the postero-superior border of the acetabulum. This is relieved by external rotation, when more of the head which lies behind the neck glides into the acetabulum. Thus by externally rotating the hip the range of the flexion is increased.

So much for the mechanics of the production of the typical deformity. The deformity being present, does it explain the clinical picture characteristic of the position? Not entirely. As stated above, the clinical pictures range from that of an acute hip with practically no motion, to a painless hip with fairly free motion but always limited in abduction and internal rotation. In certain instances the hip becomes acutely painful and practically no motion is permitted in any direction. In these instances the limitation is obviously due to muscle spasm. In the average case, however, the hip is not acutely painful and motion is painless but restricted in abduction, internal rotation, flexion, and extension. In severe cases of long duration with marked deformity there is undoubtedly some contracture of the shortened muscles which would hinder normal range of motion in the joint, as is evident from the fact that in certain cases after an osteotomy has been done it has been found necessary to divide the adductors in order to secure abduction of the extremity (Keetley [5]). It has been shown by Albert [86], however, that without fibrosis and structural shortening in the muscles their mechanical disposition offers no obstruction to motion in coxa vara. However, the essential factor in the limitation of motion is the disorganization of the hip joint itself. Not only is the femur adducted and externally rotated and at times hyperextended upon the head, but the head is deformed and is rolled partially out of the acetabulum. The position of the head is sufficient to explain in part the limitation of abduction and internal rotation, and to slightly limit flexion; because with the head in the neutral position in the acetabulum the femur is adducted, externally rotated, and hyperextended. Theoretically, these movements should be markedly increased. Practically external rotation is usually slightly increased. Adduction is about normal and extension is limited. Excess adduction is prevented by the soft parts and by the impingement of the lesser trochanter on the pelvis. Abduction and internal rotation are limited on account of the position of the femur in adduction and external rotation and also by the impingement of the denuded end of the neck on the upper and anterior parts of the acetabulum respectively. I do not believe that the pubofemoral ligament is the most important cause of limitation of abduction as was claimed by Manz [27]. The limitations of flexion and extension are due to the fact that the bearing surface of the femur is elongated in the vertical direction. The head having slipped down, the upper part of the end of the neck becomes smoothed off and enters into the formation of the

joint. The acetabulum becomes modified to accommodate the new bearing surface of the femur but the bearing surface is now egg-shaped, and in flexion and extension of the hip is rotating round its short axis. Consequently these motions are limited, as in full range of motion it would be necessary for partial subluxation of the head to occur at the extremes of motion. The tendency of the hip to rotate outward when flexed is explained above.

In certain old cases there is very little motion in the hip in any direction. This is probably due to fibrosis of the capsule and to arthritic changes which gradually develop after a period of years.

The shortening is due, not to bending of the neck, but to a slipping upward of the neck on the head. The prominence of the trochanter is due to its elevated position and also to the fact that the head in its new position causes a relative lengthening of the upper border of the neck of the femur. Its prominence is accentuated by the muscle atrophy which is constantly present. This atrophy is due to disuse and involves only the affected extremity.

Differential Diagnosis

At present when roentgenograms are the rule in the examination of a joint lesion or injury, the positive diagnosis of slipping of the epiphysis at the hip in an adolescent should rarely be missed. Yet it is most unusual for a case to be correctly diagnosed in the early stages.

Sprengel [87] in 1912 stated that of twenty cases seen in his clinic not one entered with a correct diagnosis. Most of the cases that I have seen had been diagnosed as tuberculosis of the hip. The difficulty is that coxa vara is not even considered, rather than that the two conditions so closely resemble one another.

To one familiar with the condition the characteristic history, the age and habitus (not always present) of the patient, and the position of the thigh in adduction and external rotation immediately suggest the diagnosis of slipping of the capital epiphysis of the femur.

In tuberculosis of the hip, the hip is adducted and internally rotated. Almost never is the combination of adduction and external rotation seen. Hofmeister states that it never occurs. However, Levy [88] reports a case in a boy nineteen years of age in whom the hip was adducted and strongly externally rotated. The roentgenogram showed what appeared to be a slipping of the epiphysis. The diagnosis of adolescent coxa vara was made and the hip manipulated. The boy developed general tuberculosis and died. Autopsy disclosed an old tuberculous hip with erosion of the upper part of the head and of the lower part of the neck near the epiphyseal line, giving a beak-like appearance to the lower border of the head as is seen when

it slips down and projects below the line of the neck. This is a unique case in that it is the only one I have seen in the literature in which a tuberculous hip was diagnosed as adolescent coxa vara.

In tuberculosis the atrophy is greater and the hip usually more sensitive and painful even while at rest. Epiphyseal coxa vara may be acute but quiets down very quickly after fixation and freedom from weight-bearing. In an active tuberculous hip there is generally some fever in the evening. In coxa vara the temperature is normal. In case of doubt the radiogram ought to settle the difficulty except in a very unusual case such as that of Levy cited above. It is to be emphasized that in adolescence and especially in boys, slipping of the epiphysis is about as frequently encountered as is tuberculous coxitis.

In very rare juvenile arthritis deformans as described by Brunn [89], Maydl, and others the difficulty of diagnosis may be much more pronounced. The physical findings are those of a mild coxa vara but the roentgenogram shows the arthritic changes in the joint with no displacement of the head.

In Legg-Calvé-Perthes' disease the history, limitations of motion, slight atrophy, and shortening are identical with those of a mild coxa vara. The chief differential points are the age of the patient and the X-ray appearance. Legg's disease is a disease of childhood and rarely begins after the tenth year, while epiphyseal coxa vara rarely begins before the tenth year. In Legg's disease the lesion is in the epiphysis itself. The head is not misplaced but is deformed and may, in the mushroom type, overflow the borders of the neck. The evolution of the condition is well described in two recent articles (Waldenstrom [90], and Perthes and Walsh [91]). In Legg's disease the direction of the epiphyseal line is changed to approach more nearly the horizontal; thus the flattened and broadened head approaches the great trochanter, and the upper border of the neck is shortened. In coxa vara the head slips down and away from the great trochanter, thus causing lengthening of the upper border of the neck, while the epiphyseal line approaches the vertical plane. In adult cases due to loss of the epiphyseal line and progressive changes in the head and neck it may be absolutely impossible from the roentgenogram to determine whether the original condition was a Legg's disease or an epiphyseal coxa vara.

Types of cervical coxa vara which may be confused with the epiphyseal type are the congenital, the rachitic, and those due to fracture of the neck of the femur in early life. There are a great many such cases in the literature. In the congenital type there may be other congenital deformities and there is usually a history of a peculiarity in gait since the child began to walk. The chief limitation is in abduction. The roentgenogram shows a very high trochanter with the neck arising from the shaft and pointing directly inward

or even slanting inward and downward to a variable degree, the epiphyseal line being at a right angle to the neck. The deformity may be unilateral or bilateral. Rachitic coxa vara is always bilateral. It begins in early life and is accompanied by other stigmata of rickets. It is usually painless and the chief limitation of movement is in abduction. In the roentgenogram the neck is bowed upward and it is unusual for it to be at an angle of less than ninety degrees with the shaft. The epiphyseal line is not at a right angle with the neck but slants downward and inward while the head is directed upward and inward, encroaching upon the upper border of the neck. If there is such a thing as coxa vara due to late rickets arising in adolescence it must be of this type. I have never seen such a case nor have I been able to identify one in the literature, though there are a number of cases of epiphyseal coxa vara attributed to rickets.

Fractures of the neck of the femur in adolescence are most unusual (Hoffa [66]). In such a case a roentgenogram would be necessary to determine whether the lesion was in the neck or in the epiphyseal line. Fractures incurred in children and not adequately treated result in a coxa vara resembling the congenital or rachitic types mentioned above.

In closing the question of differential diagnosis, the most important point is that a traumatic or chronic hip beginning in adolescent life has about a fifty per cent, chance of being a slipped epiphysis. The reason that so many of these cases are falsely diagnosed is that the question of epiphyseal coxa vara is never considered. Once this is considered, the picture is as a rule quite characteristic.

Prognosis

Epiphyseal coxa vara is nearly always due to a weakening of the attachment of the head of the femur to the neck. The cause of this weakening is unknown. I believe that the condition affects only the upper epiphysis of the femur. I have seen no case in which there were symptoms in any other epiphysis, nor are any such cases to be found in the literature. This limitation of the condition to the hip is usually explained on mechanical grounds, the statement being made repeatedly that no other epiphysis is subjected to such cross strain. The facts are that the epiphyses of the tarsal bones and the various apophyses are constantly subjected to cross strain, and yet there are no cases of coxa vara recorded in which these have been affected.

The condition apparently affects only the hips. There is no evidence that it is an infection or a general condition of any kind, hence the general health and life of the patient are not endangered, nor are any other joints likely to be involved.

The prognosis is then a question of what is going to happen to the involved hip and whether or not the condition will become bilateral. As regards the latter consideration,

in fifteen per cent, of the cases from the literature the condition was bilateral. In Hofmeister's series one-third of the cases were bilateral. This discrepancy is partly due to the fact that Hofmeister was looking for bilateral cases and consequently examined the apparently uninvolved hip more carefully than did those who regarded the condition as being purely traumatic. It is also partly due to the fact that most of Hofmeister's cases were of the so-called static type. I have observed that cases of gradual onset with histories of slight or no trauma are very likely to become bilateral unless carefully handled.

The end-result in the hip affected depends to a certain extent upon the degree of displacement of the head, and may be modified by treatment. Hofmeister [25] noted that without treatment there was a tendency for the pain and muscle spasm to diminish and gradually disappear, and for some motion to be restored to the hip. In 1905 [13] he stated that twenty-three of twenty-nine of his patients had been able to return to their original occupations and were for the most part free from pain. In his cases flexion was restored to the greatest extent, then internal rotation, and lastly abduction. The possibility of spontaneous improvement in a severe case is so well shown in one of his figures that it is reproduced here (Fig. 8).

Brandt [92], in a very interesting report of seven cases which had no treatment or only a high shoe or rest in bed, found that abduction was restored on an average to about twenty-five per cent, and internal rotation to about twenty per cent. In eight cases treated by manipulation (refracture of Lorenz [77]) followed by fixation in plaster the results were not so good. In treated cases the average abduction was about twenty-five per cent, in six cases. In two cases there was ankylosis in flexion, and in no case was there restoration of internal rotation.

Abrahamsen [75], in a series of old cases attributed to trauma, found disability of twenty-five to thirty per cent, as awarded by the council of assurance for laborers. In his series the displacement of the epiphysis was not completely reduced in any instance and he states that it is impossible for him to give a prognosis for such cases, but that in cases not reduced, an invalidity immediate and sometimes very marked will follow and will not diminish with the years. (Just the opposite of Hofmeister's opinion.)

The end-results of twenty-two cases treated at the Keil clinic in the period from 1899 to 1922 were recently investigated by Kappis [40]. He was able to get ten of these cases to report back for examination. Two cases treated by immobilization without reposition had severe deformity with pain and limitation of motion in the hip. One case treated by nail extension for two months showed a broadened head one and one-half years later, but the function was good. There were five cases of acute epiphyseal separation which were apparently reduced by manipulation

Fig. 8 Hofmeister's case showing spontaneous improvement after four years.

and then immobilized in plaster. These cases as a rule result in a short neck surmounted by a deformed head. Kappis considered four of them as functionally perfect and the other as a fair result, though no data regarding the mobility of the hips are given in his report.

Of more than usual interest are two old cases reported by Schmidt [93] and one by Zehnder [94]. Schmidt regarded his cases as old contusions of the head of the femur, but they are typical cases of epiphyseal coxa vara. At the time of examination the patients were men of thirty-four and forty-five years of age respectively, who had entered the hospital complaining of pain and disability in the hip. Both had had trouble with the hip off and on since reaching adult life and entered the hospital with moderately acute coxitis deformans. In one case a subtrochanteric osteotomy was done and in the other the symptoms were quieted down by rest and physiotherapy. Zehnder's case was in a man of forty-two years of age. The condition was bilateral. It began spontaneously at sixteen years. At twenty years of age he had considerable pain. The hips then quieted down and gave him little trouble until he was thirty-five years old. At that time they became painful again and this condition persisted, the pain being severe in Winter until the time of examination by Zehnder seven years later. All of Piatt's [56] five cases showed marked limitation of motion at the final examination and one of them was ankylosed.

Of our series of twenty-four cases at the Massachusetts General Hospital it has been possible to re-examine fourteen cases. These cases were all examined according to a

definite outline and the range of movement of the hips measured with a goniometer. The details of the hip examinations of these cases are given in Tables II and III. The five cases in Table II were not operated upon or manipulated. Eight of the cases in Table III were manipulated according to Whitman's method and one was operated upon. The case numbers correspond to those in Table I.

Abstracts of the histories of these cases are given below.

(NB. Abstracts of Cases 11-24 and the associated figures 9-18 have been redacted. They appear in the Supplemental materials available with the online version of CORR.)

In studying these fourteen cases we have divided them into two groups. Cases 11 to 14 inclusive were treated only by fixation and freedom from weight-bearing or corrective exercises. Cases 15 and 16 had no treatment until adult life when they entered the clinic for pain in the hip. These cases have, on the whole, fairly serviceable hips (Table II). They are all limited in abduction and internal rotation and all but one are limited in flexion. In all these hips there is moderate range of painless motion. Shortening varies from one-half to one and one-half inches. Two of these patients have no pain. The other four have moderate pain after an unusual amount of exercise.

The second group (Table III) includes one operated case and seven cases in which the hips were manipulated under general anaesthesia. In Case 17 the operation was undertaken in an effort to remove a bony block in the hip joint. The end-result is a practically ankylosed hip. The other

Table II. End results in cases which were not manipulated

Case	Hip	Length in Inches	° Thigh	° Calf	Flexion	Extension	Abduction	Adduction	Ext. Rotation	Int. Rotation	Perm. Flexion	Shortening in Inches	Atrophy Thigh in Inches
{ 11.	Rt.	33	18½	13½	90	40	40	35	40	45			
{ M. C.	L.	32	16½	13	65	15	15	30	30	20		1	2
{ 12.	Rt.	32	18¾	13	120	25	45	30	35	45			
{ S. L.	L.	30½	17¾	12½	75	0	35	5	15	0	25	1½	1
{ 13.	Rt.	39½	20½	13½	135	25	45	35	45	35			
{ E. B. C.	L.	38¾	18¼	13¼	85	0	20	5	30	0	20	¾	2
{ 14.	Rt.	33	18	12¾	110	45	35	30	40	35			
{ G. B.	L.	32½	15	12½	30	20	5	25	15	0		½	3
{ 15.	Rt.	32¼	19½	12½	100	20	50	45	40	25			
{ T. J. D.	L.	31½	18½	12½	130	0	0	40	40	0	15	¾	1
{ 16.	Rt.	29	21	15	80	10	25	25	35	0		¾	
{ S. R.	L.	29¾	21	15	115	25	40	25	45	35		¾	

seven cases were manipulated under ether anaesthesia according to the method advised by Whitman [28]. At the time of manipulation the full range of normal motion was obtained and the hips were fixed in the corrected position in plaster spicas. The results in these cases are definitely poorer than are those in the cases which were not manipulated. The average range of motion is less in the manipulated hips, and a larger percentage of them are painful after exercise. It is to be noted that in our series of twenty-four cases, thirteen were manipulated one or more times. In not a single instance was the epiphysis replaced in its normal position. Our series then gives us the prognosis only for cases in which the displacement of the epiphysis is not reduced. In such a case the epiphysis, when it finally comes to rest, is united firmly to the neck in its new position with or without treatment. Non-union in these cases is practically unknown. The only recorded instances of non-union from epiphyseal separation at the hip are two cases mentioned by Campbell [95]. They are unique in the literature and should be reported in detail. Likewise the question of necrosis of the epiphysis need cause little concern. There is usually more or less atrophy and in cases of gross displacement there may be some necrosis. An unusual case is that of Kappis [40] with total necrosis of the bone, but firm union. Instances of necrosis of bone, marrow, and cartilage, such as that reported by Axhausen, in which there was a fracture of the neck of the femur in a boy of sixteen, apparently do not occur in epiphyseal coxa vara. This is probably because the periosteum behind and below the neck usually remains intact and attached to the head.

The acute symptoms always quiet down and as a rule these hips are free from pain except after an unusual amount of exercise. The shortening and the prominence of the trochanter persist and most of the patients develop a mild scoliosis with some slight structural change. These

hips are always limited in internal rotation and abduction and are usually limited in flexion. In many of them there is permanent flexion with resultant lordosis. In some instances the hips are practically ankylosed, only a few degrees of motion being permitted in any direction.

All of these patients walk with a more or less pronounced limp and in many of them there is a positive Trendelenberg. They are handicapped in sitting, stooping, and in putting on their shoes. The atrophy of the thigh and buttock persist and in many instances there is a noticeable weakness in the affected extremity.

The roentgenograms of the older cases show typical deformity in some instances, but often the neck is shortened on both upper and lower borders and the head enlarged and flattened to resemble an old case of Legg's disease. From what we now know of the influence of abnormal strain and faulty joint mechanics upon the development of hypertrophic or osteoarthritis it is probable that all of these patients who reach later adult life will develop arthritic changes in the affected hip. A great many of the cases of malum coxae senilis are probably due to old epiphyseal coxa vara or to old Legg's disease (Figs. 19 to 25 inclusive).

In cases in which the epiphysis is replaced in its normal position the prognosis is, of course, much better. Wilson [32] has recently reported seven cases in which the epiphysis was replaced by open operation (his Case 1 is Case 10 in my series). In these cases there is at present little or no limp, no pain, and almost normal motion in the hip.

Treatment

The treatment of coxa vara is by no means standardized. The obvious thing to do is to replace the head upon the

Table III. End results in cases treated by manipulation or operation

Case	Hip	Length in Inches	° Thigh	° Calf	Flexion	Extension	Abduction	Adduction	Ext. Rotation	Int. Rotation	Perm. Flexion	Shortening Inches	Atrophy Thigh in Inches
{ 17. F. K.	Rt. L.	33½ 34½	18½ 10½	13½ 12¼	45 135	0 20	0 20	10 20	5 25	15 25	30	1	2
{ 18. K. W.	Rt. L.	30½ 31½	20½ 21½	14¼ 14¼	20 115	0 20	0 25	0 25	0 30	0 35		1	1
{ 19. A. F.	Rt. L.	31¾ 32½	19½ 21½	14¼ 14	30 120	0 25	10 25	10 25	55 50	-10 0	10	¾	2
{ 20. J. B.	Rt. L.	36½ 36	19 17	12¼ 12	115 90	25 10	25 5	25 25	45 60	45 0		½	2
{ 21. H. C.	Rt. L.	38½ 39½	21 20	14½ 13¼	60 115	15 25	5 45	25 25	40 40	10 -20		½	2
{ 22. J. E. C.	Rt. L.	39½ 39	20 17	13¼ 13½	115 20	0 25	10 45	15 45	30 50	0 45	15	½	3
{ 23. M. K.	Rt. L.	38 36½	19½ 17½	13¼ 13	115 50	25 10	45 10	45 25	50 20	45 0		1½	2
{ 24. F. A. D.	Rt. L.	37½ 36¼	20½ 18¼	14 13	130 120	35 40	45 10	25 30	40 50	45 5		1	2¼
													45° Ext. Rot. c Flex.

Fig. 19 Case 14 Duration one year and two months.

neck in its normal relationships and maintain it there until union is firm and there is no longer any danger of a recurrence of the deformity. The usual procedure both in this country and abroad (Whitman [23]; Lorenz [77]) is to attempt to reduce the deformity by manipulation under full anaesthesia or by prolonged traction in abduction and internal rotation (Sprengel [87]). The manipulation recommended by Whitman is forcible flexion and internal rotation followed by traction and abduction of the thigh. After manipulation, the hip is fixed in the corrected position by a large plaster spica. After eight or twelve weeks the spica may be replaced by a walking splint, preferably of the Bradford abduction type.

Up to 1922 when this series of cases was reviewed the above was the standard method of treatment employed at the Massachusetts General Hospital. The results obtained by us have been reviewed under the prognosis. In this day and time they cannot be considered anything but poor. The fault lies not in the execution of the manipulations but in the applicability of the method to the average case of epiphyseal coxa vara. In twenty-two of our cases (excluding the two adult cases in which the patients came to the clinic many years after the condition began) the average length of time from the onset of symptoms to the appearance of the patient in the clinic was 14.6 months. The earliest cases were admitted two months after the onset of symptoms.

We would regard it as absurd to endeavor to correct a malunion of a year's duration in a fracture of the femur in an adolescent by either manipulation or traction, yet because the lesion is in the epiphyseal line we have considered it a practicable procedure to manipulate the thigh and force the head back into its normal position. There are, of course, cases which can be cured by the manipulative method, but they are few and far between, at least from the standpoint of the orthopaedic surgeon. This is either because they have

not been seen by a physician or have not been correctly diagnosed until the epiphysis is firmly fixed in its new position.

As the anatomy of epiphyseal coxa vara varies from time to time and the condition is either slowly or rapidly progressive, the treatment should be adapted to fit the particular type of case with which one is dealing. For the purpose of treatment, epiphyseal coxa vara can be considered under five subdivisions as follows: (1) cases without displacement; (2) early cases; (3) advanced cases; (4) healed cases in young adults; and (5) old cases with arthritic changes in older adults.

(1) It has been emphasized that epiphyseal coxa vara is a condition of loosening of the epiphysis of gradual onset and that in certain instances it is possible to make the diagnosis before displacement of the epiphysis has occurred. In such cases the hip should be protected from the strain of weight-bearing by a Thomas ring or Bradford abduction splint. If the patient is overweight an obesity diet should be prescribed. Unless there are definite indications of endocrine disturbances I see no reason for using any glandular therapy, as there is no evidence as yet that the epiphyseal weakening is a result of endocrine disturbance. As the condition continues to progress over periods varying from one to three years, the splint should be worn for at least a year, and then gradually discarded. During the second and third years after the onset the patient should be carefully watched and at the first reappearance of symptoms the splint should be reapplied. The general health and hygiene of the patient should, of course, receive attention. In these cases and in those of Groups II and III the uninvolved hip should be watched carefully, as in about one-fifth of the cases the condition becomes bilateral.

(2) Early cases. These cases are those in which the epiphysis is practically normal in contour and is just

Fig. 20 Case 21 Duration two years. Coxa valga after manipulation. Duration one year.

Fig. 21 Case 12 Duration three years.

beginning to slip or in which, due to a recent trauma (not as a rule over four weeks preceding the manipulation), the head has been grossly displaced on the femur. In these cases an attempt should be made to reduce the deformity by Whitman's procedure as outlined above. It is important that the reduction be complete, and anatomic restoration of the upper end of the femur secured, because in the hip physiological cure is secured by nothing less. For this reason it is necessary to check the result after manipulation by roentgenograms and to continue to check the result until adult life is reached and there is no longer danger of recurrence. If a roentgenogram taken with the patient in the plaster spica shows the head in its normal relationship to the neck, then the spica should be left on for ten weeks. At the end of

this period the cast is removed and the patient encouraged to move the hip voluntarily in bed. At the end of a week or ten days a hip splint, preferably a Bradford abduction splint, is fitted to the patient and weight-bearing is begun. The splint is worn for about two months and then gradually discarded and normal use resumed. Massage, passive motion, and local heat may be helpful in restoring the function of the extremity but it is believed that the most important aid is voluntary motion. This is best done under the supervision of a skilled physiotherapist. Personally, for purely empirical reasons, cod liver oil is given during convalescence. Since Phemister has shown that phosphorus apparently hastens union in fractures, this is added to the cod liver oil. It is to be noted that after treatment there is

Fig. 22 Case 20 Duration four years. **Fig. 23** Case 19 Duration six and one-half years.

freedom from weight-bearing for only four or five months while it was stated above that the condition continues to progress over a period of one to three years. This is because the separation and replacement of the head seem in some way to hasten or cure the process and cause the epiphysis to unite firmly to the neck again. In the literature I have seen only one case reported as having recurred after the epiphysis was definitely replaced. This was the case of Jouon [96, 97] in a girl of fourteen who fell on the hip three months after reduction and slipped the epiphysis a second time. At least one roentgenogram should be taken during the period when the patient is wearing the splint and another should be taken after the splint is discarded and normal weight-bearing resumed. If the head has slipped

again the treatment must be started from the beginning. I have seen the deformity progress with the patient in an abduction splint. These patients should be examined at least once a year until adult life is reached. If anatomic reposition is not obtained the procedure should be that as outlined for Group III.

(3) Advanced cases with a normal or fairly normal head. This group includes the purely static cases in which the head is not separated but has slipped well down on the neck and is more or less deformed and sickle-shaped but still recognizable as a distinct mass of bone, separated from the neck by the irregular epiphyseal line. It also includes those so-called traumatic cases of more than six weeks' duration in which there has been gross displacement of the head

Fig. 24 Case 16 Duration about fifteen years. **Fig. 25** Case 15 Duration thirty-three years.

following a trauma and in which it is seen to be hooked over the postero-inferior border of the mesial end of the neck. In these cases it is useless to attempt reduction by manipulation. Not only is the head firmly fixed in its new position on the neck, but owing to its position the sharp posterior inferior border of the neck is embedded in the concave cancellous tissue of the epiphyseal region of the head, while the smooth rounded cartilaginous surface of the head glides in the acetabulum. At the limits of abduction and internal rotation permitted, the head is locked against the postero-inferior portion of the capsule and acetabulum. If these movements are forced the neck is driven further into the cancellous tissue of the head. This is admirably illustrated in our Case 21, where the right leg was abducted fully to fix the pelvis, while the affected leg

was forced into abduction. The slipped epiphysis was not appreciably moved, but the opposite epiphysis was torn loose and an epiphyseal coxa valga produced (Fig. 20).

It is to be pointed out that in these cases by forcible manipulation under anaesthesia, abduction and internal rotation of the limb can be obtained. But it does not mean anything because the capsule is simply stretched and the head is not replaced, but goes with the neck, and the deformity recurs shortly after the fixation is discontinued. Not only is this true, but from the results obtained in our series one is justified in suspecting that the trauma inflicted by the manipulation actually tends to increase the ultimate stiffening in the joint. It is obvious then that in these cases one must resort to open operation if a satisfactory result is to be obtained. The operation of choice

is, I believe, to open the hip joint, free the head from the neck with a chisel, then replace the head on the neck, wash out the joint with salt solution, suture the capsule and close the wound, and fix the hip in a plaster spica in abduction, internal rotation, and slight extension. It may be necessary to remove a portion of the end of the neck in order to effect the reposition of the head. If the head is enlarged and overlaps the neck to any great extent its edges should be trimmed. Whitman [98], who introduced this method, prefers the anterior approach to the joint. Wilson, in some recent cases, has found that the supero-lateral approach of Smith-Petersen [99] gives an admirable exposure.

(4) Healed cases in young adults with markedly deformed head and neck. These are cases in which the neck is thickened and convex above and has established a smooth bearing surface resting against the upper portion of the acetabulum. The head is in its typical location but is grossly deformed and the boundary between it and the neck is ill defined. On examining the roentgenogram the surgeon is impressed by the fact that after he exposed the hip he probably would not know what to do next. It would be difficult to decide how much to take off, as the head, once freed, would probably be so deformed that it would make a very poor joint. It has been recommended that the thing to do is to chisel off the projecting upper and anterior border of the end of the neck. This was done in one of our cases [17] and the patient now has almost complete ankylosis of the hip and is one of our worst results. In these cases it is not possible to get an even approximately normal joint. The upper end of the neck is so rounded off that it offers a very efficient bearing surface if abduction and internal rotation be restored. Consequently, the operation of choice is osteotomy of the upper end of the femur followed by fixation in abduction, internal rotation, and extension. Osteotomy of the upper end of the femur for improving the function in the hip in coxa vara was first performed by Keetley [5] in 1888 and apparently forgotten and proposed as a new procedure by Kraske [100] in 1896. Since Kraske's paper, osteotomies have been done in the neck, trochanter region, and shaft. Wedge, linear, and curved osteotomies, and at various angles have been advocated by different surgeons. Whitman prefers a linear osteotomy of the shaft just below the trochanter minor in older subjects where the external rotation is marked. I am inclined to favor an osteotomy through the cancellous bone of the inter-trochanteric region done in the shape of an inverted V with a wedge removed from the outer limb to facilitate abduction. An equally efficient but more difficult operation to perform is curved osteotomy in this region as suggested by Brackett [101]. The curve is convex upward and the inner limb is prolonged downward. Either of these types renders displacement and slipping inward of the lower fragment less likely.

At the time of the osteotomy it may be necessary to cut the adductors, as was Keetley's experience, in order to obtain abduction. The after treatment is the same as in Groups II and III.

(5) In older patients with arthritic changes one should be more conservative. In 1905 Hofmeister [13] estimated that the mortality in operations for the correction of coxa vara was seven per cent. In our series only five cases were operated upon and in one of these the wound became infected and the patient died. This, of course, was not to be expected in the usual course of events and ordinarily will not happen again for a long time. It serves, however, to emphasize the fact that any operative procedure designed to correct a coxa vara is a serious operation and should not be lightly undertaken. We believe that well trained surgeons in well-equipped hospitals can treat these cases operatively today with a mortality of about one to two per cent. We have, however, no adequate statistics to support our belief. Nevertheless, we recommend operative interference in Groups III and IV.

But the older patients are poor operative risks, especially as regards operations on the hip, and a very definite effort should be made to relieve the pain by rest, physiotherapy, general hygiene, and support to the joint before operation is even considered. If these efforts fail and the patient desires an operation, then the simplest and quickest procedure possible to relieve the condition and give a fairly serviceable hip should be done. Jones [102] does an osteotomy and produces a pseudoarthrosis in many cases similar to these. Another relatively simple procedure is the trimming down of the enlarged head and the removal of osteophytes from the margins of the acetabulum. In certain cases an inter-trochanteric osteotomy may be the best procedure. Arthrodesis should not be attempted as the eburnated bones seldom unite, and even disarticulation of the hip should be avoided in these older patients on account of its tendency to be followed by shock.

Summary and Conclusion

The history of the recognition of epiphyseal coxa vara as a definite clinical entity is sketched. The term coxa vara is defined and an anatomic and etiologic classification of the various types of coxa vara is given.

The incidence is given and the clinical picture and roentgenologic findings in epiphyseal coxa vara are described in detail. Twenty-four cases are reported.

The pathologic specimens reported in the literature are reviewed and discussed. The true pathology is unknown, as no early specimen has been described.

The various theories as to the etiology of the condition are critically reviewed and it is suggested that the condition is due to a weakening of the periosteum binding the head to

the neck of the femur. The cause of this weakening is unknown, but it is usually coincident with a period of unusually rapid growth during adolescence.

The mechanics of epiphyseal coxa vara is discussed and the differential diagnosis is given. The end-results obtained in fourteen cases are discussed and these cases are reported in detail. In our experience the cases have all been seen some time after the onset of the condition and in such cases the prognosis without open operation is that of a hip usually somewhat painful and always limited in internal rotation and abduction and often limited in flexion. In many cases permanent flexion develops and persists. The hip may become practically ankylosed in severe cases. It is felt that forcible manipulation of an old case tends to result in increased stiffening of the hip and is not justified by the results obtained in our cases. The treatment of the condition in the various stages encountered in its natural evolution is given in detail.

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Discussion

Dr. R. B. Osgood, Boston: This work stands for itself. It is exactly the kind of work we want if we are going to do intelligent joint surgery. It is this work that is going to make clinical work worth while. Without such work as this, clinical work is of little service.