TRAUMATA
of the
EPIDPHYES, DIAPHRAGM, AND EPIDPHYESAL CARTILAGES.

Being a Report and Commentary
on
Orthopaedic Cases
Treated in
THE ROYAL INFIRMARY OF EDINBURGH.

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GENERAL CONSIDERATIONS.

1. Anatomy and Physiology. In the growth of the human body, the bones like the other tissues must increase in size. This increase is of course not only in breadth, but in length. The growth in breadth is simple, — most authorities regarding it as due largely to the slow formation of bone by the periosteum, and the perichondrium. These two latter are, indeed, one and the same, being, as Stump says, both "developed from the peripheral primitive connective tissue cells of the chondrogenetic area." Sir Wm. Macewen, however expressing views similar to those published by Good sir, held that the chief function of the periosteum is to limit the formation of new bone, which is being laid down by the osteoblasts situated on the surface of the bone, in the Haversian canals, and in the marrow. The discrepancy between these two views is probably more apparent than real, arising as it does, from a difference of idea as to what constitutes the periosteum. Schafer states that the periosteum is a "fibrous membrane composed of two layers, the inner of which contains many elastic fibres," and "that it ministers to the nutrition of the bone partly on account of the bloodvessels, and lymphatics it contains, partly, especially in young animals, on account of the existence between it and the bone of a layer of osteoblasts." It is obvious, then, that if these osteoblasts are regarded as belonging to the periosteum, the latter has osteo- genetic powers; but if the osteoblasts belong to the bone which has been already formed, Macewen's view is
is well founded.

The growth of bone in length is more complicated and is performed by means of the highly organised mechanism in connection with the epiphysis. In the foetus the precursor of the skeleton is at first entirely cartilaginous, but soon centres of ossification appear, followed by the gradual transformation of the cartilage into bone. At birth the shafts of all the long bones are fully developed in shape and constitution but not in size (Baetjer and Waters); but the ends with the exception of the lower end of the femur and the upper end of the tibia are still composed of cartilage. After birth and at various ages there appear one or more centres of ossification in each end of all of the long bones, excepting the clavicle, the metatarsals, metacarpals, and their phalanges, in each of which there is only one centre. Each of the centres increases in size by extending through the cartilage "leaving however a superficial layer of it unossified, which permanently covers the articular end of the bone". Between the centre of ossification and the shaft of the bone lies the band of cartilage known as the epiphyseal cartilage, which becomes narrower with age. Direct bony union, however, does not occur normally until the attainment of full growth. Bone formation, according to Stump, is initiated by a growth-impulse later than and of a different order from the preceding chondrogenetic impulse. "It consolidates the growth registered by the cartilage, thereby fulfilling its ultimate aim, the development of an entirely new structure". The epiphyseal cartilage
cartilage is all important in the lengthening of the growing bone. Its essential functions are to form new bone, and simultaneously to reproduce its own tissue. When the latter function ceases, direct bony union with the shaft occurs. It behoves, therefore, to study in greater detail this epiphyseal cartilage.

Fraser describes its macroscopic appearance as a thin plate of bluish cartilage, and its microscopic one as a plate of hyaline cartilage differentiated into two zones which were first described by Broca. The thinner zone, that adjacent to the epiphysis is of typical hyaline cartilage. The thicker zone which forms 9/10ths of the total thickness of the plate, contains numerous actively proliferating cells arranged like "peas in a pod", except near the actual junction with the diaphysis. There the cells forming irregular masses are "large, oval, or circular, each with a distinct cell membrane, a considerable amount of cytoplasm, and a nucleus containing eosinophil granules". According to Schafer the ossification of the epiphyseal cartilage is purely endochondral, and he describes the process in three stages. In the first, the cartilaginous cells become enlarged, and, -at least in the side of the cartilage nearer the shaft, -arranged in rows radiating from the centre. Meanwhile the matrix becomes impregnated with fine calcareous granules. The above changes are accompanied by the deposition, by the subperiosteal osteoblasts, of fibrous material also destined to become calcified. The second stage consists in the irruption into the newly calcified cartilage model, of the osteo-
osteoblastic tissue from the marrow spaces of the diaphysis along channels which develop by solution of chondromucin, as well as from the subperiosteal vascular tissue as in the ossification of the shaft. This irruption is performed by means of large multinucleated osteoclasts, and the spaces which result are termed marrow spaces. It is worthy of note that Stump believes that the cartilage mass is invaded by primitive connective tissue cells, which "rapidly form a zone of syncytial tissue which continually replaces the dead hypertrophic cells at the ossification line". This zone is the site of the formation of the osteoclasts, and the endochondral osteoblasts which latter develop in accordance with growth requirements at or near the site of their activity. In the third stage the process of ossification spreads towards the extremities of the cartilage, and bone is simultaneously laid down on the walls of the marrow spaces and on the surface of the new bone under the periosteum. These stages are repeated continually as bone is formed. Of course, "beyond the line of advance of ossification, the uncalcified cartilage grows by expansion both in length and breadth."

In infancy the epiphyseal line is usually transverse, but later it assumes a cup-shaped form as in the upper ends of the humerus and tibia. (Poland).

Within these epiphyseal cartilages bone formation takes place centrally, Ollier stating "that 14/15ths of the length of a bone is due to the activity of the diaphyseal surface of the epiphyseal disc. Polands' contention that the epiphysis takes a very small part in the process
process of lengthening bone is in accordance with this. Arthur Thomson of Oxford, however, holds that owing to the eccentric growth of the bony "nucleus of the epiphysis", the epiphysis grows towards the shaft as well as the shaft grows towards the epiphysis. Piersol also believes that "ossification extends in two directions, towards the periphery and towards the adjacent end of the diaphysis".

Experimentally, Ollier showed that "when two metal nails are inserted, at a given distance apart, but nearer to the upper epiphysis than to the lower, into the shaft of the long bone of an animal, the distance between the nails is the same after the bone has grown, but that the upper nail is now farther from the upper epiphysis than the lower nail is from the lower epiphysis". Poland's deduction from this experiment that the chief growth in length of the particular bone was at the upper epiphysis is open to doubt in view of the definite finding by Ollier that trauma at a distance from the cartilage, e.g. fracture of the diaphysis, stimulated the epiphyseal cartilage to increased activity, and so resulted in increase in length of the bone.

In forming an opinion on this subject the writer thinks that value should be given to clinical findings after amputation. Poland says "conical stumps are continually found in the arm and leg after amputation from continued growth of the upper epiphyseal lines of the humerus, fibula and tibia. The radius, ulna, and femur mainly depending upon their lower epiphyses for increase in length, such stumps in the forearm and thigh from
from this cause are seldom found in children". Thus while all epiphyseal cartilages contribute to the growth of the bone in length, the cartilages late in uniting such as those at the knee, shoulder, and wrist grow more actively, and for a longer period. As might be expected, such therefore contribute more to the length of the limb than the others.

2. Traumata. The commonest injury in connection with the epiphyses is, of course, the so-called "Separation". In practice, however, it is usually found that it is the diaphysis, and not the epiphysis, which has become detached from the epiphyseal cartilage. Realising this, Ollier proposed the more accurate term "décollement diaphysaire" in place of "décollement épiphysaire", but as Poland says, "there would be little advantage in changing a title, with which all are now familiar". Other lesions in this region are the very rare "split" through the epiphyseal cartilage itself, and the not uncommon diaphyseal, or juxtaepiphyseal fracture. Of course there may be a combination of any of these injuries with or without fracture of either the diaphysis or epiphysis. The epiphyseal cartilage is not usually completely detached from the diaphysis, the common lesion being a separation along part of the epiphyseal line with a fracture running into the diaphysis, as seen in the antero-posterior X-ray photograph of Case IV. (p.43) As in ordinary fractures, cases of separation may show
may or may not show displacement. They may be either simple or compound. More than one epiphysis may be separated by one accident, e.g. the lower femoral and and the upper tibial and upper fibular.

The periosteum is the main obstacle to separation. Boyd states that the force required to tear off an epiphysis after division of the periosteum is about \( \frac{1}{5} \)th of that required when the membrane is intact. The periosteum which is very adherent to the epiphysis is but loosely attached to the shaft, with the result that if there is much displacement after separation "the end of the shaft tears a hole for itself in the periosteal tube on the side toward which it is moving, and after this, the epiphysis carries the periosteum with it stripping it off the shaft." The importance of this in regard to treatment will be noticed later. (page 23.)

Though incomplete separations may be overlooked at the time of the trauma, they may initiate pathological processes. Fairbank says that "while there is some doubt as to whether the so-called Schlätter's disease (or Osgood's disease) is necessarily traumatic in origin though certainly aggravated, and kept up by the pull of the ligamentum patellae, there is no doubt that all types of cases are met with from the complete traumatic avulsion of the tubercle (of the tibia) to the case where no displacement is present, and trauma seems to play no part in the onset". He also suggests that a mild infection plays a part in Schlätter's disease, in osteochondritis of the heel-epiphysis (commonly bilateral), and in pathological conditions of the navicular tubercle.
tubercle. He points out that the first two of these conditions are affections of epiphyses to which strong tendons are attached, so that one would expect trauma to play a part in their causation. However, he admits that he does not know of any convincing case of separation of the epiphysis of the os calcis, or of the navicular tubercle, and he believes that cases reported to be of traumatic separation of the navicular tubercle are in reality an infection of the os tibiale externum, which has a distinct centre of ossification. Schlätter's disease and the osteochondritis of the heel are probably comparable to pseudo coxalgia (the femoral head being an epiphysis subject to great strain), but not to Köhler's disease, which affects the whole of the tarsal navicular, a bone not subjected to much strain.

In this connection Davies records an interesting case in which the separation of the lower epiphysis of the femur acted as the etiological factor in Schlätter's disease. A youth of 16, when sitting on a bench with his feet on the floor and his legs at right angles to his thighs, was struck by a 80 lbs iron bar across the lower part of his thigh. The diaphysis of the femur was separated from the lower epiphysis, and dislocated backwards. The epiphysis pushed the articular surface of the patella forwards stretching the ligamentum patellae so that the latter by pulling on the tuberosity of the tibia caused a partial separation of the epiphysis. Most of the cases of Schlätter's disease are due to indirect violence through the muscular action of the quadriceps acting through the patella and ligamentum patellae, and not to direct violence. The condition usually
usually occurs in youths between 12 and 18 years of age.

Cases of juxta-epiphyseal strain occurring in infants, and described by Ollier are probably allied to these cases of partial separation. They often pass unnoticed owing to the absence of displacement, and the intact condition of the periosteum. Later arrest of growth either without acute or chronic osteitis and inflammation of the neighbouring joint may occur. Case V. in which as far as can be ascertained now, there was only partial separation, illustrates in the defective growth of bone, interference with osteogenetic function.

The relative frequency of the different separations varies much, accounted for by a. anatomical, b. physiological, and c. mechanical considerations. a. Anatomically for example, in a fall on the knee, the lower end of the femur is more liable to become separated than the upper end of the tibia, although union in the two epiphyses occurs at the same time. b. Physiologically the order of frequency is roughly, though not strictly, proportional to the period during which separation is possible. Thus the epiphyses which unite late are most commonly affected. c. The mechanical considerations, refer to the size and situation of the epiphysis in the body, and its protection or lack of protection from injury by surrounding structures. Further the presence in some epiphyses of the concavo-convex arrangement (see Case 1.), if not actually militating against separation, at least reduces the chances of displacement after divulsion.

Like fractures, separations of epiphyses may result from direct or indirect violence from without, or more
more rarely from muscular action. Either form of violence has to be very severe; greater force according to Fraser being "necessary to cause a separation of any epiphysis than to fracture the bone". Indirect violence, which is a more frequent cause than the direct, may take many forms,-the commoner being direct traction on the axis of the limb, and forcible torsion (e.g. by the spokes of a wheel). The sudden and violent contraction of a muscle is a rarer etiological factor of epiphyseal separation. When it does occur, the common sites of this lesion are the head of the fibula, the anterior superior iliac spine, and the coronoid process of the ulna.

When indirect violence is applied to any structure such as a bone or system of articulated bones as in a limb, the structure naturally gives way at its weakest point. This latter, before osseous union with the shaft is situated in the region of the epiphyseal cartilage, and particularly at the end of the diaphysis in the juxta-epiphyseal region of Ollier. With age and bony union, changes occur in the site of the weakest point, and in the injuries resulting from trauma. "Take the same degree of injury to a hip, and see what follows at different age periods. In the young an epiphyseal separation of the head of the femur results, between 20 and 40 years a dislocation is produced and after 40 a fracture of the neck is sustained" (Baetjer and Waters). Age may also be the factor in determining whether the separation is accompanied by opening of the neighbouring joint cavity. For example, "at birth, separation of the upper epiphysis of the femur, which includes head, neck
neck, and great trochanter, would be extra-capsular; three or four years later there are separate nuclei in both head and great trochanter, the neck is fully ossified from the shaft, and a separation of the upper epiphysis (head only) is entirely intra-capsular." (Treves).
The age at the time of separation therefore varies between birth and the date of union with the diaphysis, and in any given case is exceedingly important for diagnostic purposes. Some writers have described intrauterine separations, following injury to the mother's abdomen, but Poland thinks that the occurrence of these injuries apart from disease is very doubtful. Separation, undoubtedly, does occur during childbirth, but many, if not all, of these cases are probably concomitant with abnormal conditions of the bones. Poland has shown, statistically, that contrary to the ideas of former writers, "these accidents are less common in early childhood than after the age of 11 or 12", and he explains this by the greater liability to injury after these ages. Age, as shown in the discussion in Case 1, may also account for the different possibilities in varieties of lesions. (Pages 25 and 26.)

From the foregoing, the reader might be led to think that the date of union of any particular epiphysis with the appropriate diaphysis is invariable. That, however, is not so, and the conditions, which may cause predisposition to, or protection from, separation of epiphysis will now be considered. These are rickets, scurvy, congenital syphilis, tuberculosis, suppurative conditions, tumour growths, paralysis, developmental conditions,
conditions, and certain endocrine disturbances.

In rickets the epiphysis proper is not visibly affected, but the epiphyseal line being softer than normal, tends to spread out in a saucer-shaped expansion. The latter is "most marked where the stress and strain is directed perpendicular to the epiphyseal line as in the epiphyseal changes in the tibia and radius." (Baetjer and Waters). The epiphyses most affected are those which are growing most rapidly, and subjected to the greatest movement at the time of the disease (Thomson).

In rachitic children it appears that the cartilage is more adherent than normal to the diaphysis, and therefore separation is rarer, but the unequal deposition of new bone, which so frequently occurs, is of great practical importance, owing to the fact that it may produce varus or valgus deformities.

Scurvy results in the so-called Trümmer zone, which appears in the diaphysis parallel to, and about 3 or 4 m.m. from the epiphyseal line. The zone lies between areas of bone which appear denser than normal, and consists of a band of bone about 2 m.m. wide, which has undergone localised destruction. In addition periostitis, and sub-periosteal haemorrhages are usually present. The latter often become calcified. They extend only as far as the epiphyseal line owing to the periosteal attachment to the epiphysis being much firmer than to the shaft of the bone. Thus scurvy does not affect the epiphyseal cartilages unless in the very rare instances in which the sub-periosteal haemorrhages may be so excessive as to cause a pathological dislocation.
dislocation of one of the epiphyses by sheer pressure.

Bacterial infections exert various influences according to their virulence, and the site in relation to the epiphyseal cartilage. When the latter is the seat of an acute inflammation, retardation or actual stoppage of growth may result. The osteo-genetic function, however, may be stimulated firstly by the dilute toxins of an adjacent infective focus, be it acute or chronic, provided that it does not directly involve the epiphyseal junction. Secondly, according to Elmslie, growth may be stimulated by a chronic inflammatory lesion of the epiphyseal cartilage itself, as in tuberculosis in the region of the knee. This will be referred to again in connection with Humphrey's law and the prognosis after separation of the epiphysis. It is interesting to note that a chronic inflammatory lesion of the shaft, apart from the effect on the epiphyseal cartilage, "may give rise to overgrowth of the bone by increasing interstitial growth" (Elmslie).

Separation of the epiphysis insuch a case is probably more of the pathological than of the traumatic variety, even though there may be a history of injury. Thomson and Miles state that "in paralysed limbs the growth from the epiphysis is usually little short of the normal".

Generalised defective growth of bone at the ossifying junction, resulting in dwarfishing, may occur in rickets, congenital syphilis, and development anomalies such as achondroplasia.

Pituitary hyperactivity, and eunuchism on the other hand may result in delayed union of the epiphyses and giantism. In these conditions, therefore, it is conceivable that separation of the epiphyses may occur later
later than in normal individuals.

C. The Clinical Features. These vary with the degree and place of separation, and the presence or absence of displacement, and continuity with the surface. They simulate those of dislocation rather than of fracture.

The age must always be such as to render the condition possible. The swelling is often very marked. Displacement produces inability to use the limb, and a proportional degree of deformity. The abnormal mobility may simulate normal movement at the neighbouring joint, especially when the epiphysis lies intra-capsularly, but the bony landmarks reveal the true condition. The crepitus is softer than that typical of fracture, unless the separation is complicated by fracture. "The older the patient, and the further ossification has progressed the more does crepitus resemble that of fracture" (Thomson and Miles). The pain and the limitation of the tenderness to the epiphyseal line are useful aids to diagnosis, which tends to be difficult when the separation results from indirect or muscular violence without bruising of the soft parts.

Serious complications are not common, but may occur. For instance, at the lower end of the femur, the knee joint may become the site of a haemarthrosis, or an inflammation. The diaphysis, when displaced backwards may injure the popliteal nerves or vessels, and so cause aneurysm or even gangrene,--occasionally necessitating amputation. The tibia may be injured as mentioned above.
above. When the wound is compound, the risk of infection is great, and may result in periostitis and necrosis. Later complications, such as interference with growth will be considered under prognosis.

D. Diagnosis. Many cases, especially those without deformity, are regarded as sprains. Others are overlooked altogether, or treated without an exact diagnosis being made. The points to be noted are: - the site of the lesion, and especially of the tenderness, the character of the crepitus, and the findings of the X-ray examination. Reduction of the deformity, when present, helps to distinguish the injury from dislocation into the neighbouring joint. In the latter there is usually a "click", when reduction is effected, greater relief to the patient, and less tendency to re-displacement (Thomson and Miles).

E. Sequelae and Prognosis. Besides complications there may be sequelae. Of these the most important is interference with growth, -- retardation or arrest. This may occur equally across the epiphyseal line, and so cause a simple shortening of the bone, or it may be unequal, being greater at one side than at the other, and so deforming the bone in shape. Arrest of growth is sometimes associated with premature ossification of the
the cartilage. This is demonstrable by X-rays, and clinically, by deformity either in shape or size or both.

In 1922 M.K. Smith wrote that he had not been able to find any data as to the exact frequency of arrested growth after epiphyseal separation beyond the fact that it is rare. The obvious difficulty is, of course, in "following up" the cases for several years after the date of the trauma. However, Smith in "an enquiry to determine the incidence of untoward sequelae in epiphyseal line fractures" came to the conclusion that "shortening after epiphyseal injury may be the result of retarded function of the cartilage alone, or there may be premature ossification". He definitely opposes the theory propounded by Ollier on the strength of experimental data, that shortening is due to retarded proliferation of the cartilage in which ossification takes place earlier than normal, for he showed that even when growth is retarded, ossification may not occur until the normal time. Of course, when ossification does occur, whether before or at the normal time, no further growth takes place. Smith found premature ossification as early as 6 months after the injury in one case, and as late as 2½ years in another.

Poland's summation of the causes of defective growth is shortly as follows:--

1. Injury to the cartilage itself through crushing or bruising;
2. Callus with interference of the blood supply;
3. Entire destruction or serious impairment, e.g. from infection by external wound;
wound.

4. Deficient nutrition from imperfect reduction of the diaphysis;

5. Deficient nutrition from excessive callus, or retarded consolidation due to mobility of the fragments.

He also states "the relative value of each epiphysis in continuing the growth in length of a bone must be taken into account in determining the question of growth after injury, e.g. being more marked in detachment of the upper than of the lower end of the humerus". Arrest of growth is seldom compensated for later, and it may occur long after the original injury. Retardation "is more injurious in the lower than in the upper limb because from the functional point of view, it is essential that the lower extremities should be approximately of equal length" (Thomson and Miles).

When there occurs arrest of growth in one of a pair of parallel bones as in the forearm or leg, the growth of the other may continue, or be retarded, or arrested with the consequent valgus or varus deformities, mechanical dislocation (Baetjer and Waters). Moreover, an oblique fracture of a single bone such as that of the humerus, running from above the medial condyle into the middle of the joint, may retard the growth of the medial but not the lateral part of the lower epiphyseal line, and so create cubitus varus. Occasionally, when the end of the diaphysis has been the site of the injury, and the actual epiphyseal line has escaped, overgrowth may occur presumably through stimulation of the cartilage.

This is in accordance with Humphry's Law, which states that "a lesion of the epiphyseal end of a bone may pro-
produce deficient growth; a lesion of the shaft may produce overgrowth." As referred to above, Elmslie has emphasised that certain inflammatory processes may also produce either deficient or exuberant growth.

In general the \textit{prognosis} in injuries to epiphyseal cartilages must be guarded. According to M.K. Smith, who studied the possible factors for estimating the prognosis in individual cases, \textbf{a} the X-ray appearances of the injury, \textbf{b} the extent of the injury as seen clinically, and \textbf{c} the amount of the reduction of the displacement, if any, do not seem to be dependable criteria, but \textbf{d} the age of the patient at the time of the injury is more important. From \textbf{a} the X-ray appearances of the injury, there was found to be little or no difference in the frequency with which retardation of growth occurred between the cases of pure separation and those in which the separation was associated with diaphysial fracture. \textbf{b} The extent of the injury as shown by the original deformity does not give any indication as to the probability, or otherwise, of retardation of growth later on. Even cases of displacement so slight as not to require reduction are not immune from this untoward sequela. \textbf{c} Reduction, even when performed early, is no guarantee of a good result. Massart and Cabouat have recorded an interesting and unusual case in which the lower radial epiphysis on each side was separated by a fall. On one side only, however, was there any displacement. Re-examination three years later revealed a perfect result on the side which required reduction, but a shortening and radial deviation on the side which originally had no displacement.
displacement.

Zadek and Elmslie hold that imperfect reduction of the displacement involves risk of considerable retardation, or even complete arrest of growth. On the other hand, there seems to be a marked tendency for correction or compensation of the deformity to occur, even when there has been no reduction. Smith records two cases in which the late results have been excellent in spite of the fact that the patients did not seek consultation until years after the trauma, which produced a "silver fork" deformity. The age of the patient at the time of the injury appears to be of first importance in prognosis. Although the number of his cases on which to form a deduction, is rather small, Smith thinks "that there is more liability to damage of the cartilage as the time for its function to cease approaches". May it not be that just as the cells of the individual whose course is nearly run, are less robust than those of the young adult, so those cartilage cells, when their course is nearly run, are more easily disturbed than their more vigorous forbears. If Smith's deduction is correct, it is fortunate that arrest of growth is more liable to occur in bones already nearly fully grown, and therefore having less need of further growth than in those whose cartilages have still much work to perform.

Other undesirable results of separation are mal-union exuberant callus, and interference with the neighbouring joint. An authentic case of non-union after complete separation of the end of a long bone has not been found.
found in the literature. Exuberant callus may limit the movement of the neighbouring joint, or may interfere with nerves, e.g. at the lower end of the humerus. When the separated epiphysis is intra-articular, or when a fragment displaced into the joint cavity, and not properly reduced, maintains a source of irritation, a traumatic arthritis may ensue. Poland thinks that in strumous children such irritation may determine the localisation of tuberculosis in a joint.

E. Treatment. The general principles are the same as for fractures, and essentially consist of the accurate reduction of any displacement present, and the necessary fixation, followed by massage and passive movement. Reduction should, of course, be performed as soon after the injury as possible, and by manipulation when practicable. As to operative treatment, Fraser says:-

"Incision and reposition of the fragments are often the only manoeuvres necessary; the broad surfaces and the frequency of the concavo-convex arrangement generally prevent recurrences of the displacement......Children do not tolerate the use of plates and screws."

Operations to remedy the results of defective growth are numerous. In deformities of one of the parallel bones as in the forearm, or leg, resection of the growing point of, and a sufficient length of, the sound bone while producing a shortened limb, removes the inconvenient valgus or varus deformity. The patient's age, the amount of the deformity, and the relative importance
importance as regards growth of the particular cartilage, have all to be considered in recommending such operations. Some surgeons advise waiting until full development before operating. Case V illustrates how a traumatic coxa vara was cured by cuneiform osteotomy.

Attempts to irritate the cartilage by the introduction of foreign bodies into the medullary cavity, laceration of the periosteum, cauterisation and the like with a view to increasing growth, do not seem likely to succeed, although Helferich and Max Schüller claim to have had good results.

In cases where the deformity has remained unreduced, and the osteoblasts have filled up the space between the diaphysis and the periosteum torn off it, the removal of the opposite side of the diaphysis enhances the looks, and by preventing the stretching and contractions of the tendons, increases the utility of the limb.

Separation of the Lower Epiphysis of the Radius, showing wide separation of the periosteum from the shaft. (From Hutchinson.)
Case I. Compound Separation of the Upper Epiphysis of the Humerus with Complete Displacement of the Diaphysis.

James H. aetat 13 was admitted to Ward 16 R.I.E. on 24.III.26.

History. The patient had been knocked down and run over by a motor-car.

Examination. A wound 3" long was found on the posterolateral aspect of the left arm opposite the surgical neck of the humerus. The upper end of the diaphysis was separated from the epiphysis and was projecting through the wound.

Treatment. Under general anaesthesia the displacement was reduced, and extension applied by Mr. Bruce M. Dick. After excision of the edges, the wound was carbolised, and washed with sterile saline, and an iodine dressing was applied. The shoulder joint was not opened. The limb was placed in a Thomas humerus-extension splint, care being taken not to produce over-extension.

An X-ray photograph taken on 27.III.26 showed good position of the fragments. Unfortunately the wound became septic, and took seven weeks to heal. During this time there appeared in the region of the elbow a swelling which on being incised on 4.V.26. discharged a quantity of serous fluid.

The following is a print of the X-Ray Photograph taken on 27.III.26. The shadow of the ring of the Thomas splint is seen.
Commentary. The upper end of the humerus is one of the commonest sites of epiphyseal separation as well as of epiphyseal strain. The compound variety of separation is, however, comparatively rare.

The upper end of the humerus (humeral epiphysis) when fully formed, includes the head and anatomical neck, the two tubercles, the upper fourth of the intertubercular (O.T. bicipital) groove, and a small portion of the bone between the anatomical neck and the lesser tubercle, and lying lateral to that tubercle.

The epiphysis is composed of three centres of ossification which unite together at about the 5th. to 7th. year, and, according to most writers, with the shaft about the 20th. or 21st. year. Arthur Thomson, however, gives the 25th. year as the date of union with the diaphysis. The first of the centres to appear is that for the head. It is usually demonstrable within the first 6 months after birth. The second, that for the greater tubercle, forms during the second or third year, and these two centres soon coalesce. The third centre, which is for the lesser tubercle, appears between the third and fifth years. From this it will be seen that several different separations may occur: for example, the epiphysis of the head alone may separate between the 6th. month and the 2nd. or 3rd. year, and either of the epiphysis of the tubercles may separate up to the end of the 5th. year.
Ossification of the Humerus.

(From Arthur Thomson.)

1. For head, appears within first 6 months after birth.
2. For greater tubercle, appears 2 to 3 years.
3. Centres for head and greater tubercle coalesce about 5 years.
4. For lesser tubercle, appears in third year, and fuses with other centres about 7 years.
5. Proximal epiphysis fuses with the shaft about 25 years.
The surface of the composite epiphysis, and that of the diaphysis are almost flat in infancy, but with age assume the familiar cap and cone arrangement, which adds considerably to the natural resistance to displacement. The writer suggests tentatively that this change in shape, in older individuals, account in part at least, for the small tendency to displacement after separation in their case. The older the individual, the nearer is the epiphyseal line to the head of the bone, and in the adult the line marks the upper limit of the surgical neck, and in the medial under aspect, the attachment of the capsular ligament of the shoulder joint. (The remainder of the capsule adheres to the portion of the anatomical neck between the head and the tubercles). Poland, however, asserts that separation of the epiphysis does not necessarily open the joint for "the capsule is firmly attached to the epiphysis and the synovial membrane passing off from the articular cartilage is but loosely attached to the diaphysis".

In common with other separations this lesion occurs more frequently in males than in females. The age ranges from birth up to 25 years,--the commonest years according to Wilson and Cochrane being between 5 and 15 years.

Causation. This separation may be produced by either direct or indirect violence; the usual cause, according to Fraser being a severe wrenching movement. Although the number of cases recorded by Poland as known to be due to direct violence is only 7, it is of interest to note that of the 7, 4 were compound. From its appearance
appearance, the wound in the case recorded looked as if it had been made by contact with part of the car which ran over the boy rather than by the conical end of the displaced diaphysis. If this supposition is correct, the violence must almost certainly been direct. The forms of indirect violence necessary to produce the separation of this epiphysis are several, and the commoner include:--a fall upon the shoulder, a fall upon the outstretched arm causing forcible abduction, a fall upon the outer side of the elbow (Kocher), and the lifting of a child by traction on the arm. One case in a boy, recorded by Sir Charles Bell, was due to the "kick" of the butt of a musket, while shooting. Another case was reputed by the reporter to be caused by muscular action, but Poland considered the case to be one of acute osteomyelitis,--a pathological rather than a traumatic detachment of the epiphysis. Traction upon the upper limbs during delivery, especially when there is defective nutrition of the bone, may cause a separation of the cartilaginous upper end of the bone.

Separation through the cartilage is extremely rare, separation between the diaphysis and the epiphyseal cartilage, and fracture of the diaphysis itself being much commoner. Poland, who states that separation without displacement may occur, but has not yet been anatomically proved, records cases illustrating the various displacements. Of the latter the commonest is forwards and inwards, others being:--incompletely forwards (i.e. that is with only part of the width of the diaphysis opposite the epiphysis); incompletely or completely backwards;
backwards; outwards; outwards and upwards; forwards either above or below the coracoid process. Partial is commoner than complete displacement, according to Fraser. In rare cases of separation, which have been overlooked, displacement may occur at a later date. Poland does not mention any case in which the displacement is exactly comparable to that in the case recorded.

The Clinical Features simulate fracture of the surgical neck. The crepitus, however, is softer, and the head of the bone by remaining in the glenoid fossa, tends to be rotated by its attached muscles, so that the articular surface looks down rather than in. (Fraser). The deformity depends upon the displacement, and unless the latter has been complete, the limb is not shortened. There is usually not any effusion into the joint.

Complications of this lesion include injury to the axillary artery with its sequelae, injury to the shoulder joint, periostitis, and necrosis. The two last mentioned complications are rare except in compound cases.

Prognosis must in this case be specially guarded owing to the supervention of sepsis, and to the fact that the epiphysis involved is the more important of the two for the future growth of the arm.

The treatment, when displacement is present, is initiated by reduction. This is usually performed by traction on the arm in abduction, or hyper-abduction. When the manipulation is unsuccessful (or when some days have elapsed before it is attempted), traction in a Thomas arm splint is exerted before another attempt is made. Open operation in a case not already compound.
compound is seldom required, and is only performed on an account of the inter-position of the torn periosteum, or other soft tissues. (Wilson and Cochrane). Reduction is followed by immobilisation for two or three weeks, massage being started on the fifth day. Immediate active movement is not required, since there is little risk of fixation of the shoulder joint in children, and the concavo-convex arrangement reduces the likelihood of re-displacement. Fraser describes the method of splintage used for immobilisation;--the upper arm is bandaged to the chest, and a sling supports the wrist, but not the elbow which is kept flexed. The weight of the arm is thus made to exert a slight beneficial traction. When the injury is compound, the usual wound treatment should be carried out as in this case.
Case II. Separation and Anterior Displacement of the Upper Epiphysis of the Radius.

Wm. B. aetat 13 was admitted to Ward 7. R.I.E. on 16.XI.25.

History. On 12.XI.25, while practising in a gymnasium, the patient fell on his back. Thereafter he had a constant though decreasing pain on the anterior aspect of the right elbow joint. In addition there were pains shooting, intermittently, up and down the limb. He does not know the position of the elbow at the time of the fall.

Examination of the elbow revealed marked swelling but no tenderness except at a spot \( \frac{1}{2} \) " lateral & \( \frac{1}{2} \) " proximal to the medial epicondyle. Although the arm could be extended almost completely, it could not be flexed beyond a right angle. Neither pronation nor supination could be performed. An X-ray photograph showed a separation of the upper epiphysis of the radius.

Treatment. On 17.XI.25. Prof. Fraser replaced the epiphysis by open operation under general anaesthesia. With the forearm extended, an incision 3" long was made on the lateral aspect of the limb, the centre of the incision being over the elbow joint. The deep fascia of the arm was divided in the line of the incision. The belly of the brachialis (O.T. Supinator Longus) muscle, and the attachment of the extensor carpi radialis longus muscle to the distal third of the lateral epicondylar ridge of the humerus were separated by blunt dissection, and the muscles retracted. The radial collateral (O.T. External lateral) ligament was divided transversely, and the elbow joint opened immediately below the capitulum. The blood clot found in the joint was removed. The upper edge of the annular radial (O.T. Orbicular) ligament was divided and the epiphysis exposed lying upon the anterior aspect of the proximal end of the diaphysis of the radius immediately proximal to the tuberosity. With the forearm flexed and supinated, the displaced epiphysis was levered into position, and fortunately there was not any tendency for the displacement to recur. The wound was closed in layers, and a plaster jacket applied to the limb, -flexed at a right angle and supinated,- a window being cut in the plaster over the wound.

Commentary.

Separation of the upper radial epiphysis, especially when it occurs as the sole injury, is an exceedingly rare condition, though perhaps not quite so uncommon as Wilson and Cochrane suggest when they say that it is "almost unknown". The condition is probably usually
Case II. Antero-posterior X-Ray Photograph, showing Separation and Displacement of the Upper Epiphysis of the Radius.
usually complicated by some other lesion, such as a backward dislocation of the ulna, as in Moore's case published by Poland. The comparative rarity of the separation of this epiphysis is in part explained by the earliness of union, - there being less time compared with other epiphyses in which separation is likely, - for the upper portion of the head of the radius has a separate centre of ossification, which includes only the proximal part of the articular surface, and appearing about the 5th: year and uniting with the shaft at the 15th: to 18th: year (Wilson & Cochrane) is remarkable as being of all the epiphyses of the long bones, the last to become osseous, and the first to unite with the shaft. (Poland). Other factors in determining the paucity of cases of this condition are the size and situation of the epiphysis, the protection afforded it by the annular ligament, and the absence of attachments to it of ligaments and tendons. When separation does occur, the synovial membrane is nearly always lacerated, since the epiphysis is wholly intra-capsular.

In regard to causation Poland (Page 472) came to the rather unexpected conclusion that the injury is more often the result of indirect than of direct violence. To which of these it is due in this case it is difficult to say owing to the vagueness of the history.

The Clinical Features simulate those of fracture of the upper part of the neck of the radius. The limitation of movement, and the site of the tenderness in this case recorded are typical. When there is no displacement, there need be no deformity other than swelling
swelling and effusion; but in passive pronation and supination, the head of the radius does not rotate with the diaphysis, while it is usually possible to elicit muffled crepitus.

The usual displacement, when any is present, is an anterior displacement of the diaphysis, while the epiphysis retains its normal position in relation to the humerus. This case, therefore, illustrates an unusual variety of a rare lesion.

**The Prognosis** must as usual be guarded. In this case sufficient time has not elapsed to show how growth may be affected. Fortunately, the upper epiphysis of the radius is not so important as the lower one in connection with the growth of bone.

**Treatment.** If there is not displacement, active measures beyond suitable fixation, and passive movement are not indicated. In the common anterior displacement of the diaphysis, reduction is easy; but in displacement of the epiphysis, open operation, as performed in this case appears to be the only alternative.

George A. aet. 14 was admitted to Ward VII.R.I.E. on 30.X.25.

History. While pushing a hutch in a pit, the patient was struck by a second hutch on the dorsal aspect of the right forearm about the junction of the distal and middle thirds. He experienced considerable pain.

Examination. About midway between the elbow and wrist the forearm was bent at an angle, and showed a wound about 1" long on the postero-lateral aspect. The radius was fractured immediately above the insertion of the pronator teres muscle, and the ulna had a greenstick fracture about an inch lower down. The posterior aspect of the distal end of the radius was swollen, and slightly tender.

Treatment. On 30.X.25. Mr. T. McW. Millar excised the wound. By means of extension and counter extension the green-stick fracture of the ulna was "completed", and the displacements reduced. Splints were applied with the limb extended.

On 31.X.25. X-ray Examination showed in addition to the above injuries a separation of the lower epiphysis and fracture of the lateral condyle of the radius. The diaphysis was displaced medially. (These injuries had been overshadowed by the more painful injuries at the higher level).

On 14.XI.25. Under general anaesthesia Mr. Walter Mercer reduced the displacement of the diaphysis, and united the lateral condyle to the remainder of the shaft by means of wire. Access was obtained by an incision on the lateral aspect of the forearm with its centre over the epiphyseal line, the extensors of the thumb being retracted posteriorly. A bone peg was introduced into the medullary cavities of the two main fragments of the radius, entrance being gained on the lateral aspect of the middle 1/3 of the forearm. Plaster was applied, a window being made over the upper wound.

On 7.XII.25. The plaster was removed and massage begun. In three weeks both bones gradually became bowed backwards, resulting in limitation of pronation and supination. Otherwise the movements at the elbow and wrist were satisfactory.

On 4.XII.26. Under general anaesthesia Mr. Walter Mercer straightened the bones by an osteoclast. Plaster was applied to the limb from the elbow to the palm, the hand being dorsi-flexed, the elbow flexed, and the radius and ulna bowed slightly forwards (i.e. overcorrection of the deformity).
Case III. Antero-posterior X-Ray Photograph, showing Separation of the Lower Epiphysis of the Radius and Medial Displacement of the Diaphysis. The Lateral Condyle of the Diaphysis has been fractured.
Case III. Antero-posterior X-Ray Photograph, showing Reduction of the Displacement of the Lower Epiphysis of the Radius. The Lateral Condyle of the Diaphysis has been fixed to the remainder of the shaft by wire.
Commentary. With the possible exception of the lower end of the femur, the lower radial epiphysis is the one most commonly separated. This is explicable by the lateness of its union, its liability to trauma from its position, and its lack of natural protection, and the comparative absence of the concavo-convex arrangement.

The epiphysis appears about the 2nd. year and unites with the shaft between the 19th. and 25th. years; the union in females, according to Arthur Thomson, being somewhat earlier. Like other lesions of this type this separation is commoner among boys than among girls, and usually occurs between 12 and 18 years of age. Before 12 years of age, owing to the predominance of the tough cartilaginous elements, fracture of both bones of the forearm, or a dislocation of the elbow joint are more frequent than a separation of the epiphysis (Wilson and Cochrane).

The lesion is nearly always due to indirect violence such as a fall on to the outstretched hand. In falling hyperextension and pronation of the hand are instinctive reflex actions, and Cheyne showed that when the angle between the forearm and the ground is less than 60 degrees at the moment of impact, the lower end of the radius has to bear the whole shock. The mechanism of production of this separation, and the deformity resulting from it, resemble therefore those of a Colles frac-
fracture in adults. In both conditions the ulnar styloid is usually torn off by traction through the medial (C.T. Internal lateral) ligament. Most of the ages possible for the occurrence of separation of the lower radial epiphysis are coincident with those possible for separation of the lower ulnar epiphysis, and thus in rare cases of separation of the lower radial epiphysis, separation of the lower ulnar epiphysis may occur instead of the avulsion of the ulnar styloid.

The line of separation is seldom entirely between the cartilage and the diaphysis, as depicted in the diagram on page 23 but usually passes through the diaphysis as in the case recorded. The separation of the lower radial epiphysis has also been known to occur from a fall, or blow on the dorsum of the hand with flexion of the wrist. In such a case the force acts in the anterior, and not in the usual posterior direction, and the displacement of the lower fragment is then forwards and upwards instead of backwards and upwards. Owing to the multiplicity of the lesions in the case recorded it is difficult to determine the mechanism which produced the separation. Fracture of both bones of the forearm complicating this lesion is reported by Koerte (Poland) in a case in which the limb was torn off in the middle of the upper arm.

Other complications recorded include fracture of the epiphysis, laceration of the pronator quadratus muscle, injury to the wrist joint, fracture of the shaft or dislocation of the ulna, injuries of the radial and median nerves, and of the radial artery, dislocation
dislocation of the forearm backwards, and various pyogenic or tetanic infections.

The Clinical Features depend upon the presence or absence of displacement and complications. In the common variety, they resemble those of Colles' fracture, but "the pain and swelling may be comparatively slight. The line of deformity is close to the carpus, reduction is easy, and after reduction there is little tendency for the displacement to recur" (Fraser).

The Prognosis must, as usual, be guarded, and especially since the lower of the two radial epiphyses is the more important for growth. The possible results of retardation of growth in one of the pair of parallel bones were noted on page 19. In the case recorded the ossifying area was probably not seriously damaged, -- time, however, will show. It will be interesting to note if the wire inserted into the end of the diaphyses shall stimulate osteo-genesis. The progress of the injuries of the shafts to present date augurs well for a good ultimate result.

Treatment in the uncomplicated case is the same as for Colles' fracture, but it is "unnecessary for splints to be kept in position for longer than a week or ten days" (Fraser). Fracture of the condyle of the diaphysis is best treated by open operation, and wiring as in this case.
Case IV. Separation and Anterior Displacement of the Lower Epiphysis of the Femur.

John W. aetat. 14 was admitted to Ward 7, R.I.E. on 13.11.26.

History. While the patient was working a grindstone, a week before admission, the handle caught his jacket and pulled him over. As he fell forward, the posterior aspect of his right leg immediately below the knee struck the under side of the seat of a stool standing behind him. After the accident he felt pain in the knee, but could walk. Later the region became swollen and the patient could not bear weight on the limb. On 13.11.26, when he visited the S.C.R.D., a quantity of blood stained fluid was aspirated from the knee-joint with a fine needle, and an X-ray photograph taken.

Examination. The swelling obscured the outline of the bony parts. The antero-posterior diameter of the lower end of the femur of the injured side was slightly greater than that of the left side. The lateral aspect of the lower third of the thigh was discoloured. The knee was held in a slightly flexed position, movement of the joint causing pain. The X-ray photograph showed an anterior displacement of the lower epiphysis, and a fracture of the medial side of the diaphysis of the femur.

Treatment. On 13.11.26, under general anaesthesia, an attempt was made to reduce the dislocation by manipulation. After flexing the knee to relax the gastrocnemius muscle, traction in an anteroposterior direction, with gentle rotatory movements, were made upon the upper part of the leg close to the knee, counter-traction being exerted meanwhile by an assistant pulling the thigh proximally. The limb was then placed upon a Miles' double-inclined plane. On an X-ray photograph being taken, it was seen that, while partial reduction had been accomplished, the lateral condyle of the femur still showed a forward displacement of about an inch.

On 16.11.26, Prof. Fraser reduced the displacement by open operation under general anaesthesia. The knee-joint being slightly flexed over a sandbag, an incision 4" long was made in the vertical line of the lateral border of the patella, and ending at the upper border of that bone. The lower end of the incision curved slightly backwards. The fascia lata and vastus lateralis muscle having been divided in the line of the incision, and the blood vessels having been ligated, the bone was exposed. The epiphysis was levered back into position, but the displacement tended to recur unless the knee was kept rigidly at a right angle. The wound was closed in layers, and plaster applied from the groin to the toes with the joint at a right angle. The knee-joint was not opened. The X-ray photographs unfortunately showed redisplacement.

The patient is to be re-admitted for further treatment.
Case IV. Antero-Posterior X-Ray Photograph, showing Separation and Displacement of the Lower Epiphysis of the Femur and Fracture of the medial side of the Diaphysis.
Case IV. Lateral X-Ray Photograph, taken on 28.iii.26. Unfortunately there is still displacement of the epiphysis. Bone is being formed between the anterior surface of the end of the diaphysis and the periosteum which has been torn off it. The lack of clearness is due to the thickness of the plaster-jacket applied immediately after the open operation.
Case IV. Lateral X-Ray Photograph of another case to compare with that of case IV. This shows separation and posterior displacement of the lower epiphysis of the femur. (From a negative very kindly lent to the writer by Dr. J. M. Woodburn Morison and Mr. Walter Mercer, F.R.C.S.).
Commentary. Separation of the lower epiphysis of the femur is probably the most common of all separations, although Baetjer and Waters regard it as uncommon. This frequency may in part be due to it being the last epiphysis in the body to unite with its diaphysis. With the occasional exception of the upper end of the tibia it is the only one whose ossification begins before birth. It unites with the shaft about the end of the 21st year, and includes the complete articular surface of the lower end of the femur. The line of the cartilage is sufficiently accurately represented by the adductor tubercle (Fraser). Separation occurs usually between the ages of 8 and 14 years. Commenting upon the much greater frequency among boys than among girls, Poland in 1898 remarked that "the modern tendency for the female sex to imitate the habits of the males may, however, in the future considerably modify this"!

Causation. According to most writers the lesion is the result of extreme force. Poland, however, thinks that the violence need not be so great, since during hyperextension the tibia acts as a very powerful lever by means of the popliteus muscle, and the crucial and other ligaments. Indirect is commoner than direct violence. The origins of the gastrocnemius muscle from the epiphysis, and the fact that the knee-joint depends for its strength upon its ligaments rather
rather than upon the contour of its bones, are important factors in causing this separation, when the knee is forcibly hyperextended and rotated. These movements usually follow the engagement of the leg in the spokes of a revolving wheel,-- hence the name "cart-wheel fracture". Owing to the decreasing use of carts and cabs, this separation will probably be less common in the future. The history in this case suggests strongly a mode of production of this separation very similar to the "cart-wheel".

According to Wilson and Cochrane, at the time of injury the diaphyseal origin of the gastrocnemius muscle (i.e. on the back of the femur, immediately proximal to the epiphyseal line) is torn off owing to the loose attachment of the periosteum there, and the end of the shaft thus denuded "is displaced downwards into the popliteal space". The remainder of the gastrocnemius muscle then rotates the separated epiphysis onto the position of right-angled flexion.

Displacement may be absent, but when present, is according to the literature most commonly an anterior displacement of the epiphysis as in this case. It is interesting to note, however, that out of 4 consecutive cases of this separation X-rayed by Dr. Woodburn Morrison, 3 showed posterior and only one showed anterior displacement of the epiphysis.

Apart from the action of the gastrocnemius muscle, referred to above, the direction of the violence plays a part in determining the direction of the displacement, and may account for the cases recorded in which
Mechanism of Displacement in Separation of the Lower Epiphysis of the Femur. (After Wilson and Cochrane.)

Separation as a result of hyperextension.

Characteristic displacement with the shaft protruding downward and backward & the cartilage lying anterior and flexed, due to the action of the gastrocnemius muscle.
which the epiphysis has been displaced in the following directions:--backwards and outwards; outwards; forwards and outwards; forwards, and inwards; inwards. In rare cases the displacement has occurred days subsequent to the separation. The capsule of the knee-joint is seldom damaged. The complications of this separation were taken as the examples for the general commentary on complications. (See pages 16 and 17.)

The Clinical Features in the typical case include marked swelling of the knee, undue prominence of the patella, a transverse depression immediately above the latter, across the front of the thigh, fulness in the popliteal space, feeble pulsation in the posterior tibial artery, increased lateral and antero-posterior mobility at the knee, and soft crepitus. (Fraser).

The lesion is often compound, and often associated with fractures of the diaphysis, and epiphysis. In the present case a small portion on the medial side of the diaphysis has separated. (See X-ray page 43.)

Diagnosis. Supracondylar fracture which is commonest in the adult male occurs at a higher level, and is associated with coarser crepitus, and a less marked degree of displacement. Dislocation of the knee-joint is rare in young subjects and results in fixation of the joint; there is no shortening of the limb, and the deformity differs from that typical of separation of the epiphysis.

Prognosis. Apart from complications such as gangrene and secondary haemorrhage, which may call for amputation the prognosis must be guarded. In rare cases the knee-
knee-joint becomes stiff. The most important sequela is the arrest of growth, and is especially serious as the growth of the femur depends more on the lower than on the upper epiphyses. If the osteogenetic function is upset unequally over the growing surface, valgus or varus deformities may arise (see Case V), but if the arrest occurs equally, shortening of the limb results with secondary tilting of the pelvis and scoliosis of the spine.

Treatment. Apart from the method of reduction which was tried first in this case, Fraser describes a procedure, in which during the gradual flexion of the knee, the lower part of the thigh is grasped so that while the fingers in the popliteal space rest on the upper fragment displaced backwards, the thumbs press the upper border of the epiphysis into position. After reduction the tendency to re-displacement is proportional to the amount of extension of the knee above 120 degrees.

As after-treatment it seems advisable to immobilise the joint in a flexed position with splints until the swelling has subsided. Thereafter plaster may be applied. Later still the knee should be extended, and a new casing of plaster applied and kept on until on an average eight weeks have passed since the date of the trauma.
Case V. Traumatic Genu Valgum following injury to Epiphyseal Cartilage at Lower End of Femur.

Alex. M., aetat 22, ploughman, was admitted to Ward VII. R.I.E. on 20.1.25, complaining of pain in the right knee, and of becoming easily tired when walking.

History. Previous to October 1919 the patient was quite well. He then, when standing erect, received a kick from a horse on the lateral condyle of the right femur. This knocked him over, and he fainted. He was taken to a country hospital, where on examination, no wound was found on the surface, but the knee was very painful. Whether or not it could be moved then is not now remembered by the patient. The limb was placed on a double-inclined plane for about 10 weeks, at the end of which time the knee although no longer painful was very stiff on movement. The patient then noticed that the injured limb was shorter than its neighbour, and that the right knee was bent inwards towards the left one. This latter abnormality increased after walking. From April 1920 he has been in nearly constant employment until Dec. 1924, when he had to stop work on account of the pain in the knee.

Examination. The patient was well built without any indication of rickets. The right lower limb showed a marked degree of genu valgum, which was obviously due to a deformity in the region of the lower end of the femur, and not below the knee. The patella was displaced laterally, allowing palpation of the inter-condylar space. There was little atrophy of the muscles and no tenderness.

While a line drawn from the anterior superior iliac spine to the great toe on the left side passed through the centre of the patella, the corresponding line on the right side ran along the outer edge of the lateral condyle of the femur. The knee did not contain any fluid. The movements there were normal with the exception of a very slight limitation of extension, and were not accompanied with either pain or crepitus. On flexion the deformity disappeared, and there was seen on the upper aspect of the lateral condyle of the femur a vertical ridge 2" long, and of bony hardness to the touch which was invisible when the knee was extended.

On palpation the medial condyle of the femur was irregular in outline.

When standing with the feet together, the right knee was in front of the left, and the pelvis was slightly tilted down on the right side. There was no scoliosis of the spine. With the knees touching, and in the same antero-posterior plane, the medial malleoli were about 4" apart. On walking the right thigh was rotated outwards, and the foot inverted.

An X-Ray photograph showed that the extra-articular part of the medial condyle of the femur was out of shape.

Treatment. On 22.1.25, Sir Harold Stiles performed cuneiform osteotomy, using Chiene's method. Under general anaesthesia, with the thigh rotated outwards, and the knee semi-flexed over a sandbag, an oblique incision 3" long was made in front of the tendon of the
the adductor magnus muscle, passing forwards and downwards to a point ½" in front of, and ¾" above the adductor tubercle (i.e. avoiding the epiphyseal line.) The vastus medialis muscle (which in this region covers but has no attachment to the medial aspect of the femur) was divided in the line of the incision. Branches of the arteria genu suprema were ligated or pulled aside. An H-shaped incision was made in the periosteum, which was then lifted off the bone. A broad osteotome was used to cut a wedge out of the bone, so that the lower border of the wedge was transverse, and the upper one oblique. The wound was temporarily covered with gauze, and by pressing his knee on the lateral aspect of the thigh opposite the wound, the surgeon broke the femur across. Difficulty was experienced in doing this, presumably owing to hardness of the bone following the accident.

Diagram illustrating Cuneiform Osteotomy for Genu Valgum. (Chiene's Method.)

The limb could now be straightened to the normal outline. After closure of the wound, a plaster-casing from the pelvis to the foot was applied to the limb, the deformity being corrected and the knee extended.

Progress. (May, 1926.) The patient writes that his symptoms, though alleviated, are still present and that he limps in spite of wearing a thick sole.
Case V. Photographs taken before operation.

Front View.

Back View.
Commentary.

Genu Valgum is due to the growth at the ossifying areas of the femur or tibia or both being greater on the medial than on the lateral side (Macewen & Mickleiz). "This inequality of growth is nearly always due to rickets, and its direction is determined by a faulty attitude of the limbs in standing and walking. The legs being abducted, the weight of the body falls unequally on the medial and lateral parts of the ossifying junctions, and inequality of growth results." According to Thomson and Miles, in the rachitic form which is frequently bilateral, the lower epiphysis of the femur is normal and the adjacent third of the diaphysis is lengthened on the medial, and shortened on the lateral side. This results in the oblique apposition of the epiphysis to the diaphysis with apparent lengthening and abnormally low position of the medial condyle. The tibia is often similarly affected and the neck of the femur becomes shortened, and its angle diminished.

Natural attempts at compensation of the genu valgum include bowing inwards of the lower third of the leg and thickening of the articular cartilage of the lateral condyle, and the lateral meniscus.

This case, however, was obviously due not to rickets, but to the injury to the growing area on the lateral side of the lower end of the femur. Although the diagnosis made at the time of the injury is unknown to the writer, it seems probable that the trauma consisted of a partial separation of the epiphysis. The age of the patient then (17 to 18 years), and the fact that osseous union in that region does not normally occur until the
the 21st year, are in consonance with this diagnosis. Alterations occur in the soft parts in consequence of the bony changes. The sartorius and gracilis muscles become posterior, instead of medial to the knee, and the biceps muscle, and the ilio-tibial band are shortened, and displaced laterally. "The popliteal artery lies on the back of the lateral condyle instead of in the hollow between the condyles, and the tibial (C.T. internal popliteal) nerve is displaced even farther outwards." (Thomson and Miles).

Besides the two causes mentioned (rickets and trauma) genu valgum may result from 3. faulty position of the limbs in utero; 4. spastic paralysis; 5. osteomyelitis; of the lower end of the femur; and 6. disease of the knee joint, such as tuberculosis, arthritis deformans, and Charcot's disease.

Diagnosis of the condition is easy. The lateral displacement of the patella, and the quadriceps tendon, and the disappearance of the deformity on flexion of the knee owing to the sliding of the tibia behind the projecting medial condyle, seen in this case were typical. The patella, however, was not displaced to such a degree as to be dislocated on to the lateral condyle on flexion of the knee.

Treatment. The operations for knock-knee include the following:--

1. Macewen's linear osteotomy of the femur above the condyles.
2. Sir Robert Jones' method, whereby three fourths of the thickness of the femur is divided with a modified Adam's saw, and the remaining fourth is broken across
across after the healing of the wound in the soft parts.

3. Chiene's Cuneiform Osteotomy, as performed in this case.

If required, similar procedures may be carried out on the tibia. In all cases, the limb, after operation, is put up in plaster,-- preferably with slight over-correction of the deformity in the direction of genu varum.
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