CHAPTER L

MUSCLES, TENDONS, AND BURSÆ

JOHN CHARNLEY

INJURIES OF MUSCLES AND TENDONS

Contusion of a muscle results from direct injury. Localised pain follows attempts at contraction, and an extravasation of blood occurs within the muscle sheath. This extravasation often appears at a considerable distance from the actual site of injury, e.g. hæmorrhage from a torn rectus femoris in its upper part usually appears near the patella.

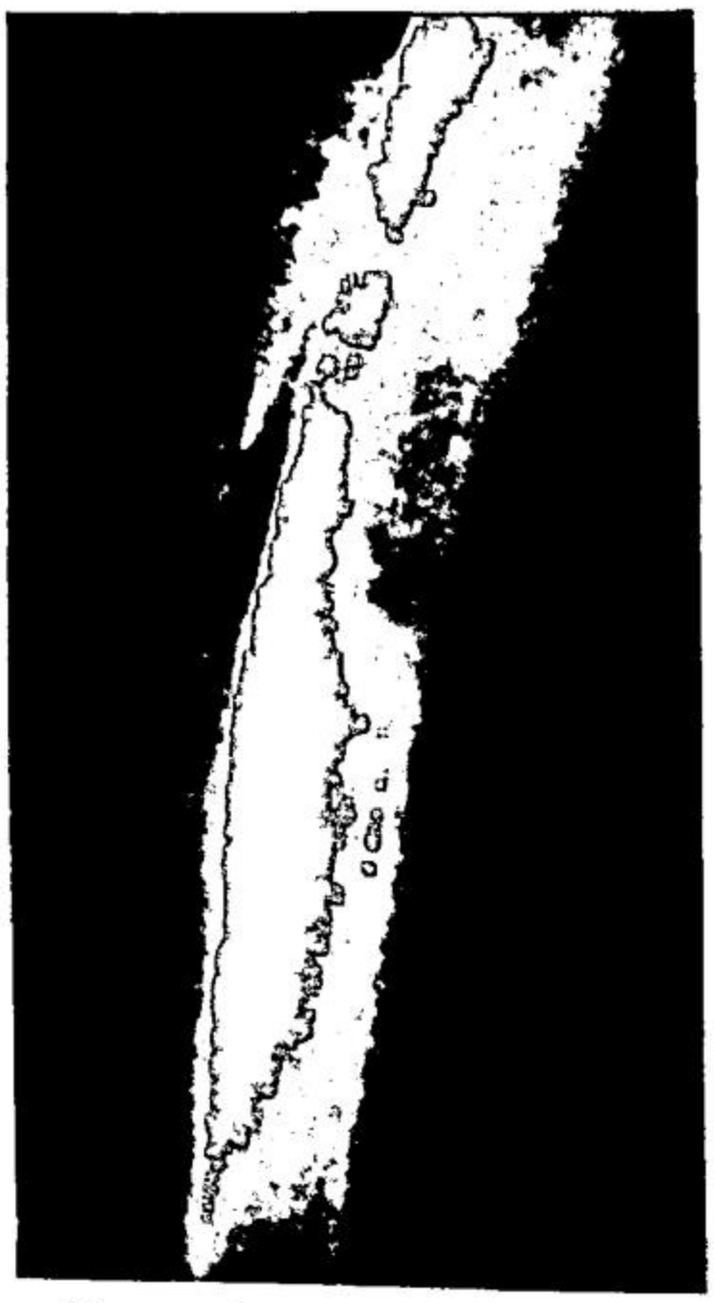

FIG. 1648.—Myositis ossificans of the thigh. Late appearance of bone on anterior aspect of the femoral shaft.

Rest and pressure dressings are required for the first two days, and, when risk of further extravasation has passed, gentle active movements will expedite absorption, and prevent, or limit, subsequent stiffness.

The rupture of some deep fibres of the quadriceps with a hæmatoma on the anterior surface of the femur is a not uncommon spontaneous injury in sport, but it may also result from a direct contusion. If too vigorously managed and passively stretched, this is a notorious site for 'myositis ossificans' (fig. 1648).

Rupture of a muscle usually occurs at the junction of tendon and muscle itself. Thus the *quadriceps extensor* ruptures immediately above the patella. It is an injury which occurs in elderly patients, often after a trivial indirect injury such as stumbling. The gap is easily visible and palpable when the patient contracts the quadriceps muscle (fig. 1649). The patient is unable actively to extend the knee. Repair with mattress or interlocking stitches is necessary. The prognosis regarding complete restoration of function is less favourable than in the case of a fractured patella, as accurate approximation of the muscle is difficult, and the fibrous union in the muscle tends to stretch.

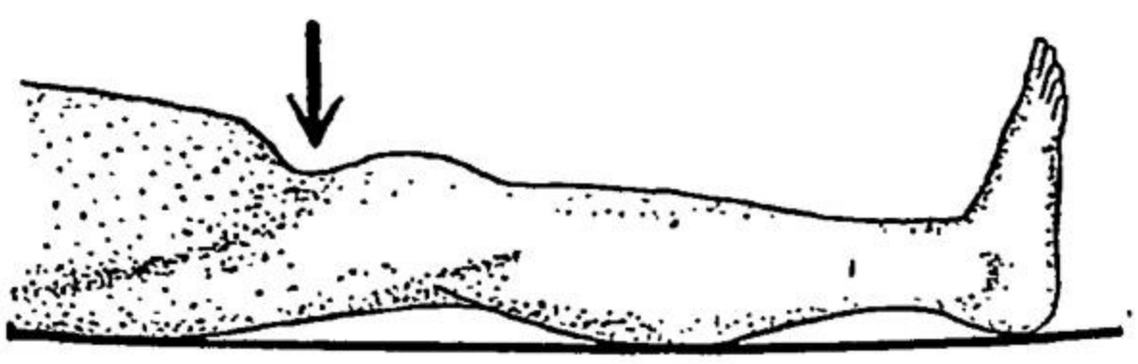

FIG. 1649.—Torn quadriceps femoris muscle.

Rupture of the muscle belly of *rectus femoris* occurs at about mid-thigh level. This is an injury of young athletic persons and is by indirect violence during very great effort. Extension of the knee is still possible after the

pain of the rupture has subsided. When all local œdema has disappeared, the proximal end of the muscle will become prominent and stand out as a visible lump when the patient contracts the thigh.

Rupture of Tendons.—Normal tendons rupture with great rarity; indeed, with the exception of 'mallet finger,' all tendon ruptures occur in or after middle-age and sometimes in association with local attrition by friction against bone. The *Achilles tendon* is the commonest tendon to rupture, and as it is frequently diagnosed incorrectly, special note should be made of its clinical features. It is an injury most common in males in later life and, though it can happen during games and severe exertion, it more frequently occurs as a result of a stumble when the violent contraction necessary to regain balance causes the rupture. The sensation of rupture is often mistaken for a blow on the back of the leg and the patient will often turn round to see who has hit him. The rupture usually occurs about 1 inch to 1½ inches (2·5 cm. to 3·75 cm.) above the insertion of the tendon into the os calcis, and thus usually occurs in the substance of the tendon itself.

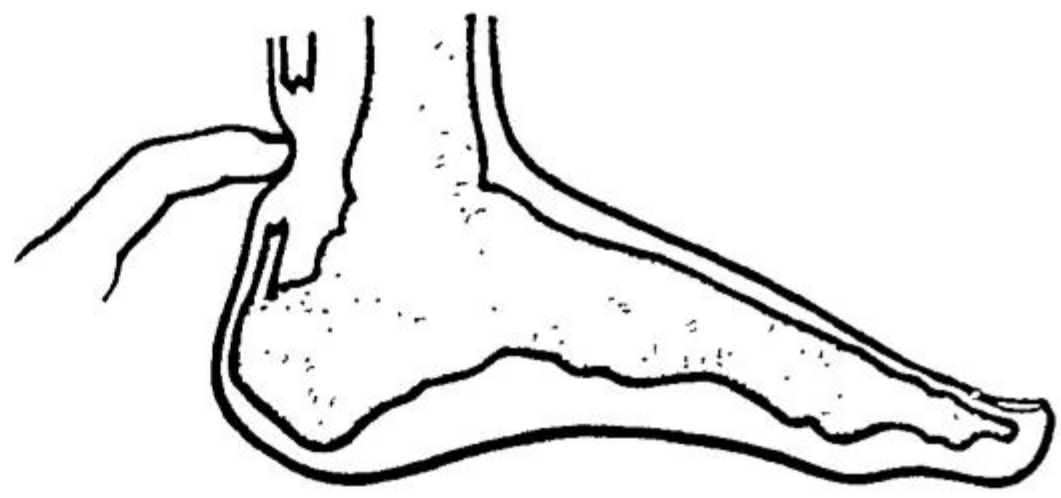

FIG. 1650.—Palpable gap in diagnosis of rupture of Achilles tendon.

Clinically, a gap is easily palpable at the site of the rupture, and in early cases this is sometimes even visible (fig. 1650). The foot can be dorsiflexed to a greater extent than the normal foot. The power of plantar flexion is markedly reduced, but it is to be noted that it is never completely absent. This is a most important point, because one can be led to imagine that the tear must be incomplete by the fact that some power of plantar flexion exists. This power is, of course, exerted by the long flexors of the toes, tibialis posterior, and peroneus longus. Very few cases of suspected 'partial' rupture of the tendo Achillis are in fact incomplete; it is dangerous to make this diagnosis without an expert opinion, because suture of the tendon is much more difficult if the operation is delayed.

FIG. 1651. — Spontaneous ruptured long head of the biceps tendon and 'bunching' of the muscle nearer the elbow than normal.

Early suture of the Achilles tendon gives excellent results, but late suture is usually disappointing because the proximal end has retracted and lost its elasticity, so that the gap cannot be closed by plantar flexion of the foot and flexion of the knee (in which position the gastrocnemius and soleus muscles are relaxed).

The *tendon of the long head of biceps* is sometimes torn where the tendon is frayed in the bicipital groove in the case of osteoarthritis of the shoulder joint (fig. 1651). Recognition is easy, as on flexing the forearm the soft muscular belly is drawn downwards towards the elbow. Some hypertrophy

of the short head partially compensates for the resulting deficiency. Efforts at repair are not always successful, and are unnecessary in elderly patients.

Rupture of the *tendon of the supraspinatus* is a not uncommon accident in middle-aged men, and may occur after a trivial injury (see p. 1299).

The pubic attachment of the *adductor longus* muscle is sometimes partially avulsed when riding a frisky horse. Myositis ossificans may subsequently supervene. Tetanus or strychnine poisoning may cause such violent contractions that rupture of the *rectus abdominis* muscle has resulted (fig. 22).

Rupture of the *extensor longus pollicis* tendon is an occasional sequela of a Colles fracture (p. 1189).

FIG. 1652.—Avulsion of a flake of bone to which the long extensor tendon is attached, resulting in a 'mallet' finger.

A '*mallet*' *finger* (*syn.* baseball finger) is due to avulsion of an extensor tendon of the finger, which occasionally includes a small flake of bone from the base of the distal phalanx (fig. 1652). In treatment the finger is splinted in a position of right-angled flexion at the proximal interphalangeal joint, with hyperextension of the terminal interphalangeal joint, so that the central slip of the extensor tendon is relaxed. For this purpose the patient is shown how to press the thumb against the finger-tip so that the correct position is maintained. A dry tube of plaster is then slipped over the finger and the hand dipped in warm water. The wet plaster is then moulded by the surgeon, and the finger is retained in the correct position until the plaster dries (fig. 1653).

The treatment of mallet finger causes much dissatisfaction to surgeon and patient alike. From the point of view of the surgeon, the failure is to prevent recurrence of the flexion deformity of the

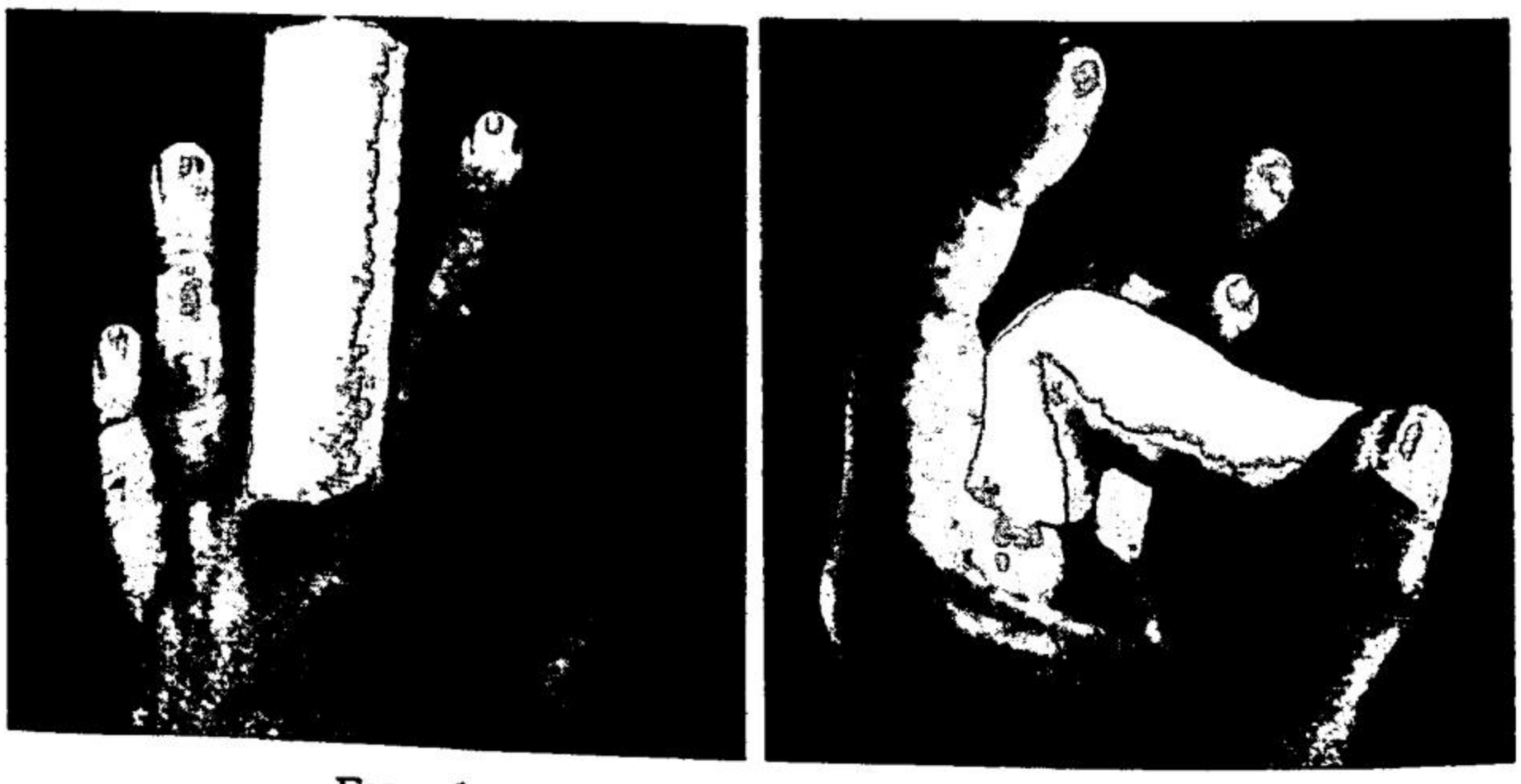

FIG. 1653.—The treatment of 'mallet' finger.
(*Gypsona Technique, T. J. Smith & Nephew, Ltd.*)

distal phalanx which is the essential deformity. Even in recent cases and when the phalanx is held in its correct position for six weeks, the avulsed tendon often fails to unite to the bone and the deformity recurs. From the

patient's point of view, the trouble is often not so much the disfigurement but the persistent pain in the affected joint. The pain disappears in a few weeks with reassurance and use and, fortunately, the deformity usually improves spontaneously after a few years. Despite this, the orthodox treatment of plaster fixation for six weeks in the fully corrected position is advised lest the patient alleges neglect. An alternative is the use of adhesive strapping renewed daily by the patient.

'Tennis Elbow.'—This is a very common minor malady of which the underlying pathology is still obscure, despite the fact that the condition has been recognised for many years and has often been explored at operation without any recognisable abnormality being visible. It seems to be a painful disorder of the aponeurotic fibres through which the common extensor origin is attached to the external epicondyle. No recognisable histological abnormality is present. The condition sometimes starts spontaneously, and though it takes its name from the strain commonly experienced by tennis players, few of the numerous sufferers ever play this game.

Clinically, the patient often complains of pain on the outer aspect of the elbow when lifting small objects by dorsiflexion of the wrist; the patient is often surprised at this, pointing out that it does not hurt to lift heavy objects with the elbow straight, e.g. buckets of coal. On physical examination there will usually be a point of localised tenderness over the external epicondyle, though sometimes the site of maximal tenderness may be more distal, lying over the radio-humeral joint-line or even over the head of the radius.

Many methods of treatment have been advocated with varying degrees of success. Short-wave diathermy, repeated injections of local anæsthetic, manipulation, and even local excision of the tender area. All methods have their successes and all their failures, but in the end, after six to twelve months, one can be fairly certain that a spontaneous cure will result under any form of therapy.

Recently it seems likely that the local injection of 25 mg. of hydrocortisone frequently produces a cure within two or three days. This suggests that 'tennis elbow' is one of the manifestations of 'collagen degeneration.'

Hernia of a muscle sometimes follows a tear of the muscle sheath, the adductors and biceps brachii being the muscles most commonly affected. On contraction, muscular fibres protrude through the aperture in the sheath. This feature distinguishes a torn sheath from a torn muscle, as in the latter case a gap appears between the two portions on contraction. If disability ensues, the sheath is sutured.

A small rupture of the sheath of the *tibialis anticus* is not uncommon in athletes. The swelling appears over the belly of the muscle on the outer side of the tibia. Unless the clinician is aware of the condition, he may be puzzled by its appearance. No disability results, and the swelling disappears as life becomes less strenuous.

Displacement of tendons occasionally occurs where these structures traverse fibro-osseous canals, e.g. in the region of the wrist or ankle, or the long head of the biceps in the arm. Sudden pain occurs, followed by a

sensation of weakness and further pain on attempted movements. The displaced tendon, if superficial, e.g. the peroneus longus, can be palpated in its abnormal position. The replaced tendon should be immobilised for at least eight weeks. The condition sometimes recurs, and if disability persists, the tendon is fixed in position, e.g. a flap of periosteum is raised from the bone in order to form a tunnel for the tendon. 'Snapping hip' is discussed elsewhere (p. 1293).

Collagen Degeneration in Tendon.—A new epoch in the study of pain arising in tendinous or aponeurotic structures is marked by the concept of 'collagen degeneration.' It is now recognised that tendon is composed of the chemical substance 'collagen,' which possesses a specific molecular structure and that the very large and complex molecules arrange themselves in parallel fibres. These fibres can be demonstrated by electron microscopes, and they can be dissolved into a homogeneous solution by chemical means and re-precipitated to reconstitute the original fibre pattern. It seems likely that localised areas of 'degeneration' of collagen can occur in tendon—especially after middle-age and at sites where tendon is exposed to great strain. This may well be the explanation of the so-called condition of 'tendinitis' which has been recognised clinically for many years in connection with the supraspinatus tendon of the shoulder. On the basis of collagen disease a number of painful conditions affecting the shoulder can be conveniently considered at this point, i.e. periarthritis of the shoulder, supraspinatus tendinitis, spontaneous rupture of the supraspinatus tendon, calcification of the supraspinatus, and 'subacromial bursitis.'

Periarthritis of the Shoulder.—This is a common shoulder complaint in persons beyond middle-age, affecting women more often than men. It starts insidiously, or suddenly, as pain in the shoulder which is frequently worse at night. In the early stages a full passive range of movement will be present if the patient permits examination, but later organic changes develop and the shoulder joint may become so stiff as to suggest an ankylosis. Though movement is restricted in all directions, the first to be lost is external rotation, which is soon followed by loss of abduction. Unless movement of the scapula is controlled during examination, the degree of ankylosis of the shoulder will appear less than it really is.

It seems likely that this condition starts as a patch of 'collagen degeneration' in one of the tendons of the short rotator muscles which blend intimately with the capsule of the shoulder joint. As part of the process of removal of the necrosed collagen fibres, a round-cell infiltration develops and the whole joint capsule becomes thickened and indurated. The capsule adheres to the articular cartilage of the head of the humerus like a postage stamp. The condition is quite localised, the patient in good health, and there are no systemic changes of a 'rheumatoid' nature.

The diagnosis is made by the normality of the X-ray. Many of these apparently ankylosed shoulders must in the past have been mistaken by the old surgeons for tuberculosis (so-called 'caries sicca'), but nowadays the absence of destructive changes in the X-ray will immediately establish the diagnosis.

The natural history of untreated 'periarthritis' of the shoulder is that spontaneous cure is eventually to be expected, though it may be delayed two or three years. Frequently in periarthritis a superadded psychosomatic element is present, and gross degrees of stiffening are probably the result of the patient avoiding movement and permitting the shoulder to stiffen.

Mild cases are treated by heat and exercise with liberal doses of analgesics. Cases of longer than three months' duration, if showing marked restriction of movement, are sometimes manipulated under anæsthesia and followed by heat and exercise. Manipulation is not to be recommended in the early stages, and in any case the return of movement after manipulation is often disappointing and may take three to six months of intensive physical treatment. After an initial two or three days of increased pain, manipulation does, however, make the shoulder more comfortable and more useful, even though the passive range may not improve till much later.

Hydrocortisone appears to be of value if injected at the time of manipulation (25 mg.) as it reduces post-operative pain.

Supraspinatus Tendinitis.—Painful disorders localised to the supraspinatus tendon can be distinguished from periarthritis by the clinical fact that these shoulders are passively mobile, whereas periarthritis shows restriction of all passive movements (and especially of external rotation). Clinically the painful supraspinatus tendon evokes a spasm of pain in the middle range of abduction, i.e. the patient may be able actively to abduct the arm only 40 or 50 degrees from the side of the body, but if the arm is then passively abducted above the horizontal it can be actively sustained above the head. Similarly, on attempting slowly to lower the arm a sudden spasm of pain will cause the patient to drop the limb hurriedly when the horizontal position is being approached.

Supraspinatus tendinitis is probably a patch of 'collagen degeneration' localised to the supraspinatus tendon; it may be a matter of the extension of the lesion to other parts of the 'rotator cuff' (and possibly a superadded psychosomatic element) which decides whether or not it becomes a periarthritis.

The term *subacromial bursitis* is synonymous with supraspinatus tendinitis because the supraspinatus tendon lies in the floor of the subacromial bursa.

Spontaneous Rupture of the Supraspinatus Tendon.—A supraspinatus tendon may rupture spontaneously when the patient is performing sudden movements against resistance with the arm above the head. No normal tendon would rupture spontaneously in these circumstances. The tear may be complete or incomplete. Partial tears are common in elderly patients, and after the discomfort and pain have settled the shoulder will resume full activity even though the partial tear is unhealed. Complete spontaneous tears are decidedly uncommon, and are often only diagnosed in retrospect by the patient being unable to elevate the arm after several months of physical treatment. It is doubtful whether, even if diagnosed early, complete spontaneous tears are worth attempts to suture the pathological tendon. The disability is usually not great and rehabilitation will work wonders if the patient is co-operative and there is no compensation element for an alleged injury. Complete *traumatic* tears, which are associated with very severe violence (such as dislocation of the shoulder) where the ruptured tendon is of normal consistency, will hold sutures.

Calcification of the Supraspinatus Tendon.—The supraspinatus tendon is a common site for the accumulation of the chalk-like deposits of 'calcinosis.' While slowly accumulating inside the tendon the shoulder is free from symptoms, but once the calcified mass starts to extrude spontaneously into the subacromial bursa, which it does rather like toothpaste, an attack of shoulder pain is produced. If the extrusion is massive, the pain may be fulminating and of intense severity. There may or may not be an associated mild injury to precipitate the extrusion. X-rayed at this time the calcified area will be seen lying in the region of the supraspinatus tendon above the head of the humerus (fig. 1654), but as symptoms subside the calcified shadow will be seen disappearing in films during the subsequent three or four weeks.

FIG. 1654.—Supraspinatus calcification. Faint shadow of calcium seen lying above the head of the humerus just lateral to outer margin of the acromion.

In some cases, though very rarely, operation can be undertaken to remove the calcified deposit. The vast majority of cases respond to heat, analgesics, and exercise to prevent stiffening of the shoulder.

TENDON SHEATHS

Simple tenosynovitis follows excessive or unaccustomed use, and is commonly seen in connection with the extensor tendons of the hand or the Achilles tendon. Pain and local œdema are present, and a characteristic soft crepitus (likened to the creaking of new leather) is palpable when the fingers are moved. An adequate period of rest is needed, and in the extensors of the wrist a minimum of six weeks' fixation in plaster is required if a return of the trouble is not to be expected.

Acute suppurative teno-synovitis either follows wounds, e.g. extension from whitlows, or is blood-borne. Severe pain results from any movement which causes the tendon to glide in its sheath. If due to a virulent organism, suppuration is probable, which rapidly extends along the tendon sheath. Unless early and adequate incisions are made, sloughing of tendons is likely to occur (p. 1158).

Tuberculous tenosynovitis is of two types:

(*a*) The endothelial lining of the sheath is replaced by œdematous granulation tissue containing miliary tubercles. Very little free fluid is present. A soft, elastic swelling appears, and if the disease progresses pus may form and track into neighbouring sheaths or joints.

(*b*) An effusion occurs in the tendon sheaths, and 'melon-seed' bodies are usually present in large numbers, so that a soft, coarse crepitus is detected on pressing fluid from one part of the sheath to another. These 'melon-

seed' bodies may be rounded, and in appearance resemble grains of boiled sago (fig. 1655). The term 'compound palmar ganglion' is applied to this condition when it occurs in connection with the flexor tendons of the fingers. A soft, painless swelling appears (fig. 1656), and fluctuation may be transmitted above and below the anterior annular ligament.

FIG. 1655.—'Melon-seed' bodies from a case of compound palmar ganglion.

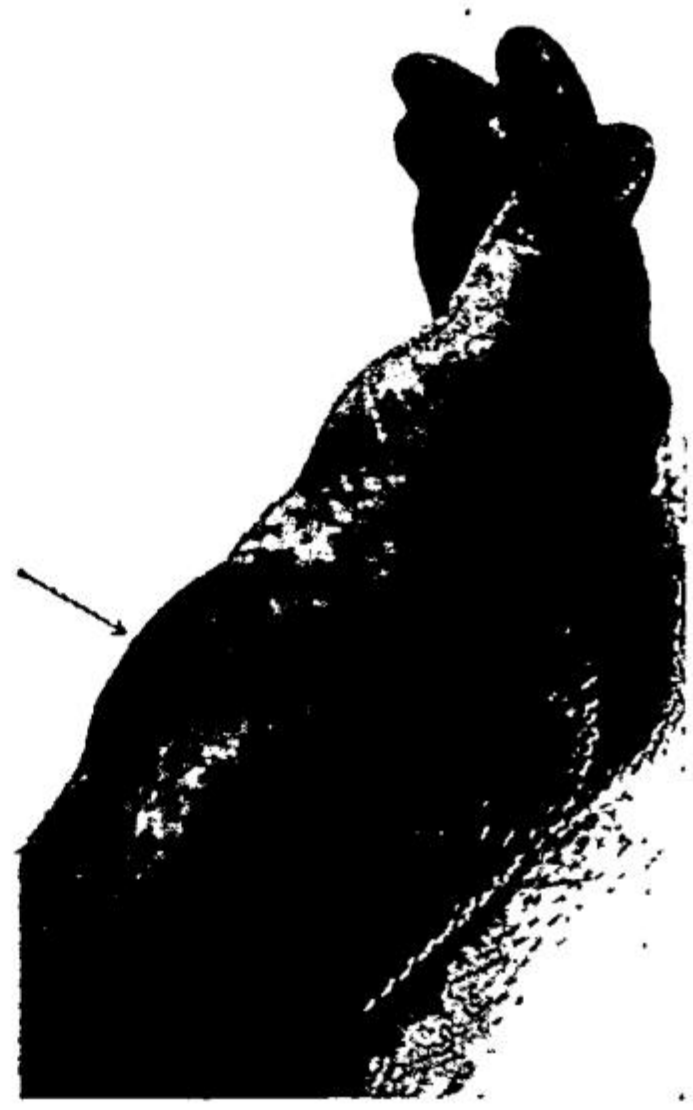

FIG. 1656.—Compound palmar ganglion, showing swelling above the anterior annular ligament.

As with all forms of tuberculous disease of bone, joint, or tendon, obvious wasting of adjacent muscles is present. Treatment consists in general measures and the application of a plaster cast, but if the condition progresses careful dissection and removal of the diseased tendon sheaths is indicated.

Stenosing teno-synovitis (or *tendo-vaginitis*) (*syn.* de Quervain's disease) is a fibrous thickening of the sheath of a tendon, and at the wrist is characterised by thickening and tenderness immediately above the radial styloid process. The abductor pollicis longus and extensor pollicis brevis, as they lie on the lower and outer aspect of the radius, are most commonly affected, especially in workers who use their thumbs excessively (e.g. charwomen wringing cloths). The condition is cured by incision of the thickened sheath under local anæsthesia, after which suture of the skin only is sufficient.

Trigger Finger.—This is a condition affecting the flexor tendons of the fingers or thumb. In adults it usually affects a single digit, but it is occasionally seen in infants, when it often affects several digits of both hands.

Most commonly it is due to a constriction of the entrance to the fibro-osseous tunnel at the level of the metacarpophalangeal joint. This constriction impresses a groove in the enclosed tendon which 'snaps' as it passes through the constriction. While the flexor muscles are strong enough to flex the finger against the trigger mechanism, the extensors are not strong enough to extend and the finger has to be extended passively with a 'click.' Sometimes a small, tense ganglion may arise in the tendon sheath to cause the trigger phenomenon by encroachment on the width of the tunnel.

The condition is easily cured by slitting the fibro-osseous tunnel at the level of the constriction.

Carpal Tunnel Compression.—It is now becoming recognised that many of the symptoms which in the past were ascribed to the cervical rib, and the 'costoclavicular syndrome,' are in reality the result of compression of the median nerve in the wrist at the site of the carpal tunnel. The carpal tunnel, which contains the flexor tendons and the median nerve, is formed by the concavity of the carpus being closed on the palmar surface by the anterior annular ligament which is attached on the radial side to the os multangulum major and tuberosity of the scaphoid and on the ulnar side to the pisiform and hook of the lamate (fig. 1657). The clinical features of this condition are worthy of careful note because it is easily diagnosed and, what is more, is easily cured by a relatively minor surgical operation.

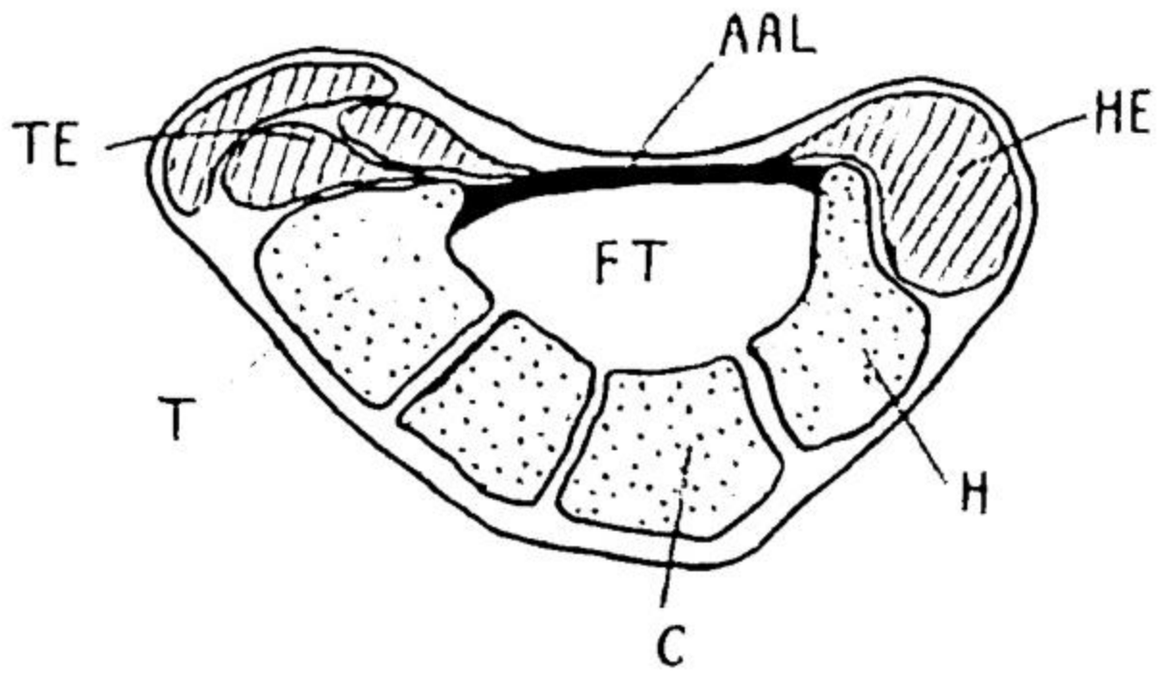

FIG. 1657.—Carpal tunnel formed in the concavity of the carpus by the anterior annular ligament on its volar aspect. T, os multangulum major; C, capitate; H, hamate; FT, flexor tendons; AAL, anterior annular ligament; TE, thenar eminence; HE, hypothenar eminence.

The patient is usually a middle-aged female and frequently has bilateral symptoms though one side may predominate. She complains of severe 'burning' pain, or severe 'pins and needles,' in the hand and fingers. Characteristically this is much worse at night, while in the day it may be tolerable. The fingers on waking sometimes may feel stiff and the patient may have difficulty in tying knots or buttoning clothes while dressing first thing in the morning, but this wears off in the course of half an hour. In a minority of cases objective impairment of sensation can be detected in the three digits supplied by the median nerve. The patient may sometimes describe abnormal sensation in all the digits (i.e. including the little finger) which might suggest a more proximal lesion because the ulnar nerve lies outside the carpal tunnel. The strict localisation of acroparæsthesiæ to the thumb, index, middle and ring fingers, as might be logically expected from involvement of the median nerve on anatomical grounds, is not absolutely essential in the diagnosis of carpal tunnel compression, but the digit most severely affected is invariably one of those supplied entirely by the median nerve (i.e. thumb, index or middle finger).

If the carpal tunnel is explored through a longitudinal incision on the palmar surface of the wrist, the median nerve only rarely shows clear visible evidence of local constriction. What is commonly seen is a soft swelling of the median nerve proximal to the carpal tunnel which terminates sharply at the point where it passes under the carpal ligament. Nissen believes that in this condition the para-tenon of the flexor tendons has become bulky and thickened and that this is the space-occupying agent which causes compression of the median nerve.

Because the condition is so much commoner in middle-aged women than

K. I. Nissen, Contemporary. Orthopædic Surgeon, Royal National Orthopædic Hospital, London.

in men one is tempted to think of an endocrine explanation, but trials of endocrine therapy have not encouraged this idea. Whatever may be the pathology, the fact is quite definite that simple decompression of the tunnel by a longitudinal ventral incision cures the condition in an almost dramatic fashion. In a severe case the patient may be practically symptom-free in twelve hours after having had the discomfort for five years. The operation can be done as an out-patient because no deep sutures are inserted.

A simple ganglion appears as a localised, tense swelling often in connection with a tendon sheath or near the capsule of a joint, and contains clear gelatinous fluid. It is a mucoid degeneration of connective tissue, and is predisposed to by injury. It is a manifestation of ' collagen degeneration.' Simple ganglia are most commonly found on the dorsum of the wrist and foot (fig. 1658). They occur more commonly in females than in males and much less commonly in children or old people. Rupture of the ganglion can be accomplished by pressure, or a blow, and although recurrence is likely this simple method is worth a trial. Some cases are cured by aspiration with a wide-bore needle and injection with a sclerosing agent, followed by firm pressure for a few days. If simple measures fail, excision may be deemed necessary, but even then, to the patient's annoyance, there can still be a recurrence. Not infrequently a ganglion disappears spontaneously, so unseemly haste on the part of the surgeon is unwise.

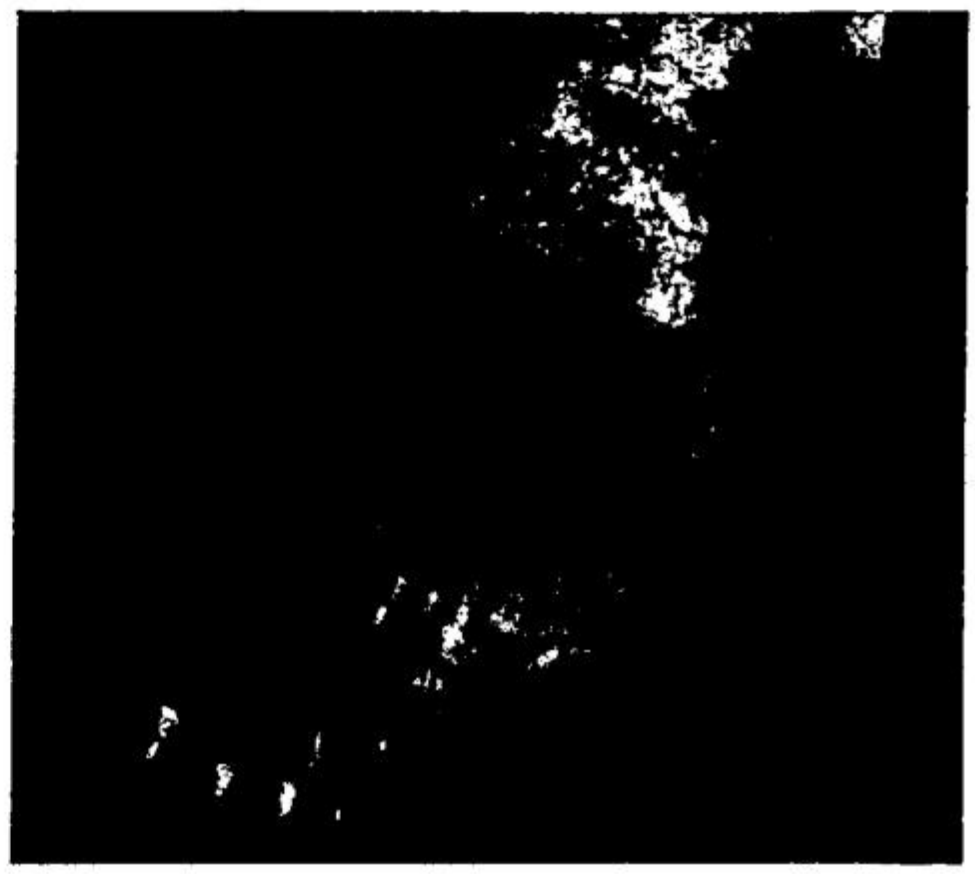

FIG. 1658.—Simple ganglion in connection with the tendon of the peroneus brevis muscle.

Tumours of tendon sheaths occasionally occur, in the form of *synoviomata*. These tumours arise from the synovial membrane lining the tendon sheath, and are either innocent or malignant. In the past the benign synovioma was called myeloma or giant-cell tumour. In both the innocent and malignant types ' foam ' cells are characteristic, which are large and spheroidal and contain numerous fat droplets.

CUT TENDONS

In a book of this nature space precludes other than an abbreviation of general principles, with a short account of some common injuries.

Cut tendons are a common cause of disability after open wounds of the hand and fingers, and only too frequently receive inappropriate treatment by surgeons who have not received adequate training in this often difficult problem.

Flexor tendons are provided with a sheath, and consequently considerable retraction of the cut ends occurs when such a tendon is divided ; union is therefore unlikely without surgical intervention. Extensor tendons are enclosed in loose elastic and connective tissue—the paratenon—and the severance of such tendons results in a minor degree of separation ; union of extensor tendons may therefore occur if the tendon is relaxed for an adequate period, though of course direct suture is to be preferred.

Immediate repair of tendons is only indicated under the following circumstances:

(1) A competent surgeon is available, and suitable instruments and sutures are to hand.

(2) The wound must be uncontaminated, and not more than six hours should have elapsed since the accident occurred.

(3) There is no loss of skin or serious damage to bones or joints. A divided nerve is not a contraindication, as it may be sutured immediately or subsequently.

Unless these conditions are fulfilled it is only permissible to attend to wound toilet, suture the skin, and administer penicillin in order to obviate infection. A formal operation and suture is performed when the wound has healed, usually within four weeks. A further lapse of time results in excessive retraction of the ends so that approximation is impracticable, and a tendon graft is then required.

Flexor Tendons.—If conditions are suitable, immediate suture sometimes yields satisfactory results. If both the sublimis and profundus are divided within the digital sheath, the profundus alone is sutured, and the superficial tendon removed. Suture of both tendons inevitably results in the formation of adhesions and impairment of function. Even in expert hands the suture of a tendon is likely to fail owing to adhesions if it is performed anywhere inside the flexor sheath, i.e. anywhere between the level of the distal interphalangeal crease and the transverse palmar crease (the so-called ' danger area '). Under ideal conditions the best results are obtained by using a tendon graft (complete with its natural paratenon) attaching this distally to the distal phalanx and proximally to the cut end of the profundus tendon in the palm. In this way the flexor sheath contains no suture line.

Excepting when the flexor tendons of the fingers are divided in the ' danger area,' the suture of all other tendons presents no special difficulty if ordinary surgical principles are followed.

TENDON SUTURE

Some of the important points in technique are as follows:

A bloodless field is obtained by means of a sphygmomanometer. Incisions follow the natural creases of the hand, or in the case of a digit pass longitudinally just posterior to the digital vessels and nerve. The most suitable suture material is 40-gauge stainless steel wire, which should be threaded into an atraumatic needle. If these needles are not available, the tendon can be transfixed with a hypodermic needle along the lumen of which the wire is threaded, and the needle is then withdrawn. Various stitches are used to approximate the ends of the tendon (fig. 1659). Measures to prevent adhesions by insulating tendons with flaps of fascia or artificial preparations are not recommended,

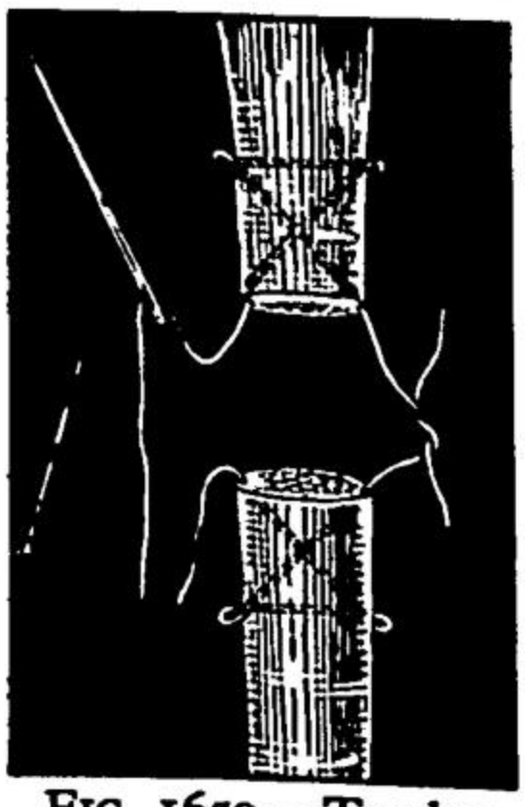

FIG. 1659.—Tendon suture.

and reliance is placed on covering the suture line with any local tissue available.

TENDON GRAFTING

This procedure is necessary if excessive retraction has occurred, if part of the tendon has been destroyed or if suture of a flexor tendon of the finger is needed in the 'danger area.' Considerable skill and experience are necessary to obtain a good result. The palmaris longus or extensor indicis are most suitable in the hand, or grafts may be taken from the long extensor tendons of the toes. The paratenon is included with the graft. Free exposure is necessary. Preservation or reconstruction of the fibrous sheaths over the interphalangeal joints is important so that there is no 'bow-stringing' of the tendon in flexion.

TENOTOMY AND TENDON LENGTHENING

Tenotomy is needed to correct deformities caused by spastic conditions of muscle or by rigid contractures. It is one of the oldest orthopædic operations and was originally done almost exclusively by subcutaneous puncture in order to reduce the possibility of sepsis. Subcutaneous tenotomy is used where the exact amount of elongation is not important—i.e. where the total abolition of the action of that tendon is needed.

The most important examples of tenotomy concern (1) the tendo Achillis, (2) the sternomastoid, and (3) the adductor tendons of the thigh.

The tendo Achillis needs elongation in spastic paralysis and clubfoot to correct fixed equinus deformity. This is usually done by open operation and a 'Z' method of lengthening enables an exact elongation to be obtained (fig. 1660) so that the 'equinus' deformity is not made into a 'calcaneus' deformity.

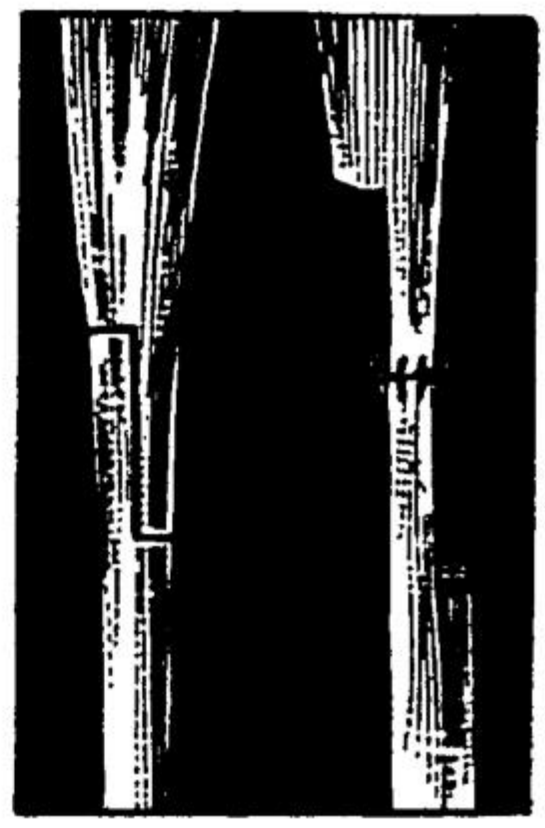

FIG. 1660.—Tendon lengthening.

The sternomastoid muscle and tendon need division in cases of torticollis. Here simple division is necessary and elongation by a predetermined amount is not wanted. The operation can be done by subcutaneous puncture, but open operation is strongly to be advised because of dangerous structures nearby, and because tight fascial bands may need division as well as the muscle and tendon.

FIG. 1661.—Tendon shortening.

The adductor tendons are usually tenotomised near their attachment to the pubic bone, which is done by subcutaneous puncture with a narrow-bladed 'tenotomy' knife.

SHORTENING of a tendon is accomplished by the 'Z' method (fig. 1661). The two halves of the tendon, after separation, are shortened as required, and the tendon is then sutured.

TENDON TRANSPLANTATION is performed in order to restore muscular balance, or to supplement the action of ligaments (p. 1339).

INFLAMMATION OF MUSCLES

Acute suppurative myositis as a primary lesion is an almost unknown condition. Collections of pus form in muscles in the course of pyæmia, but these are silent collections often mimicking a tuberculous 'cold' abscess.

'*Rheumatic*' *myositis* is a misnomer but a term not easily abandoned. This is particularly the case when pain and stiffness of muscle, as in 'stiff-neck' or in 'lumbago,' seems to follow exposure to draughts and dampness. Though it has for years been customary to use the term 'rheumatic myositis or fibrositis,' and even to palpate 'fibrositic nodules' in muscles so afflicted, the fact is now undisputed that no histological abnormality can be discovered in these tissues. The present tendency is swinging to the belief that most of these acute muscle pains with spasm and tenderness are probably reflex guarding mechanisms evoked by a sudden derangement of an underlying disc which has the same dermatome innervation. This would certainly seem to be the case in acute lumbago, because so often a person suffering from this condition will later develop an unequivocal disc protrusion and sciatica. Acute lumbago often occurs in young men of athletic build who after three weeks recover completely; there is no suspicion of 'rheumatism' in these cases, and the whole picture is suggestive of a mechanical derangement parallel to internal derangement of the knee.

Whatever may be the theories of causation of the 'lumbago-fibrositis-fibromyositis-sciatica' group of minor maladies, the best treatment still remains the same as if they were based on the older conception of 'rheumatic inflammation' locally in the muscles. Radiant heat and short-wave diathermy, counter-irritation with embrocation, aspirin and anti-rheumatic mixtures, and rest are still the most effective remedies. Widespread searches for septic foci are no longer encouraged.

FIG. 1662.—Gumma of the left sterno-mastoid muscle. The patient exhibited extensive leucoplakia and fissuring of the tongue.

Syphilitic myositis may occur as a localised gumma, particularly in the sternomastoid muscle or tongue (fig. 1662). An indurated swelling appears, which gradually involves the overlying skin or mucous membrane. More rarely a diffuse myositis occurs, e.g. parenchymatous glossitis, the tongue eventually becoming fibrotic.

Tuberculous myositis is, to all intents and purposes, non-existent.

Traumatic myositis ossificans occurs principally in the brachialis muscle after dislocation of the elbow and in the quadriceps of the thigh after direct

contusion (see fig. 1648). A much less common site is in the attachment of the adductor muscles to the inferior ramus of the pubis—'rider's bone.' When ectopic ossification occurs in other sites, as for instance round the hip-joint, it is not truly a 'myositis,' probably being more often in the joint capsule.

This condition is much less common today than formerly, probably because the evil effects of passive stretching exercises applied to the stiff elbow after dislocation are widely known. If myositis is developing, the elbow becomes stiff and a palpable deep thickening can be detected in front of the elbow joint. X-ray will reveal a haze of new bone formation in the lateral view three to four weeks after the injury. Treatment is to apply a sling and to avoid all strain such as weight-lifting or 'deep-friction' massage. Recovery may take many months.

Myositis ossificans generalisata is a rare condition, commencing in young adults, in which muscles are gradually transformed into bone. The condition usually commences in the flat muscles of the back (fig. 1663), and spreads to the spinal and thoracic muscles. The condition steadily progresses, and the patient gradually becomes more rigid ('poker' man), until fatal respiratory complications supervene. Congenital absence of the last phalanx of the big toes and inability to flex the thumbs are sometimes associated conditions.

Trichiniasis is an uncommon cause of myositis in this country. Nematode worms obtain access to the alimentary canal in infected pork. After a few days the embryos find their way to striated muscles via the lymphatics. The muscles become painful and indurated, and the migration of the embryos continues for from two to four weeks, during which period eosinophilia is present. The embryos become encysted, or eventually perish and calcify. The treatment is symptomatic.

FIG. 1663.—Ossification of the flat muscles of the back. The child had characteristic deformities of the thumbs and toes. *(G. D. F. McFadden, Belfast.)*

TUMOURS OF MUSCLES

Innocent.—Lipomata and fibromata occasionally occur (Chapter iii).

Malignant.—Primary fibrosarcoma is not common. This tumour was formerly considered to be a simple fibroma, and it is sometimes difficult to be dogmatic in distinguishing a fibroma from a slowly growing fibrosarcoma. Failure to realise the sarcomatous nature of these tumours accounts for Paget's description of them as 'recurrent fibroids' (fig. 50). A slowly growing swelling appears, which is firm, circumscribed, and connected with the muscle. Exploration is necessary, and on confirmation the tumour is removed with a wide margin of surrounding muscle. Even then local recurrence is all too common, and dissemination by the blood-stream will already have occurred in the majority of cases.

Secondary invasion of muscles sometimes occurs, e.g. the pectoralis major, following carcinoma of the breast.

DISEASES OF BURSÆ

Injury.—Acute traumatic bursitis follows injury and may also follow unaccustomed exercise, e.g. inflammation of the bursa under the tendo Achillis after a cross-country run.

Chronic bursitis is the result of repeated slight injuries, or constant pressure, to *anatomical* bursæ, e.g. housemaid's knee (lower pole of patella), student's or miner's elbow (olecranon) (fig. 1664), weaver's bottom (tuber ischii).

There is a very common chronic bursa to be found in the popliteal fossa, lying between the inner head of the gastrocnemius and the semimembranosus tendon (fig. 1665). Enlargement of the semimembranosus bursa is common in children. If disability results,

FIG. 1664.—Chronic olecranon bursitis.

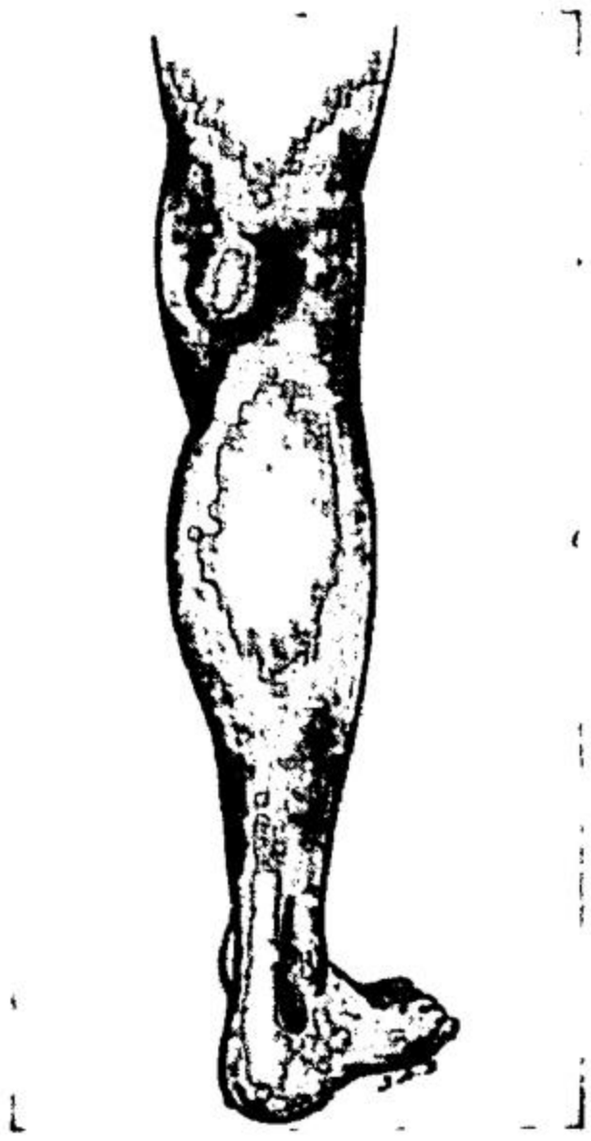

FIG. 1665.—A semimembranosus bursa, tense in extension and flaccid in flexion.

aspiration is performed, but most cases disappear spontaneously. Popliteal bursæ, which communicate with the knee joint, sometimes enlarge as a result of such conditions as osteoarthritis of the joint, and in the case of osteoarthritis this type of popliteal swelling is known as 'Baker's' cyst. The Baker's cyst is an overflow of synovial fluid from an osteoarthritic knee joint into the communicating anatomical bursæ, but the pathological nature of the much more common semimembranosus bursa is more like a simple ganglion.

Adventitious bursæ form as a result of prolonged pressure over bony prominences, e.g. Billingsgate hump, due to pressure of a fish-basket over the seventh cervical spinous process. The term 'adventitious' means that no anatomical bursa was present at the site of the newly formed cyst, and that it was generated in connective tissue as a result of repeated friction. One of the commonest of these is the 'bunion' on the big toe (fig. 1666).

Infection.—ACUTE SUPPURATIVE BURSITIS is due to direct infection by penetrating wounds, or from local subcutaneous infection and involvement of the prepatellar bursa. In the case of prepatellar bursitis, a 'sympathetic' effusion into the knee joint sometimes follows, but confusion with infective arthritis should be avoided, as in the latter condition any attempt to move

the joint is painful, and pain is elicited by pressure in the popliteal space. The pyogenic organisms responsible for this condition usually respond to chemotherapy, but if they do not, or if pus is already present, drainage may be necessary.

CHRONIC INFECTIVE BURSITIS can be pyogenic, tuberculous, or, rarely, syphilitic. One very common type of chronic bursitis needs special mention because it has been given the special name of a 'bunion.' This is an 'adventitious' bursa produced by the friction of a shoe against the prominent head of the first metatarsal bone in 'hallux valgus' (p. 1336). At first sterile, this bursa later becomes infected, and thereafter runs a recurrent course in which it flares up, discharges pus, settles down, and again flares up. Treatment in an acute attack is by local heat, rest, and antibiotics, but the prevention of further attacks can only be by the radical cure of the deformity by operation in a quiescent phase.

FIG. 1666.—A bunion.

Tuberculous bursitis resembles tuberculous teno-synovitis, in that two varieties occur: in one the effusion contains 'melon-seed' bodies; in the other the bursa becomes lined with granulation tissue, may progress to abscess formation, and eventually fistulæ. The *gluteal bursa* between the insertion of the gluteus maximus and the great trochanter is particularly prone to tuberculous infection. In some cases as time passes a tuberculous focus declares itself in the great trochanter. Tuberculous *subacromial bursitis*, containing melon-seed bodies, may indicate disease of the humeral head, and a tuberculous arthritis of the shoulder may occur later.

A tuberculous bursa should be completely excised, an operation which often requires considerable patience on account of ramifications and loculations of the bursa.

Syphilitic bursitis occurs during the secondary stage, and gives rise to transitory, and often symmetrical, effusion. During the tertiary stage, a local gumma or a diffuse gummatous bursitis are uncommon manifestations.

New-growths.—An endothelioma from the lining membrane, or fibrosarcoma from the wall, occur as curiosities.

CHAPTER LI

DEFORMITIES

JOHN CHARNLEY

DEFORMITIES can be *congenital* or *acquired* in origin, and *fixed* or *mobile* in type. *Fixed* deformities are those which cannot be corrected by gentle persuasion exerted by the examining hands, whereas *mobile* deformities can be so corrected.

The wide range of deformities can be reviewed by considering the pathological changes in the anatomical structures responsible for these deformities :

(1) **Skin and Subcutaneous Tissues.**—*Burns* are common causes of fixed deformities when they produce scars across the flexor aspects of joints. *Dupuytren's contracture* is a spontaneous contracture affecting the fibrous tissue of the palmar fascia.

(2) **Muscles and Tendons.**—*Ischæmic contracture* of muscle following trauma or embolism results from the contraction of scar tissue left after necrosis of the contractile substance of the muscle belly. *Infantile paralysis* (poliomyelitis) is often followed, in untreated cases, by contracture of the muscle groups no longer opposed by normal muscles.

(3) **Joints.**—(*a*) Congenital deformities, such as congenital dislocation of the hip, club-foot, congenital absence of limbs or parts of limbs.

(*b*) Ankylosis following arthritis (e.i. septic, tuberculous, and rheumatoid arthritis).

(*c*) Traumatic dislocations if unreduced.

(*d*) Hysterical deformities are produced by the patient holding the joint in an abnormal position for many months.

(4) **Bones.**—(*a*) Congenital and familial errors of growth (i.e. achondroplasia, fragilitas ossium, absence of bones, etc.).

(*b*) Metabolic diseases of bone (i.e. rickets, renal rickets).

(*c*) Fibrous dysplasias of bone (Paget's disease, osteitis fibrosa cystica).

(*d*) Irregular growth at epiphyses due to trauma or disease.

(*e*) Malunited fractures.

(5) **Nervous Lesions.**—Spastic deformities due to Little's disease or hemiplegia in later life. Flaccid deformities due to poliomyelitis or peripheral injury of nerves (both followed later by contracture of unopposed groups, i.e. claw-hand after injury of both median and ulnar nerves).

Consideration of the above causes will suggest that deformities are often preventable, and that in some cases operations would be rendered unnecessary if care and foresight were used in the early treatment ; this is especially the case in acute anterior poliomyelitis. The following summary indicates the surgical procedures which may be adopted for the correction of deformities :

(i) Manipulation, such as the daily correction of a club-foot by moulding into the over-corrected position assisted by a splint.

(ii) Operations on soft parts, such as fasciotomy, tenotomy, or tendon transplantation.

(iii) Operations on joints, as by performing arthrodesis of the tarsus for a flail ankle joint.

(iv) Operations on bones, either osteotomy, excision, or amputation.

Baron Guillaume Dupuytren, 1777–1835. Surgeon, Hôtel Dieu, Paris.
William J. Little, 1810–1894. Physician to the London Hospital.

The following are some of the factors which require consideration in deciding whether intervention is advisable in any given deformity. Age is of obvious importance and, as a general rule, the older the patient the less need arises for correction. Patients often adapt themselves to a long-standing deformity in a remarkable manner, and in such cases anatomical correction may interfere with function. A well-known example of this is seen in the fixed equinus deformity of the foot often encountered in extensive paralysis of the lower limb by poliomyelitis; not only does this equinus make up for loss of leg length, but it may mechanically assist the action of a weak quadriceps muscle to hold the knee in extension and help a patient to walk without the need of a caliper splint.

TORTICOLLIS (*syn.* WRY NECK)

It is customary to classify torticollis under the headings of congenital or acquired, but the condition commonly called 'congenital' torticollis is now known to be acquired as a result of trauma during childbirth. True congenital deformities of the bones of the cervical spine are commonly encountered (hemivertebræ, congenital fusions, congenital short-neck, etc.), but these rarely produce a torticollis as the main feature of the deformity.

Torticollis results from the following causes:

(1) **Acute Rheumatic.**—This is due to fibrositis following exposure to cold or a draught, e.g. a chilly drive in a draughty car. The onset is sudden, and muscles are tender on pressure. Radiant heat and salicylates hasten recovery. It is probable that the so-called 'acute rheumatic torticollis' is protective spasm covering an acute protrusion of a cervical intervertebral disc, but this does not mean that 'old-fashioned' treatment on the basis of 'fibrositis' is in question, nor that the patient need be alarmed by any mention of disc protrusion unless simple remedies have failed to produce a cure after three or four weeks. It is very easy to make a patient into a confirmed neurotic by talking glibly about 'discs out of place' in the neck.

(2) **Spasmodic.**—This distressing condition, fortunately uncommon, occurs chiefly in middle-aged neurotic females. It is characterised by clonic spasms of the sternomastoid and trapezius muscles on one side of the neck, and later the deep cervical muscles on the opposite side may be affected. The head is continually jerked downwards towards one shoulder, particularly during excitement, and mental instability may be an associated condition. Treatment is unsatisfactory, but every effort is made to discover any functional cause or source of peripheral irritation. Division of the spinal accessory nerve on one side, and of the opposite posterior primary divisions as they lie in the semispinalis cervicis, is sometimes necessary, but even this procedure is not always successful, as the lesion, whatever it may be, would seem to be at a high level in the cerebrum.

(3) **Inflammatory.**—This may be due to parotitis, acute adenitis of the cervical lymph nodes, or even from Pott's disease of the cervical spine with cold abscess in the neck.

(4) **Hysterical.**—Torticollis is a fairly common manifestation of hysteria, and there will usually be other bizarre features of the cases suggesting this diagnosis. There are those who might consider 'spasmodic torticollis,' (2) above, as an hysterical condition.

(5) **'Congenital.'**—This is a condition which only renders itself noticeable in children between the ages of five and seven years. It is now believed that these children have all demonstrated a 'sternomastoid tumour' during the early weeks immediately following birth. This is an oval swelling the size and shape of a hazel nut, lying with its long axis in the length of the affected sternomastoid muscle (p. 189). It is the result of stretching of the muscle fibres during birth, and has the same pathology as the Volkmann's ischæmic contracture in which necrotic muscle fibres are replaced by granulation tissue, which later contracts and abolishes any normal elasticity

Richard von Volkmann, 1830–1889. Professor of Surgery, Halle.

of the muscle belly. In torticollis the latent interval between the injury at birth and the first appearance of the deformity is explained by the fact that between five to seven years of age the child's neck starts to elongate during growth, so that from being an infant with an almost imperceptible neck it starts to take on the adult shape. The inextensibility of the affected sternomastoid muscle thus causes the head to be drawn to the affected side. In the untreated case the deformity can become extreme, so that in adult life the ear on the affected side may be in contact with the tip of the shoulder. Even if left untreated for only a few years, asymmetrical growth changes will start in the face, and these will interfere with a perfect cosmetic result. The asymmetrical changes in the face are probably due to the head adapting its position so that the eyes will both work on the same horizontal plane. In later stages the cervical vertebræ will take on permanent wedge-shaped deformities.

Treatment.—If a sternomastoid tumour has been recognised soon after birth, the parents should be instructed to have the child kept under careful supervision during subsequent years and to see that the child can stretch the affected muscle fully (i.e. the child should be able to look upwards and over the shoulder on the affected side—rotation of the chin to the affected side combined with extension of the neck).

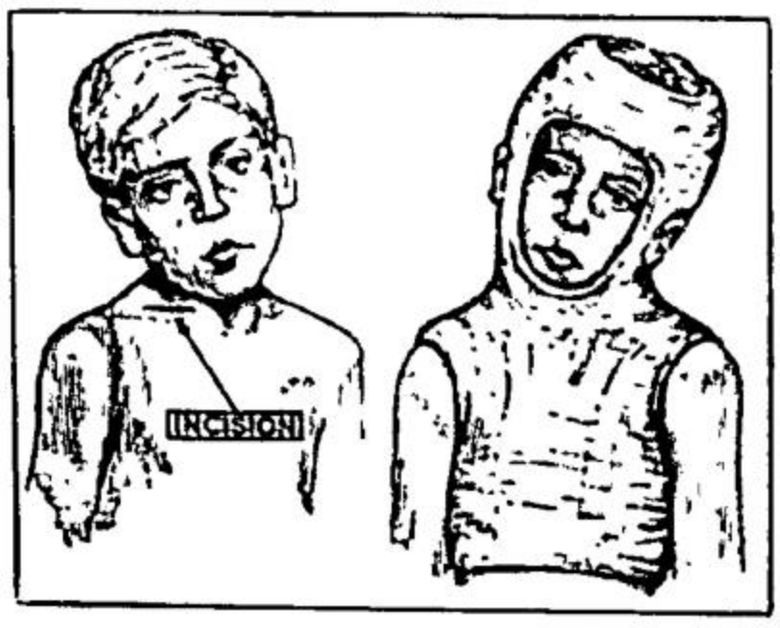

FIG. 1667.—Operative treatment of congenital torticollis.

If the contracture develops, treatment by tenotomy gives highly gratifying results.

In a few cases, where a very localised band of fibrous tissue is present, the operation of subcutaneous tenotomy can be performed through a puncture wound. It is generally agreed that the best results are with an open operation so that other shortened fascial structures can also be divided. Open operation also avoids damage to important veins. After operation it is advisable to fix the head and neck in an over-corrected position in plaster for three or four weeks (fig. 1667). It is usually necessary to attend a physiotherapy department for a few weeks, in order to get the little patient's confidence in active exercises designed to keep the affected muscle stretched.

SPINAL DEFORMITIES

Scoliosis is defined as lateral curvature of the spine. In many cases the lateral curvature is complicated by a rotational deformity which, in the thoracic region, is transmitted to the ribs, producing asymmetry of the thorax. Frequently the deformity of the ribs is one of the most striking aspects, producing, in addition to the scoliosis, an appearance of kyphosis (kyphoscoliosis). In very severe cases the vital capacity of the chest is so seriously diminished that the patient usually succumbs to intercurrent infection before later life. Sometimes the scoliosis may compress nerve roots and cause severe neuralgic pain or press on the cord on the concave side and produce spastic hemiparesis.

The causes of scoliosis may be classified:

(1) *Congenital.*—This is the result of a congenital hemivertebra, which in the thoracic region is confirmed by co-existing congenital anomalies of the associated ribs (fig. 1668).

(2) *Postural.*—This is a type of lateral curvature which affects children of school age and is characterised by being a simple C-curve without rotation of the vertebræ and with the deformity fully mobile and correctable. It is seen now much less commonly than formerly, probably because of school gymnastics and the avoidance of bad postures when sitting at school desks. The treatment of this type of case is obviously by gymnastics and lessons in deportment standing in front of a mirror.

(3) *Paralytic.*—This is the scoliosis which accompanies extensive paralysis from acute anterior poliomyelitis. Some of the most severe cases of scoliosis ever to be encountered are in this group. Generally the paralysis is so widespread that, in addition to the scoliosis, the patient will have paralysis of both legs and walk only with the aid of crutches and double leg calipers.

FIG. 1668.—Lumbar scoliosis: hemi-vertebra of L.5 with spina bifida occulta.

The treatment of paralytic scoliosis presents the orthopædic surgeon with what is sometimes an insuperable problem. Prolonged bed rest and avoidance of early weight bearing is a preventive measure when the weakness of the spinal muscles has been detected, but obviously a time must come when the young person must be allowed to be up and about. The fitting of a spinal brace may help considerably to minimise the development of deformity. In cases where the erector spinæ has been completely and permanently paralysed, it is doubtful if anything can be done to prevent a considerable deformity even while under treatment. So great are the bending forces exerted by the superincumbent body weight that even spinal fusions over large areas of the spine will bend or crack under the strain.

(4) *Pulmonary* conditions will produce a scoliosis when disease of one lung results in contraction of the chest wall on that side. In the past the worst examples followed from the treatment of empyema by prolonged drainage through tubes in the chest wall, but the modern treatment of these suppurative conditions of the pleura has made this complication one of the rarer causes of scoliosis. Extensive thoracoplasties with complete collapse of one half of the chest may cause a slight deviation of the spine, but not usually to such a degree as to produce a clinically detectable deformity of the spine.

(5) *Idiopathic Scoliosis.*—Though of unknown origin, this is the commonest scoliosis, and next to the paralytic the most severe. In this serious condition the experienced orthopædic surgeon can prevent a patient becoming a helpless cripple and ' hunchback ' and maintain a condition of the spine which will

appear comparatively normal to the lay observer. It is to be noted that the emphasis here is laid on the maintenance of an acceptable condition of the spine; in other words, early diagnosis and early treatment are the fundamental aspects of this problem. The orthopædic surgeon presented with a case of advanced deformity can do nothing to restore the cripple to normal, but his knowledge of the natural history of the development of these gross deformities may enable him to halt the progress of crippling deformity in early cases.

Idiopathic scoliosis is much commoner in girls than in boys. It does not usually present itself until the child is about ten years of age, but from then until puberty a rapid and sometimes appalling deterioration takes place. The deterioration may thereafter continue at a slower rate until the maximum deformity is achieved at about the age of twenty years. Much can be done for these unfortunate patients if the condition is diagnosed between ten years of age and early puberty, but if missed at this crucial time the orthopædic surgeon can alleviate only a limited number of cases.

The fundamental nature of idiopathic scoliosis is still obscure. It has often been attributed to a paralysis of the intrinsic muscles of the spine by a condition such as poliomyelitis, but the preponderance of girls (poliomyelitis affects both sexes equally) and the absence of paralysis in the extremities is against this. It is, in fact, the complete normality of the rest of the body which distinguishes this condition from the scoliosis of poliomyelitis. There is a possibility that there may be some obscure neurological cause underlying it, as it is sometimes seen in Friedreich's ataxia and in von Recklinghausen's disease (neurofibromatosis).

In order that the body may remain in balance, the *primary* curve of the scoliosis is balanced by secondary curves above and below it. When the patient is fully clothed these compensatory curves will bring the shoulders over the pelvis and no particular abnormality will be visible. The main effects of a severe scoliosis will be (*a*) loss of height due to the spine becoming 'concertinaed,' and this may account for a loss of three inches to six inches of height, according to the severity of the deformity, and (*b*) the presence of a 'rib hump,' which gives the patient the appearance of a 'hunchback' in addition to being a little dwarfed. This rib hump is very characteristic of idiopathic scoliosis, and is best demonstrated in an early case by standing behind the unclothed patient and asking her to touch her toes. Even in the absence of any very marked clinical deviation of the spine, this test will show the asymmetry of the chest (fig. 1669). This simple test is of very great importance because the deformity of the spine discovered by X-ray is often much greater than other clinical tests would leave one to suppose. The reason is that the rotation of the vertebral bodies, which always accompanies the lateral curvature in idiopathic scoliosis, is such that the tips of the spinous processes turn towards the midline (so diminishing the apparent curve), and the bodies turn away from the midline, so increasing the curvature (and these, being intrathoracic, are not visible until X-rayed). The presence of a rib hump, rendered more clearly manifest in flexion, will therefore make the surgeon suspect rotation and the possibility that the clinical

Nikolas Friedreich, 1825–1882. Professor of Pathology, Heidelberg.
Friedrich von Recklinghausen, 1833–1910. Professor of Pathology, Strasbourg.

deformity, as demonstrated by marking out the tips of the spinous processes, is concealing a more serious radiological appearance.

Treatment.—The ideal treatment of idiopathic scoliosis is early diagnosis and prevention. So rapidly can the deformity progress once it has started, that the aim of treatment should be frequent surveillance during the year after the deformity has first been noticed. Comparable anteroposterior X-rays of the spine should be taken every three months during the first year, and careful measurements of these curves will show whether the deformity is increasing. It is valueless to depend on clinical impressions of what the spine looked like. Without this careful supervision it may sometimes happen that, within a year of the curve being first noticed, a deformity has developed which may be too severe to be held in correction.

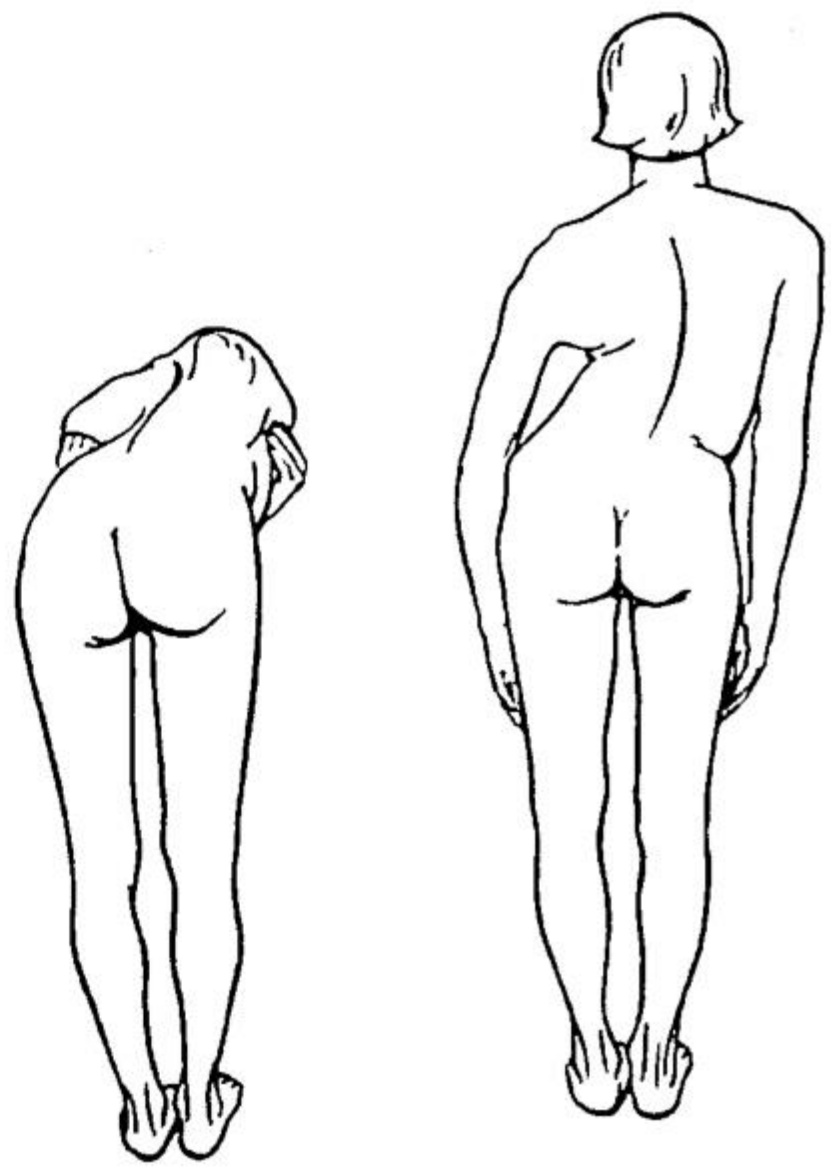

FIG. 1669. — Scoliosis showing 'rib-hump' (rotatory deformity) revealed in flexion.

It is true that all cases of idiopathic scoliosis do not behave alike. There are certain types which are benign in their untreated natural history (many of these occurring in the lumbar region). On the other hand, there are others of a most sinister character (especially those in the thoracic region), and until more is known of how these can be distinguished the routine of careful surveillance by X-ray is to be advised in all cases.

In most of the severe cases a rapid deterioration of the shape of the spine takes place in the two or three years prior to puberty, and thereafter no further deterioration is likely. Thus a child presented for examination at puberty with only a mild curvature can be reassured, but she should be checked by comparable anteroposterior X-rays on several occasions.

In all these mild cases the importance of exercises while under surveillance will be manifest : exercises to encourage bending to the side of the convexity and rotation exercises in the appropriate direction to de-rotate the spine. The child should be instructed to sleep on the side of the concavity and not to carry loads on this side.

If the deformity has reached a degree to be easily visible to the lay person, and if there is a strong suspicion that the curvature is of the serious kind which will increase before puberty is reached, there is no point in adopting inefficient conservative methods which may waste time and allow a deformity to develop. These cases are best admitted to hospital and corrected by orthopædic apparatus, after which the corrected position should be maintained by spinal fusion.

Technique.—The most widely used method of obtaining correction is by the use of the Risser jacket (fig. 1670). This is a plaster body cast, including the head and one thigh, applied with the patient bent to the side of maximum correction which can be tolerated. The cast is heavily padded with sorbo rubber at the essential points

J. C. Risser, Contemporary. Associate Professor of Orthopædics, California.

where experience has shown that pressure is likely to be encountered. When the cast is dry it is sawn across at the level of the apex of the primary curve and angulated (taking out wedges if necessary). The new position is held by means of metal hinges incorporated with the plaster to hold the two halves together. A very slow correction can then be obtained from week to week, and checked by X-ray. When the primary curve has been corrected as far as the surgeon thinks desirable (and this is often not a complete straightening of the curve), a hole is cut through the back of the plaster over the region of the scoliosis and the operation of spinal fusion is performed through this window. The bone used is generally taken as small chips from the patient's own tibia, and the volume can be increased by adding 'banked bone.' Sometimes, in a severe case, the operation is performed in several stages so that a long length of spine is fused on both sides of the spinous processes. After operation, six months are necessary for consolidation of the fusion, and another year of ordinary activities in a carefully moulded corset is advisable so that the soft new graft is not subjected to severe bending strains.

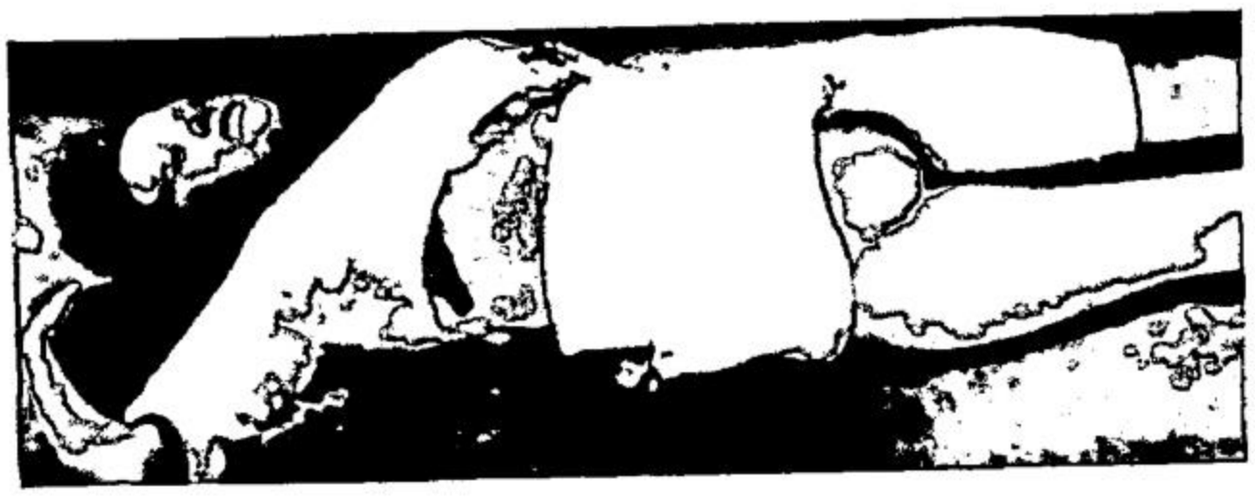

FIG. 1670.—Risser jacket.

Kyphosis can be defined as an increased dorsal convexity of the spine. The deformity of kyphosis lies in the anteroposterior plane (unlike scoliosis, which is in a lateral plane), and it produces a flexion deformity of the spine whether it occurs in a region which is normally convex (i.e. the thoracic spine) or in a region which is normally concave (i.e. the lumbar or cervical spine).

Three clinical types of kyphosis are encountered:

(1) '**Knuckle.**'—This is nothing more than the undue prominence of a single spinous process. The general curvature of the spine as a whole is normal, and is merely interrupted by this prominent knuckle (fig. 1671 (*a*)). Sometimes such a prominence may be of no significance, being only a congenital irregularity of the spinous processes. When due to disease, it indicates the collapse of a single vertebral body.

(2) **Angular.**—This is a sharp angular break in the line of the spine, so that the parts above and below no longer form part of a simple curve (fig. 1671 (*b*)). This type of kyphosis always implies severe collapse of at least two, and often three, vertebral bodies.

(3) **Round.**—This is usually seen in the thoracic region as an increase in the normal convexity of this region, and it indicates that the increased wedging of the vertebræ responsible for it is distributed more or less equally over five to eight thoracic vertebræ.

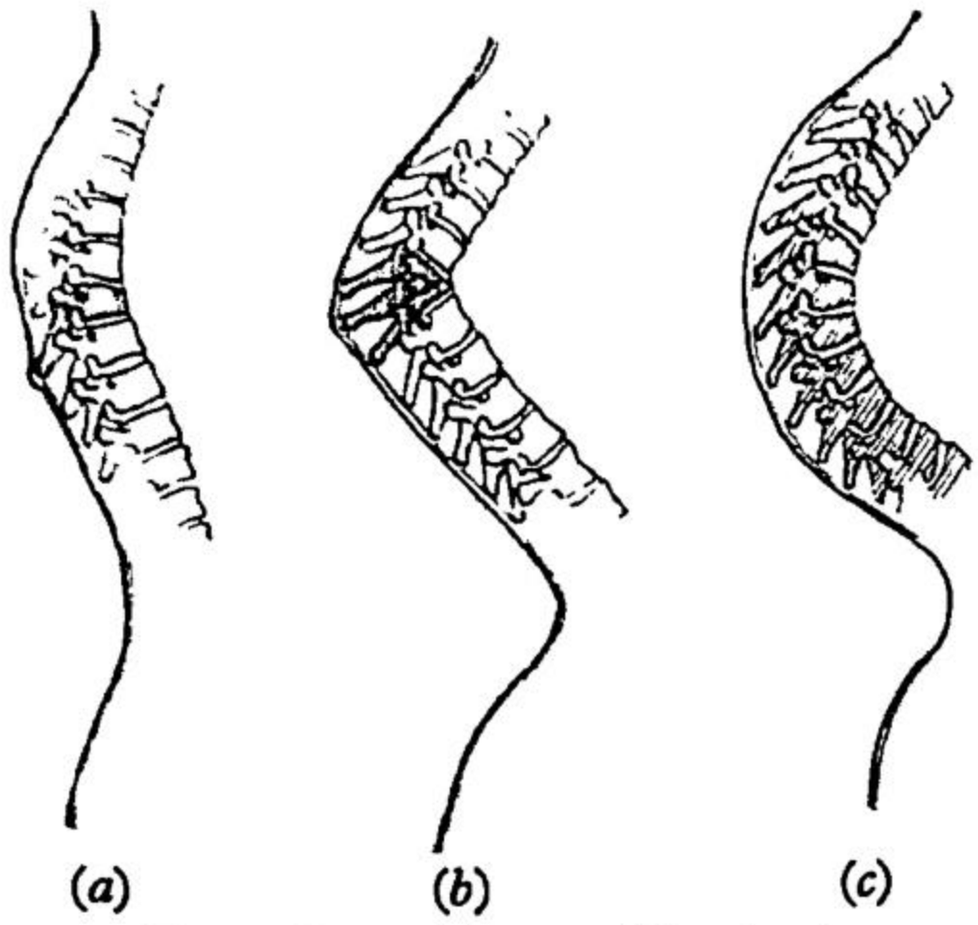

FIG. 1671.—Types of kyphosis.
(*a*) Knuckle. (*b*) Angular. (*c*) Round.

The causes of kyphosis can be classified as:

(1) *Traumatic.*—Severe fracture-dislocations of the spine will produce a marked *angular* kyphosis; mild compression fractures may be detectable as a knuckle kyphos.

(2) *Inflammatory.*—Of these, only Pott's disease produces kyphosis. Tuberculous caries of the spine in its earliest stages will be suspected if there

is rigidity of the spine on attempted forward flexion, and especially if there is a knuckle kyphos. The later stages of the disease may develop angular kyphosis if several bodies are destroyed. In late healed cases the presence of old sinus scars will clinch the diagnosis of Pott's disease.

(3) *Neoplastic.*—Secondary carcinomatous deposits occur with great frequency in the red marrow of the vertebral bodies, but it is unusual for a kyphos to develop. More often the patient will succumb to paraplegia or from the effects of other secondary deposits elsewhere before sufficient collapse takes place to cause a marked deformity.

(4) *Osteochondritis* (*syn.* Scheuermann's Disease).—This is a disorder of the epiphyses in rapidly growing children (cf. Perthes disease, Osgood-Schlatter, etc.) which affects the vertebræ in the thoracic region. It is the commonest cause of ' round shoulders ' in otherwise healthy young people. It produces a marked increase in the normal convexity of the thoracic spine which is compensated by an increase in the concavity (lordosis) of the lumbar spine below it.

The disease often starts with pain in the back at puberty, and the condition can progress until about the age of eighteen. Lateral X-rays of the thoracic spine show some irregularity of the anterosuperior and anteroinferior angles of the vertebral bodies at the site where the normal epiphyses are present. Eventually the vertebral bodies from about the second to the tenth will show excessive wedging.

If recognised in the early stages, a period of three months on a plaster bed with a hinge to correct the deformity, followed by a posterior spinal support to brace the spine, is a logical order of treatment. In practice, such a drastic curtailment of school activities is rarely necessary, and if the patient concentrates on hyperextension exercises, has a daily régime which increases the number of hours he lies flat on his back, and reduces the spare time left for ' lounging about,' this is as much as is usually necessary to control the condition. A well-fitting back-brace is permissible, provided that it does not take the place of the exercise. A large part of the external deformity of ' round back ' is attributable to a bad position of the shoulders, and many young people can conceal the fixed deformity of the spine by developing a good carriage with shoulders well braced back. It must be confessed that the most elaborate and time-consuming mechanical treatment of the deformity, even in its early stages, may sometimes fail to produce a perfectly normal spine, and therefore the development of a good carriage is in the end the most important part of treatment.

(5) *Ankylosing Spondylitis.*—The characteristic deformity of this condition is a rigid flexion of the whole spine from the upper cervical to the lower lumbar region. It is not a true kyphosis in the sense of a localised increase in dorsal convexity at one part of the spine, but is merely the abolition of the normal concavities in the lumbar and cervical regions (see p. 1285).

(6) *Paget's Disease.*—An increase in the curvature of the thoracic spine is common in generalised Paget's disease, and accounts partly for the patient's loss in height. In this condition the bones are invaded by fibrous tissue and, though in many cases they appear radiologically denser than normal, they are at the same time brittle and also capable of slow bending under body weight.

(7) *Senile Kyphosis.*—As a normal part of old age, the thoracic spine develops an exaggerated convexity which explains the loss in height which is so characteristic of old age. The underlying pathology is that of a disuse

Holger Werfel Scheuermann, Contemporary. Director of Radiological Department, Military Hospital and Sundby-hospital, Copenhagen.

atrophy of the vertebral bodies. There is no pain in this condition, which does not bring the patient for treatment, and therefore it does not rank as a disease.

(8) *Acute Osteoporosis of the Spine.*—This is very similar to senile osteoporosis in its general appearances but occurring in patients of fifty to sixty years of age. It is almost always encountered in females, and if occurring rather earlier is called 'post-menopausal' osteoporosis of the spine. This condition seems to be related to the failure of some ovarian secretion, because great relief from symptoms can frequently be obtained by the administration of dienestrol which these patients can usually take over long periods without causing uterine bleeding. There is rarely much re-ossification of the spine, but the symptoms are held in control.

FIG. 1672.—'Fish' vertebræ in severe osteoporosis of the spine.

In severe cases a characteristic radiological appearance of 'fish vertebræ' is seen (fig. 1672). This is caused by the bone of the vertebral bodies being too soft to resist the internal pressure of the intervertebral discs which thus tend to assume a biconvex, or even spherical, shape.

Strictly speaking, acute osteoporosis of the spine should not be considered here under the heading of kyphosis because it does not usually cause this deformity. It manifests itself by pain and rigidity of the back. It is probably, however, related to senile osteoporosis and cannot be considered in relation to 'general diseases of bone' because it is essentially a local condition affecting the spine alone.

Lordosis is an exaggeration of the dorsal concavities of the spine and is most commonly encountered in the lumbar region. If for any reason, such as Pott's disease, a kyphosis exists in the dorsal region, then a compensating lumbar lordosis will develop to restore the centre of gravity of the body. In patients with gross abdominal obesity the lumbar spine becomes lordotic to restore equilibrium, and the same happens as a transitory mechanism during the later stages of pregnancy.

Spondylolisthesis.—This is a condition in which a lower lumbar vertebra, usually the fifth, slips forward through the plane of the intervertebral disc below it and so carries with it the whole of the upper portion of the spine. The essential lesion is a separation of the body of the vertebra from the posterior articulation, lamina, and spinous process as a result of a defect in the pedicles which hold these two parts of the vertebræ together (fig. 1673). Because the lamina is left behind in its normal position, the forward displacement of the vertebral body does not narrow the spinal canal. The deformity can, however, cause root pressure which from time to time manifests itself as sciatica.

In general, the main symptoms are usually those of long-standing low-back pain. On examination, in a mild case nothing will be found other than some excessive prominence of the first sacral spinous process. In a severe case, where the lumbar vertebra has become dislocated in front of the sacrum, there will be a severe lordosis and a rather characteristic shortening of the trunk, so that the lower ribs seem to rest on the brim of the pelvis.

FIG. 1673. — Spondylolisthesis of fourth lumbar vertebra on fifth.

Though trauma was frequently regarded in the past as a common cause of spondylolisthesis, accurate X-ray studies now show that a congenital defect in the development of the pedicles is much the commonest explanation. X-ray studies often reveal a condition sometimes known as ' prespondylolisthesis,' or ' spondylolysis,' where slipping of the vertebræ is absent, or minimal, in the presence of defects in the pedicles.

The majority of these cases never require any special treatment other than simple placebos for backache, such as local heat and rest from time to time. A stiff lumbosacral corset will give relief to the majority and a few will require lumbosacral fusion to abolish pain. As in the management of any case of ' low-back pain,' it is unwise to alarm the patient with injudicious reports about the X-ray appearance. Many cases of severe spondylolisthesis go through life with nothing more than an occasional attack of ' lumbago.' Injudicious remarks can convert a mild case into a complete invalid.

MEANING OF VALGUS AND VARUS

The terms valgus and varus, so frequently used in describing orthopædic deformities, often puzzle the student. Essentially valgus means ' knock-knee ' and varus ' bow leg,' and it is difficult to see how these terms could be applied, for instance, to the hip or the foot.

Whatever the level of the deformity, its effect should be considered on the displacement of the end of the extremity towards or away from the midline of the body. Varus deformities are those which displace the hand or foot *towards* the midline ; valgus deformities *away from* the midline. In knock-knee (genu valgum) it is not the knee itself which is displaced medially, it is the foot which is displaced laterally.

UPPER EXTREMITY

Cubitus Valgus.—Normally the forearm lies in a slightly abducted position in relation to the axis of the humerus (the ' carrying angle '). This varies from about 10 degrees in men to 15 degrees in women (because of the greater width of the female pelvis in relation to the shoulders). Fractures of the external condyle of the humerus in young children frequently fail to unite, and continued growth of the medial condyle in later life produces the condition of cubitus valgus, where the forearm may be abducted 45 degrees

in relation to the axis of the humerus. In this position the ulnar nerve suffers excessive friction at the medial condyle, and an interstitial neuritis develops which produces anæsthesia and an insidious paralysis of the small muscles of the hand supplied by the ulnar nerve. If recognised early, transposition of the ulnar nerve in front of the medial epicondyle will avert the further development of symptoms, but it rarely produces improvement if serious wasting of the intrinsic muscles has already developed.

Cubitus varus is a less common deformity ('gun-stock' deformity) due to mal-union of supracondylar fractures. It is an ugly deformity but does not interfere with function, and its correction by osteotomy is dictated entirely on cosmetic grounds.

FIG. 1674.—Madelung deformity.

Madelung's deformity (manus valga) is a radial displacement of the carpus with abnormal prominence of the lower end of the ulna (fig. 1674). It is a term for a deformity and comprises many ætiological conditions. Anything arresting the growth of radius will produce the deformity. It is usually symptomless and only rarely does the prominent lower end of the ulna need resection.

Congenital absence of the radius occasionally occurs, in which case growth of the ulna pushes the hand to the radial side. The lower articular surface of the ulna is expanded, and articulates with the proximal row of carpal bones. This is a form of Madelung's deformity.

Congenital dislocation of the head of the radius sometimes causes great confusion if the surgeon is unaware of the condition. Dislocation of the head of the radius may be diagnosed radiologically for the first time after an injury, though it has actually been present for many years. Attempts to reduce it will, of course, fail. It can be diagnosed by the fact that the head is not quite normal in shape (not being cup-shaped at its extremity) and that it is longer than it should be for a simple dislocation.

Congenital elevation of the shoulder (*syn.* Sprengel's shoulder) is a condition in which the scapula is smaller than normal and situated at a higher level. The inferior angle is rotated inwards, and abduction is restricted (fig. 1675). In bilateral cases the appearance of the patient at first suggests that the neck is abnormally short. In some cases the neck is indeed abnormally short as a result of the congenital fusion of cervical vertebræ. The rhomboid muscles are partially fibrous or even cartilaginous or ossified, and the trapezius and serratus muscles are sometimes deficient.

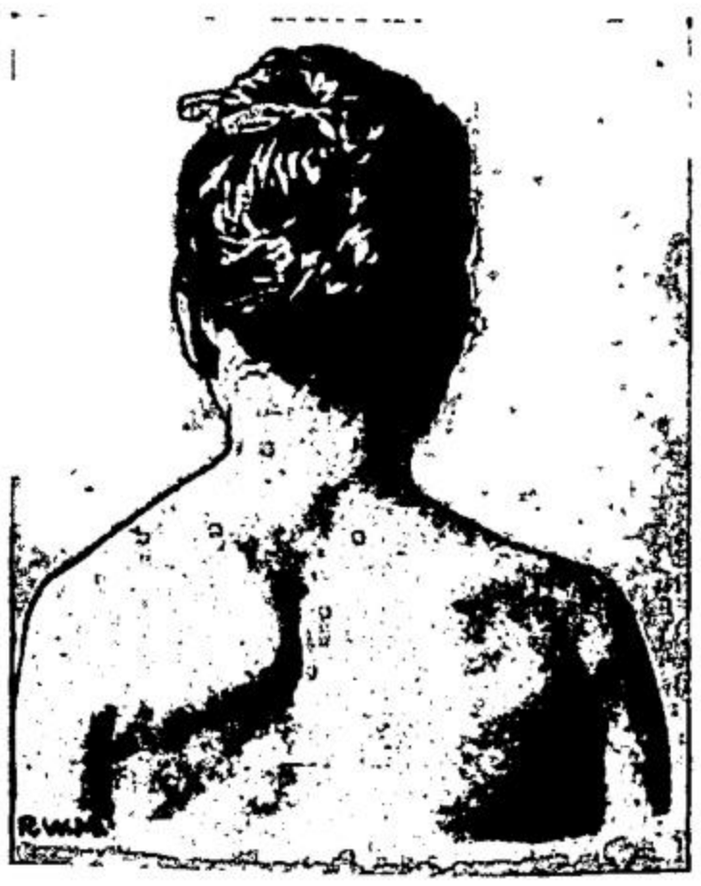

FIG. 1675.—Sprengel's shoulder. (*Sir John Fraser.*)

Treatment consists in exercises if such are considered necessary, but surprisingly little disability results. Operations to improve function are unsatisfactory, but the upper and inner portion of the scapula may be excised for cosmetic improvement.

Dupuytren's Contracture.—This is a localised thickening of the palmar fascia which involves the overlying skin of the palm and which shows a strong tendency to contract and eventually draw the affected fingers into

Otto Madelung, 1846–1926. Professor of Surgery, Strasbourg.
Otto Sprengel, 1852–1915. Surgical Director, Grossherzoliche, Krankenhaus, Braunschweig.
Baron Guillaume Dupuytren, 1777–1835. Surgeon, Hôtel Dieu, Paris.

rigid flexion. Most commonly it starts near the base of the ring finger and soon draws that finger into the palm of the hand (fig. 1676). Later it involves the fifth finger in the same way. In long-standing cases permanent changes take place in the metacarpophalangeal joints and the proximal interphalangeal joints which render futile any attempts to straighten the fingers.

FIG. 1676.—Dupuytren's contracture. Note puckering of adherent skin in palm.

The pathology of the condition is unknown; the consensus of opinion would seem to favour a chronic inflammatory origin, but in all probability it will prove to be a primary disorder of the 'collagen' substance of fibrous tissue. In the past it was customary to attribute it to repeated trauma in persons using tools, etc., which pressed on this region. On the other hand, it is known to be familial and is frequently seen in persons who have never done a day's manual work in their lives. The fact that it is so often bilateral is against any traumatic origin. It is distinctly more common in men than in women.

Early cases can be treated by night splintage and gentle stretchings done by the patient. On the other hand, the most perfect surgical cases are those which are operated on before serious contracture develops, and radical excision of the affected area is followed by quicker rehabilitation in the early cases than in the later cases.

In the past the operation of 'subcutaneous fasciotomy' was often practised; through puncture wounds the tight bands were divided and the finger partially straightened. There is nowadays very little need for this procedure, and radical excision can give very excellent results in all but the severe cases where permanent joint changes have developed. In the latter it may be advisable to amputate.

Congenital deformities of the fingers include the conditions of syndactyly, macrodactyly, and congenital contracture. *Syndactyly*, or webbed fingers, is a condition in which two or more fingers are joined together (fig. 1677). An X-ray should be taken, and if normal bones are present, separation of the fingers will improve the function of the hand.

FIG. 1677.—Syndactyly.

The two-stage operation (Didot) should be performed, the first step of which consists in establishing an epithelialised tunnel at the base of the web. This is obtained by dividing the base and stitching a flap of adjacent skin over the raw surface. A glass rod is inserted between the fingers and kept in position until the tunnel is covered by epithelium. The second stage consists in a plastic operation, two flaps of skin, the length of the web, being dissected from the front and back of the fingers respectively in such a manner that when the web is divided the raw surfaces of the fingers are covered, one by the dorsal, and the other by the palmar, flap. Syndactylism of the toes needs no treatment, and may even benefit swimmers!

Alphonse Didot, a surgeon of Brussels, described his operation in 1849.

Macrodactyly consists in overgrowth, possibly enormous, of a digit. A plastic operation, or amputation, is occasionally necessary.

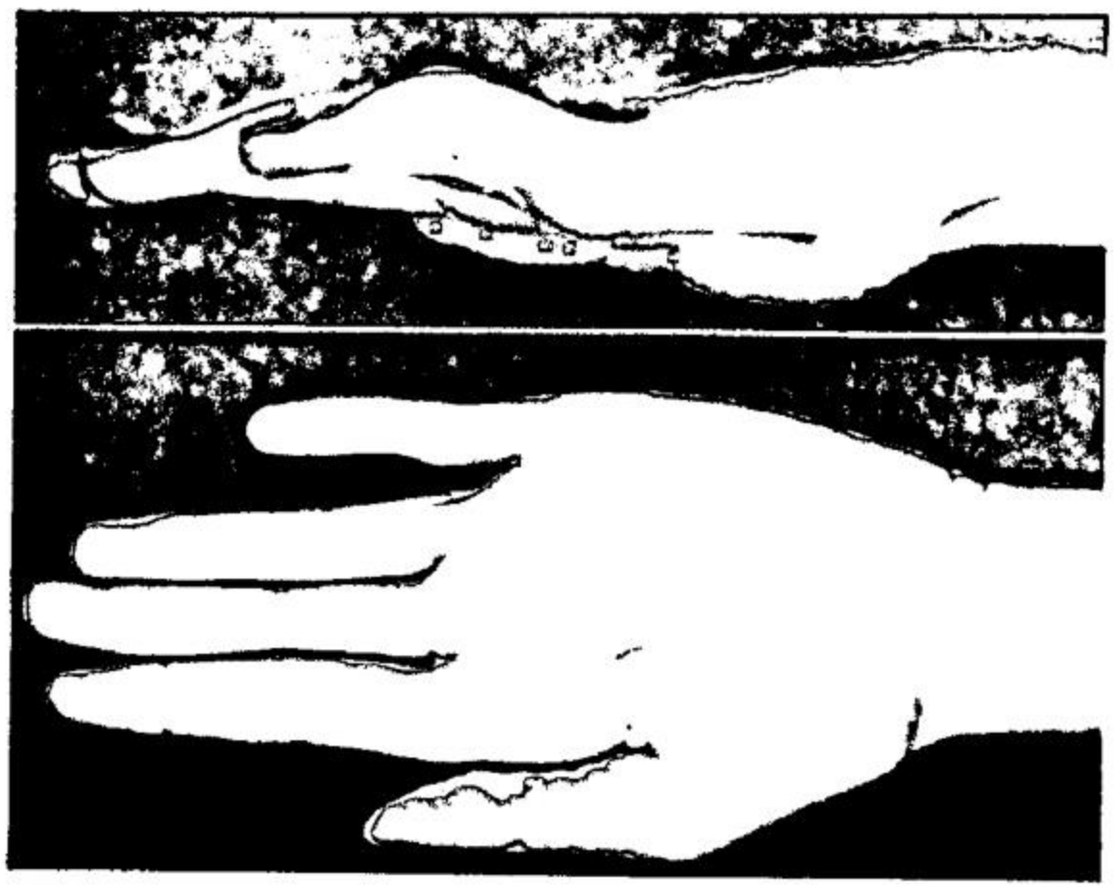

FIG. 1678.—Congenital contracture of the little finger.

Congenital contracture of the fifth finger is a condition not encountered in the other digits. Hyperextension occurs at the metacarpophalangeal joint, and flexion at the proximal interphalangeal joint (fig. 1678). The condition is usually bilateral and does not produce symptoms. It is easily differentiated from Dupuytren's contracture as there is no skin involvement and it usually occurs in young people, whereas Dupuytren's contracture is rarely seen under middle-age. Treatment is seldom necessary.

DEFORMITIES OF THE LOWER EXTREMITY

Congenital Dislocation of the Hip.—Though this is a comparatively rare condition in England, it is an extremely important matter to the orthopædic surgeon because, by early diagnosis and skilful treatment, children may grow into complete normality who otherwise would go through life seriously crippled.

It would seem that as the result of some gene the embryo affected in this way develops with the head of the femur at some slight distance from the socket, and though the head of the femur and the acetabulum both retain the 'primary modelling' of their parts they do not later receive the 'secondary modelling' which comes from the natural pressure of the head and socket against each other. For this reason, the acetabulum remains flat and shallow with an undeveloped upper lip which offers no stable platform under which the head of the femur can lodge.

If the condition is undiagnosed and untreated, the child walks with a characteristic limp because the pelvis is merely slung to the upper end of the femur by capsular and ligamentary structures.

Clinical Features.—The clinical features which lead to a diagnosis are very different in the infant and in the established case which has been walking for some years without treatment, and for this reason the two clinical types are dealt with separately.

In Infancy.—The difficulty in diagnosis in infancy is, of course, the fact that bony points are not palpable and the errors of the tape-measure are too great to be of value. The child moves both legs freely, and frequently the first suspicion that all is not well suddenly occurs to the parents when the child is about the end of its second year of life. Up till this time any slight limp on one leg is attributed to difficulty in learning to walk, and if the condition is bilateral the diagnosis may be even more difficult. If the

diagnosis can be made during the first year of life, the prospects of a very successful result are appreciably greater than if the child has been taking weight on the dislocated joint for two or three years. The features to be observed in infancy are therefore :

(1) *Asymmetry of skin creases* on the inner aspects of the thighs. Asymmetry of creases can be present with normal hip joints, but the reverse is uncommon (fig. 1679).

(2) *Telescoping of the Hip*.—Traction may reveal the ability to draw the hip down and then feel it telescope upwards.

(3) *Limitation of abduction* compared with the opposite side (fig. 1680). This is only likely to be noticeable if the head of the femur is grossly dislocated. This may be noticed when applying the infant's ' nappy.'

(4) *X-ray Examination*.—In infancy this is the only way a diagnosis can be made with certainty in cases of ' subluxation '; the previous clinical signs are merely suggestive pointers to lead to the child being examined radiologically. Because the epiphysis for the head of the femur does not appear until one year after birth, it will be realised that mild degrees of subluxation may not be obvious. The most important radiological test at this stage is Shenton's line. In the normal hip this is a regular arcade which can be traced without any break in continuity from the under-surface of the neck of the femur to the under-surface of the pubic ramus (fig. 1681). If the cartilaginous head of the femur is slightly subluxated upwards, a ' step ' will be visible in this arcade.

FIG. 1679.—Asymmetrical skin creases in C.D.H. (*J. C. R. Hindenach.*)

FIG. 1680.—Limited abduction of left thigh in C.D.H. (*J. C. R. Hindenach.*)

When the capital epiphysis appears, the radiological diagnosis is much easier. In congenital dislocation the epiphysis is often a little later to appear on the affected side than on the normal side, and even when present it is never quite as large as the normal side. When the epiphysis is present, subluxation can be detected by its position in reference to two lines, one horizontal and one perpendicular, drawn through the acetabulum. The horizontal line is drawn through the centre of the ' triradiate cartilage ' of the acetabulum (fig. 1681) and the ossific nucleus of the head should lie below this line. The perpen-

E. W. H. Shenton, Contemporary. Consulting Radiologist, Guy's Hospital, London, and St. Bartholomew's Hospital, Rochester, Kent (the oldest hospital in England, situated on the Pilgrim's Way to Canterbury).

dicular is drawn through the outer lip of the acetabulum and the ossific nucleus should lie medial to this. It will be appreciated that this line is sometimes rather difficult to place because a lack of distinctness of the lip of the acetabulum is characteristic of congenital dislocation.

FIG. 1681.—Shenton's line. Note small ossific nucleus on dislocated side above and lateral to vertical and horizontal lines.

Treatment. — The diagnosis having been established within the first year of life, treatment consists of nothing more complicated than holding the thighs widely separated. In this position the head of the femur lies opposite the defective acetabulum, and the tone of the adductors in this position will help to compress the head against the acetabulum and stimulate it to model itself into a deep cup to surround the head. Obviously this position must be maintained for at least one year. In the early phases of infancy a pillow or specially folded daiper can be used to abduct the thighs (Putti), but in the later stages some type of abduction splint is needed.

In Later Childhood

(1) *True Shortening.*—This will take place above the great trochanter as revealed by Nélaton's line.

(2) *Prominence of the Great Trochanter.*—If the condition is bilateral, this will be associated with widening of the perineum which shows as a space between the inner surfaces of the thighs at the root of the limb.

(3) *Difficulty in palpating the femoral artery* at the level of Poupart's ligament because of the absence of the femoral head which should be behind it, so indicating emptiness of the acetabulum. Direct palpation of the femoral head in its abnormal position, which is the logical counterpart of this procedure, is not always possible.

(4) *Limitation of abduction*, due to shortening of the adductors, but full movement in all other directions.

(5) *Trendelenburg's Sign.*—To elicit this sign the patient stands with her back to the surgeon, and is first told to stand on the 'good' leg and bend up the knee on the 'bad' side. The patient will then be balancing on the good leg, and it will be noticed that the opposite, unsupported, side of the pelvis is lifted above the horizontal. This is the normal action of the pelvis in walking, and it is due to the pull of the gluteus medius acting between the crest of the ilium and the great trochanter (fig. 1682). This is a negative (normal) Trendelenburg sign (fig. 1683 (*b*)).

The patient is now told to "stand on the 'bad' leg and bend up the knee on the 'good' side." If a positive Trendelenburg sign is present, the oppo-

Vittorio Putti, 1880–1940. Instituto Rizzoli, Bologna, Italy.
Auguste Nélaton, 1807–1873. Professor of Clinical Surgery, Paris.
Friedrich Trendelenburg, 1844–1924. Professor of Surgery, Leipzig.

site, unsupported, side of the pelvis will drop below the horizontal (fig. 1683 (*a*)). This means that the mechanics of the hip are so defective that the gluteus medius cannot elevate the pelvis as it should.

This 'sign' is repeated at every step when the patient is walking and gives rise to the characteristic 'dipping' gait of congenital dislocation. If the condition is bilateral, the gait is well described as 'waddling.'

The most marked examples of the Trendelenburg sign are seen in congenital dislocation of the hip, but it is also present, in a less marked degree, in many other disorders of the hip (i.e. un-united fracture of the femoral neck, defective arthroplasty of the hip, osteoarthritis, and paralysis of the gluteus medius).

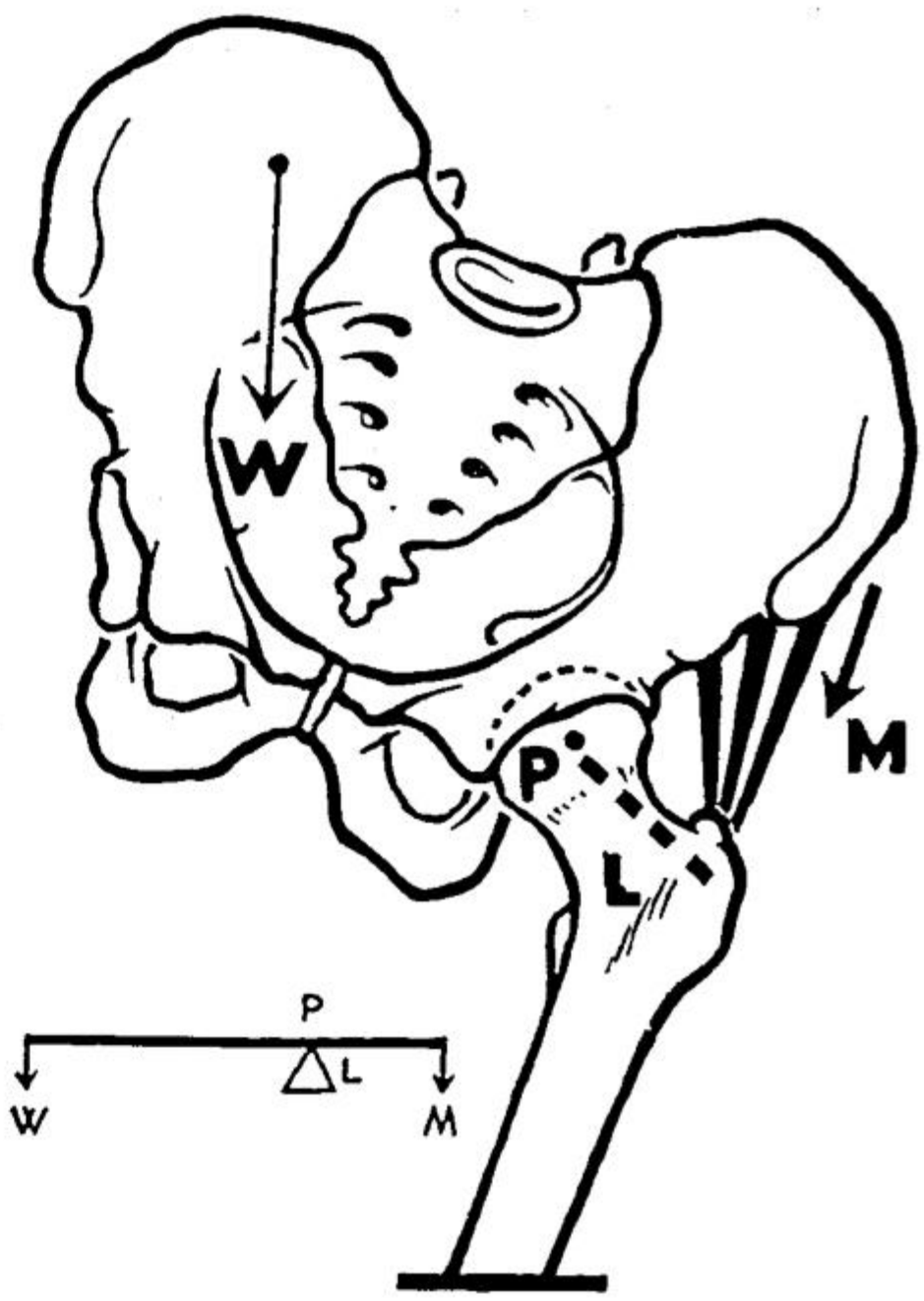

FIG. 1682.—Mechanism of Trendelenburg sign. Tension of gluteus medius elevating pelvis.

Radiological diagnosis at this age offers no difficulty, the condition being obvious. In tracing Shenton's line, a word of caution should be sounded; in some severe dislocations a first glance may suggest that Shenton's line is

(*a*) (*b*)

FIG. 1683.—(*a*) Trendelenburg's sign positive — standing on defective hip. (*b*) Trendelenburg's sign negative — standing on sound hip.

intact because the curve denoted by the under-surface of the *lesser* trochanter may be level with the under-surface of the pubic ramus. It is important to note that the essential line is the under-surface of the *neck* of the femur.

Treatment.—The case first seen under two years of age is first *manipulated* under anæsthesia, and if a satisfactory reduction is easily obtained the hip is held in the 'frog' position in plaster (fig. 1684) for about one year.

FIG. 1684.—Application of plaster of Paris for bilateral congenital dislocation of the hips.

An alternative method favoured by some is the gradual reduction by traction and abduction on a special frame.

If there is evidence of recurrence after a year or more of careful conservative treatment, operation is advisable. Many very successful results have been obtained by the simplest conservative methods, but there is always a 'hard core' of cases (perhaps 25 per cent.) which relapse and eventually require operative treatment.

Operation is required in cases which re-dislocate after initial treatment and in all cases first seen over about five years of age.

In some cases the operation consists merely of an open reduction, but in others, if the acetabulum is very undeveloped, a 'shelf' operation may be advisable. In this procedure a small bone graft is inserted into the dorsal lip of the acetabulum so as to help to retain the head of the femur in its reduced position.

The rôle of the anteverted state of the femoral neck which is commonly associated with congenital dislocation is becoming recognised as an important feature. After open reduction many surgeons recommend a 'derotation' osteotomy.

Late Cases.—Sometimes cases of congenital dislocation will present themselves at, or after, the age of puberty. At this age any attempt to reduce the hip by operation will produce a stiff and painful joint, and as most of these cases are quite remarkably active and pain-free despite their limp, it is best to wait until pain starts in later life, when an arthrodesis may be required.

COXA VARA

The normal angle between the axis of the neck of the femur and the shaft of the femur is about 130 degrees. In coxa vara this angle is diminished, and in some cases may be as little as 90 degrees. The effect of this will be to lower the level of the femoral head below the level of the tip of the great trochanter and so cause true shortening of the limb.

The most important causes of coxa vara are:

(1) Congenital. This is a very rare condition, but it is of interest in that it produces some of the most extreme cases of coxa vara ever encountered, the shaft-neck angle often being less than 90 degrees.

(2) Conditions causing softening of the bones, i.e. rickets, osteomalacia, Paget's disease.

(3) Trauma. Fractures of the neck of the femur which unite with a

shaft-neck angle of less than normal are examples of ' traumatic coxa vara.' This does not cause any symptoms.

(4) Pseudocoxalgia (Perthes' disease). Pseudocoxalgia has been described elsewhere (p. 1237), but special mention has to be made of the very important condition of slipped epiphysis as a cause of coxa vara.

(5) Slipped epiphysis.

Slipped epiphysis (epiphysiolysis) affects children between the ages of ten to fifteen years and consists of a displacement of the epiphysis of the femoral head in relation to the neck of the femur taking place through the plane of the epiphyseal cartilage. The epiphysis slips into the varus position at the same time as slipping posteriorly (being the same as if one considers the shaft and neck of the femur sliding into external rotation in relation to the head) (fig. 1685). After a period of disability and pain, during which the slipping process is taking place, the epiphyseal line ossifies and the head of the femur will unite and the patient will spontaneously recover almost full function, though with the permanent physical signs of limited abduction (i.e. the varus element) and limited, or absent, internal rotation (i.e. the external rotation of the shaft). Later in life symptoms of osteoarthritis will develop.

FIG. 1685.—Slipped epiphysis.

Many children suffering from this disease are grossly over-weight and show pituitary dysfunction of the Fröhlich type, but the remainder appear to be children otherwise normal in all respects.

Two quite distinct clinical types of slipped epiphysis are encountered: (1) acute displacement and (2) chronic displacement.

(1) *Acute Slipped Epiphysis.*—Careful questioning will often reveal that the acute case is really an acute episode in what has been a chronic slip, but the symptoms prior to the acute slip can be so slight as to pass without notice. The acute slip often follows an injury of some magnitude, such as a fall off a bicycle or at football, and thereafter the patient is unable to move and experiences severe pain. These cases on X-ray will show a complete displacement of the epiphysis and the clinical signs will be identical with those of a subcapital fracture in an adult (fixed external rotation, shortening, and limited abduction).

Treatment.—The acute case is treated exactly like a subcapital fracture of the femur in an adult. It should be reduced under anæsthesia without

undue delay (by internal rotation and abduction, i.e. the opposite of the deformity) and a Smith-Petersen nail (or preferably some form of screw) is inserted under X-ray control to maintain the reduced position.

(2) *Chronic Slipped Epiphysis.*—In this condition the child, between ten and fifteen years of age, is noticed to have a limp, and this may arouse no comment until after a week or two it gets worse and the patient then starts to complain of pain.

On examination the condition may at first be difficult to diagnose, because there may be spasm and limitation of movement in all directions, suggesting an inflammatory process (i.e. early tuberculosis). Rest in bed for a day or two will relieve the pain and spasm, after which limited internal rotation, limited abduction, and slight shortening may be demonstrable. X-ray will show some degree of slipping of the femoral epiphysis. If treatment is not instituted, the early slip will continue slowly or it may culminate in a sudden complete slip. It is to be noted that the earliest sign of slipping is best seen in the lateral radiograph even when the anteroposterior view seems normal.

Treatment.—Attempts to reduce the chronic slipped epiphysis are not to be encouraged because they will need great violence to move the head and thus may cause damage to the blood supply of the head. If the head has slipped only a slight degree, the position can be accepted and treatment directed to preventing further deformity. This can be by (1) *conservative* methods—i.e. skin strapping traction in abduction for nine to twelve months or till radiological evidence of fusion of the epiphyseal line is appearing; or (2) by *operation*, in which case a nail, bone graft, or threaded wires can be inserted under X-ray control so that the child can be allowed up, non-weight bearing, in a much shorter period.

If gross slipping has occurred by the time the patient is first seen, operative treatment is indicated, and in this case an osteotomy should be performed to correct the external rotation and the varus deformity.

GENU VALGUM

Knock-knee of a mild degree is very frequently encountered in healthy, well-nourished, and well-cared-for children without any recognisable pathology. The common cause of severe knock-knee in the past was simple rickets, but this is now very rare (p. 1229).

The degree of knock-knee can be measured by the intermalleolar separation present when the inner aspects of the knees are just allowed to touch. In children of about four years of age this separation can be as much as 2 to $2\frac{1}{2}$ inches (5 to 6·25 cm.) without there being any evidence of systemic disease to account for it. This type of knock-knee often corrects itself spontaneously, and it is certainly true that in healthy children it never gets worse than when first seen. To the parent one of the main sources of alarm is the fear that if a child has $2\frac{1}{2}$ inches (6·25 cm.) of knock-knee at four years, then by continued growth of the tibia, in the absence of treatment, one might expect twice this amount of intermalleolar separation when the tibia has grown to double its length. In fact, the opposite happens; even in the absence of

treatment the intermalleolar separation may diminish slightly as the child gets older, but even if it does not, the total appearance of knock-knee is concealed by the fact that $2\frac{1}{2}$ inches (6·25 cm.) of intermalleolar separation constitutes a negligible deformity in the adult.

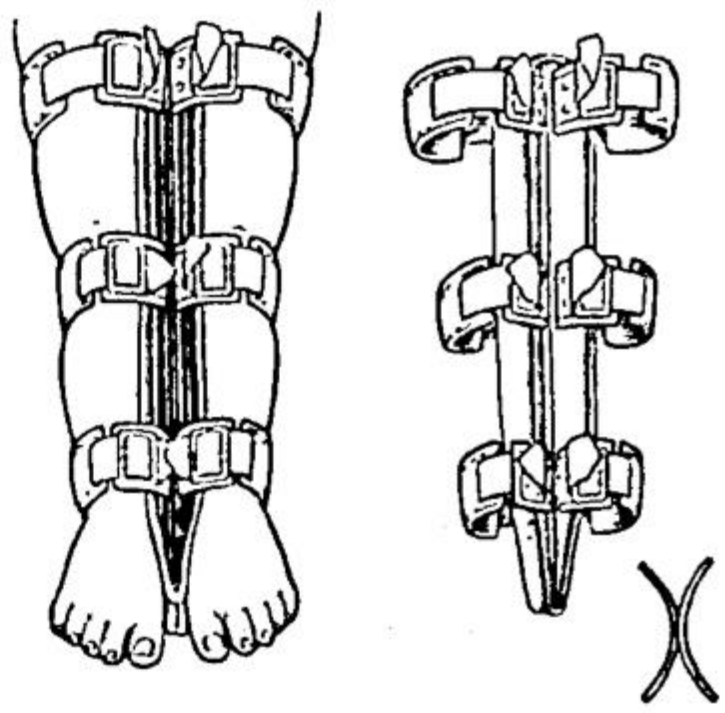

FIG. 1686.—Mermaid splint for knock-knee.

In this common type of mild knock-knee the only treatment needed is to elevate the *inner* borders of the shoes by $\frac{1}{4}$ inch (6 mm.) and to prohibit, as far as is reasonably possible, the child from running about barefoot or in uncorrected shoes. This régime must be adhered to for at least five years. More severe cases will benefit from a 'Mermaid' night splint (fig. 1686) designed to exert a continuous moulding force on the knees, and in all cases the mother should be taught to mould the knees in the varus direction night and morning for about five minutes each day.

FIG. 1687.—Genu recurvatum.

General bone diseases in childhood are often accompanied by knock-knee, and one of the most severe of these is *renal rickets* (p. 1231). Most of the generalised diseases of bone are associated with dwarfism or other evidence of generalised growth disturbance.

Genu varum (*syn.* bow-legs) is less common than knock-knee, and in the past was most commonly due to rickets. Since rickets is now almost extinct in civilised communities, bow-legs are very rarely encountered and never to the gross degree of deformity which was a common occurrence in the past. If the deformity cannot be explained as part of a generalised disturbance of bone growth, it is usually the result of a local error in growth of the upper tibial epiphysis ('tibial varus').

The treatment of mild cases is by daily moulding, night splints, and the wearing of shoes raised $\frac{1}{4}$ inch (6 mm.) on the *outer* borders. Severe degrees of deformity are corrected by osteotomy.

Genu recurvatum is due to abnormal hyperextension of the joint, and severe degrees are often congenital in origin (fig. 1687).

Serious genu recurvatum often follows poliomyelitis, where the hamstrings are paralysed and the quadriceps is left with some considerable power. This deformity is sometimes seen in spastic paraplegia, though more commonly in this disease the child walks with the knees partially flexed.

FLAT-FOOT (PES PLANUS)

Though it is a simple matter to diagnose 'flat-foot' on anatomical grounds, it is often difficult to decide whether such a deformity is to be

undue delay (by internal rotation and abduction, i.e. the opposite of the deformity) and a Smith-Petersen nail (or preferably some form of screw) is inserted under X-ray control to maintain the reduced position.

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the tarsal joints by painful spasm. Though common in the past it is not now very frequently seen, as working hours are controlled and employees in their first job are not exposed to duties for which they have had no previous training.

Treatment is by two or three weeks' partial rest, foot-baths, and graduated return to duty.

Sometimes 'acute flat-foot' is the result of local inflammation, and in this connection the best-known cause is gonococcal fasciitis.

(3) *Chronic Flat-foot.*—This is the end-result of untreated foot strain. It is seen frequently in waitresses and others who spend long hours on their feet carrying weights. In the later stages the feet become painless and the gait shuffling and inelastic. In its final stages this type of foot can be painless though rigid.

The treatment of chronic flat-foot applies mainly during the years when the foot is progressively breaking down. Arch supports moulded to the corrected shape of the foot and exercises to encourage walking on the outer borders of the feet with toes in-turned will prevent further deterioration if the patient co-operates.

Theoretically some of these feet in the stage of painful collapse might be rendered painless and capable of more prolonged stress if all the tarsal joints were fused (so-called triple arthrodesis of the tarsus). In fact the results of this operation, though occasionally done in the past, are not very encouraging, and the patient should be readjusted to some employment not demanding such heavy strains on the feet.

(4) *Traumatic Flat-foot.*—This is the flat-foot resulting from fractures which abolish the longitudinal arches. Fractures of the os calcis produce a very severe grade of flat-foot with a rigid subastragaloid joint. Mal-united Pott's fractures cause the appearance of flat-foot if the foot is everted.

(5) *Spastic Flat-foot* (Peroneal Spasm).—This is not an uncommon cause of some of the most severe degrees of flat-foot, and its early recognition is important if treatment is to be effective.

The condition is often unilateral, which tends to distinguish it from the other more common types of flat-foot. It occurs in children about the age of ten years and in another group it seems to present itself for the first time in early adult life (twenty to thirty years). The presenting symptom is pain in the foot coming on after standing or at the end of the day.

On examination the foot is grossly flat and strongly everted, and the essential feature in the diagnosis is the inability of the surgeon passively to invert the foot. Passive attempts to invert the foot will cause the tendon of peroneus brevis to stand out like a bow-string above and below the external malleolus.

The essential pathology of this condition is unknown. The consensus of opinion is that the primary site of the disorder lies in the interosseous ligaments between the astragalus and the os calcis and that spasm of the peronei is a protective mechanism which relaxes these ligaments in the everted position of the foot. Certainly in early cases the condition is merely

one of spasm, because under anæsthesia (or even local anæsthesia of the external popliteal nerve) the foot can easily be fully inverted. In later neglected stages of the condition the foot becomes rigidly fixed in eversion and bony changes take place in the shape of the tarsal bones rendering the deformity permanent.

Treatment.—In children manipulation of the feet under anæsthesia and fixation in a walking-plaster for as long as six months is a procedure well worth trial. It is true that some cases relapse, but on the whole the results are satisfactory.

In the adult, treatment is more difficult because the pathology of the condition is obscure. There are some who believe that the condition is nothing more than an hysterical phenomenon and that the bony changes which result are due to long-standing spasm. In the adult the only treatment of value is an operative correction of the deformity by 'triple arthrodesis' in which suitable wedges are cut out of the subastragaloid and midtarsal joints to restore the normal shape of the foot. The amount of disability, the patient's occupation, and the possibility of a functional basis will have to be explored before such a radical step is taken, requiring as it does some six months before the patient is fit for work.

PES CAVUS (*syn.* CLAW-FOOT)

Pes cavus is an increased concavity of the arch of the foot, so that the instep is unduly high (fig. 1688). It is sometimes associated with nervous diseases, e.g. poliomyelitis and Friedreich's ataxia.

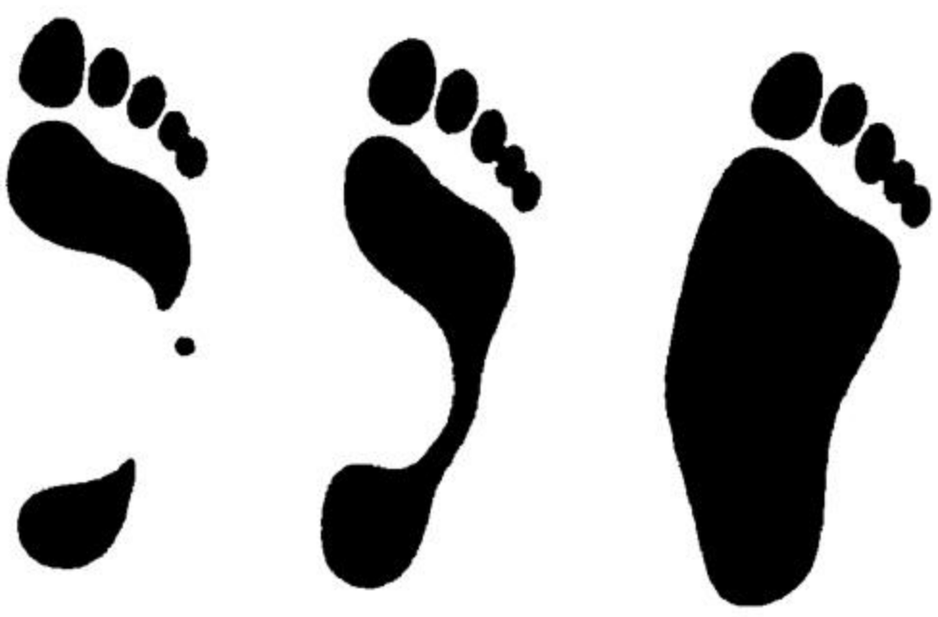


FIG. 1688.—(*a*) Pes cavus. (*b*) Normal. (*c*) Pes planus.

In most cases the condition occurs idiopathically, anda possible explanation is a transient mild poliomyelitis affecting the lumbrical and interosseous muscles of the foot. The clawing of the toes could be explained because it is the intrinsic musculature of the foot which extends the toes (i.e. flexes the metacarpophalangeal joints and extends the interphalangeal joints). Without this mechanism the pull of the long flexors of the toes would cause the toes to crumple up into the claw position.

Another mechanism in the deformity of pes cavus is the shortening of the plantar fascia, which can be felt as a tight band stretched across the arch.

The treatment of pes cavus should be commenced when the condition is first diagnosed in childhood. If treatment is started in adult life, it is likely to be disappointing, therefore at this age before considering the treatment of the anatomical deformity the surgeon must satisfy himself that the patient has sufficient disability to warrant a time-consuming surgical programme. Many cases of pes cavus are able to play games and walk long distances.

Such symptoms as are present in some of these cases can often be traced to painful callosities under the metatarsal heads due to the 'high loading' to which the small area of skin is subjected in this shape of foot. Carefully moulded insoles will do much to alleviate this source of discomfort.

In very advanced cases in elderly patients the clawed toes may be a source of great discomfort, due to callosities, and it may be impossible to wear ordinary shoes. In these cases with rigidly contracted toes, often associated with rheumatoid arthritis, very great relief can be obtained by amputation of all the toes through the metatarsophalangeal joints. When this is done, an ordinary shoe can be worn if it is fitted with a cork insert to fill the space left in the toe of the shoe.

In childhood the attempt to prevent the development of pes cavus is well worth major surgical intervention. The mildest cases are treated by subcutaneous fasciotomy of the plantar fascia accompanied by wrenching of the foot to lower the arch. A more radical method of abolishing the 'tie-bar' of the plantar fascia is the Steindler operation in which the plantar fascia and all muscle attachments are erased from the lower surface of the os calcis by open operation. Often the long extensor of the great toe can with advantage be transplanted to the neck of the first metatarsal to elevate this bone and so reduce the arch.

In cases where the toes all show considerable clawing, good results can be obtained by transplanting the tendons of the flexor sublimis digitorum on to the dorsal surface of the proximal phalanges of the toes so that this will flex the metacarpophalangeal joints.

TALIPES (*syn.* CLUB-FOOT)

The term talipes, or club-foot, is used to cover a group of foot deformities in which the sole of the foot is no longer plantigrade. In the commonest club-foot, which originally gave the condition its name, the foot is so twisted that the sole faces medially and the patient walks on what was originally the dorsal surface of the foot and its outer margin (equino-varus). Pes planus and pes cavus are not classed as club-foot because in these the sole of the foot is plantigrade, though the foot itself may be abnormal in shape.

To describe the deformity of any particular club-foot the term talipes is qualified with four adjectives describing the pure elements of the deformity, i.e. equinus, calcaneus, valgus, and varus. Equinus (i.e. like a horse) means that the patient walks on the tips of the toes because the tendo Achillis is too short. Calcaneus means that he walks on the heel, usually because the calf muscle is paralysed. Valgus indicates that the foot is everted and varus that it is inverted. It will be realised that only rarely are these deformities encountered in their pure form and usually combinations such as talipes equino-varus and talipes calcaneo-valgus are encountered (fig. 1404).

Club-foot can be divided into two groups: (1) congenital and (2) acquired.

Arthur Steindler, Contemporary. Professor of Orthopaedic Surgery, Iowa.

Congenital Club-foot.—Though club-foot in newly born children may be part of a widespread error of development, as shown by association with club-hands, congenital dislocation of the hips, spina bifida, or harelip, these account for only a minority of cases. The common club-foot usually occurs in what is otherwise a completely healthy baby.

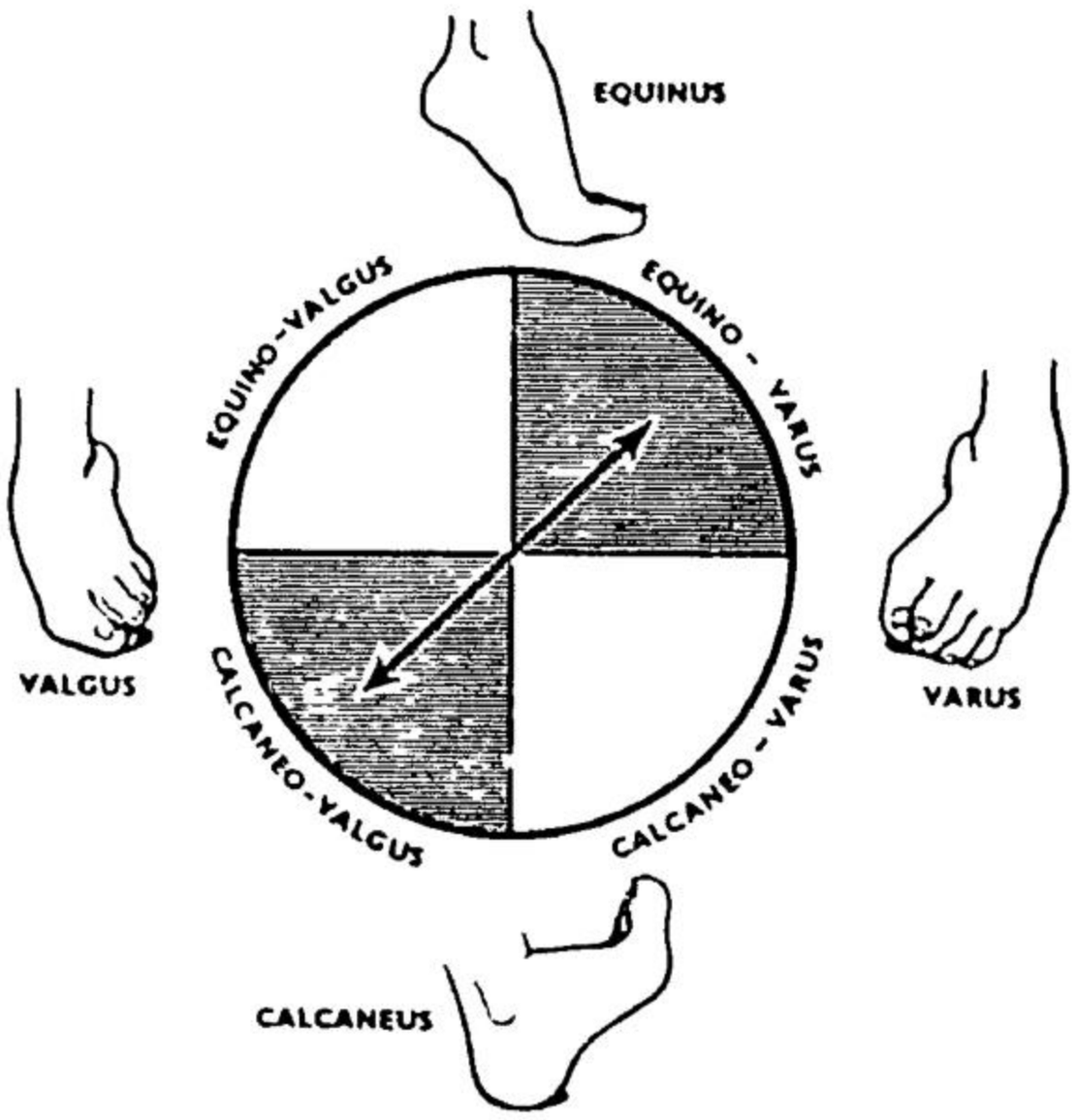


FIG. 1689.—Nomenclature of talipes. Shaded quadrants indicate the common varieties. To treat equino-varus over-correct into calcaneo-valgus and vice versa.

The exact ætiology of club-foot is still obscure. The old theory of malposition in utero is no longer tenable because simple mechanical malpositions are easily corrected and, once corrected, the limb will hold its correction and grow normally. In club-foot, however, there is a persistent tendency for the deformity to revert to its original condition, and the surgeon and nursing team are faced with a continuous fight against relapse until the child is three or four years old. It is probable that the fundamental abnormality lies in the muscles of the leg and that certain muscle groups are less extensible than others. As the tibia grows in length, it is suggested that all the muscle groups do not elongate at the normal rate and thus there is a tendency for the foot to be pulled into deformity. This theory would explain the constant tendency to relapse as growth continues.

In the common talipes equino-varus the muscular imbalance would favour the calf muscles, tibialis anterior, and tibialis posterior over the peronei. It is certainly a fact that even when excellent results have been achieved a child who has had a unilateral club-foot never has a calf which is as well-developed as the normal side.

Treatment.—Basically there is nothing more subtle in the treatment of club-foot than is used in making a tree or plant grow in a predetermined direction by holding it in the desired position for long enough. The sole difficulty is in the devising of apparatus to be effective and convenient. The foot is held in slight over-correction, i.e. an attempt is made to convert the foot into the opposite type of deformity—equino-varus into calcaneo-valgus and vice versa (fig. 1689). The treatment is as follows (though details vary greatly according to the surgeon):

(1) For first two or three weeks after birth. Moulding into the direction of over-correction by the parent or visiting nurse. This may be combined with strapping. This is usually sufficient for calcaneo-valgus but not for equino-varus.

(2) Denis Browne splints strapped on to both feet (connected by a metal bar) so that the feet are held everted for six months (fig. 1690).

(3) Plaster-of-Paris applied at regular intervals in attempt to hold the correction in more resistant cases or in cases received late.

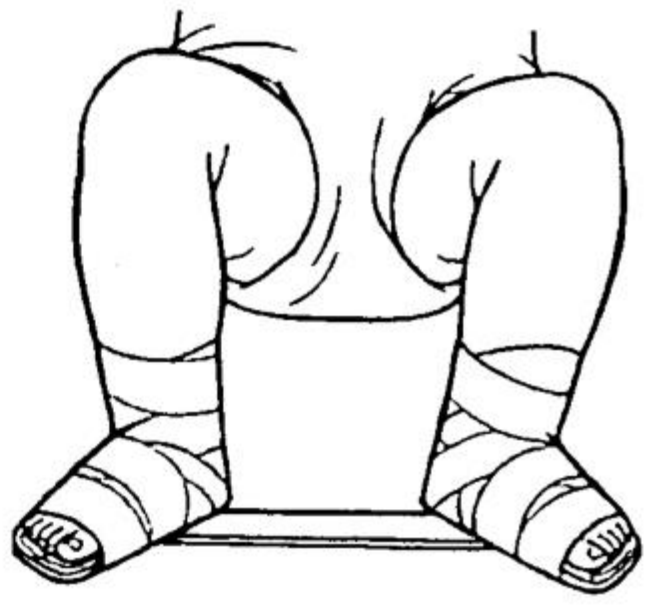
(4) After six months detachable Denis Browne splints attached to boots,

Denis Browne, Contemporary. Surgeon, Hospital for Sick Children, London.

and later used as a night splint till walking is well established.

During this process of correction, in the case of the common congenital talipes equino-varus (C.T.E.V.), it is customary to correct the varus element first and only later to start correction of the equinus deformity.

In cases of relapsing club-foot or incompletely corrected cases first received two or three years after birth, the 'Kite' method of correction has now received widespread approval. In this a plaster is applied to the limb and, when hard, it is wedged along a line chosen to correct the selected element of the deformity.



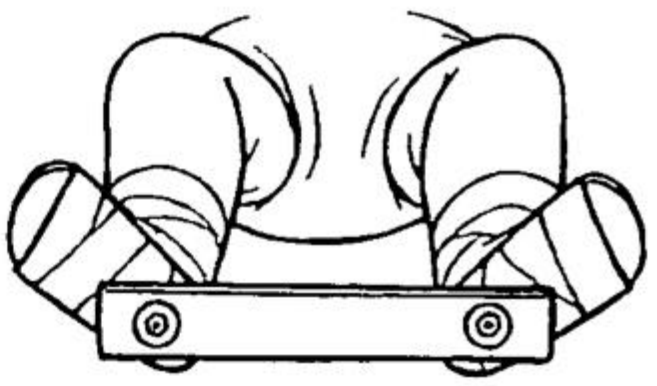


FIG. 1690.—Denis Browne splint.

In a residue of cases operative treatment is needed. The operations available are :

(1) Elongation of the tendo Achillis for the equinus deformity.

(2) Transposition of tibialis anterior to the outer side of the foot for persistent recurrence of varus.

(3) Division of all ligamentary structures round the tarsal joints on the inner side of the foot.

(4) Mid-tarsal-subastragaloid fusion of the tarsus with removal of wedges of bone to get the foot plantigrade.

Acquired Talipes.—By far the commonest cause of acquired talipes is poliomyelitis (paralytic talipes). In neglected paralysis of the muscles of the anterior compartment of the leg, the foot will develop a rigid and fixed equino-varus deformity. The patient may have difficulty in wearing normal shoes and may develop painful callosities on the outer aspect of the foot. On the other hand, many patients may have minimal disability but considerable deformity, and judgment is needed in deciding whether they will be improved by operative intervention. If the equinus deformity compensates for loss of length due to interference with growth, conversion to a plantigrade foot may be a poor exchange if the patient then has to wear a surgical boot with an ugly 'raise.'

Other acquired deformities result from a multitude of different causes, such as fixed equinus from decubitus in bed without a cage and foot support, burns to the calf, ischæmic contracture of the calf, spastic paraplegia in children, spastic hemiplegia in older people, etc.

The treatment of these deformities is by tenotomy of the tendo Achillis or by operations on the tarsus to remove appropriate wedges.

is a result of plantar fasciitis following foot strain, which is perhaps aggravated by some focus of infection. Persistent local tenderness suggests the diagnosis, and an X-ray shows the bony outgrowth projecting forward from the under-surface of the bone. A horseshoe-shaped sorbo insole should be

J. Hiram Kite, Contemporary. Atlanta, Georgia, U.S.A.

fitted in order to relieve pressure, but if disabling symptoms persist excision is occasionally performed through a lateral incision.

HALLUX VALGUS

is encouraged by wearing of boots or shoes with pointed toes. The deformity, which consists in abduction, or outward displacement, of the big toe tends to be progressive, because the direction of pull of the extensor longus hallucis tendon further increases the deformity by a 'bow-string' mechanism when once outward displacement has occurred (fig. 1691). The following conditions are often associated :

FIG. 1691.—Hallux valgus.

(1) Hammer-toe, owing to the misplaced big toe exerting pressure on the adjacent second toe.

(2) A bunion, which is an inflamed adventitious bursa, developing over the prominent head of the first metatarsal bone as a result of pressure. Suppuration sometimes follows, and the big toe joint may be secondarily affected.

(3) Osteoarthritis of the big toe joint, owing to pressure, malalignment of the bones, etc. Severe pain results, and X-rays frequently show osteophytic outgrowths.

Treatment.—The conservative treatment of hallux valgus is unsatisfactory. As the patient is almost invariably a female, it is usually too much to expect that she will accept the scientific advice of wearing shoes with low heels, wide fronts, and a straight inner border. A small rubber pad can be worn in the cleft between the first and second toes, but this also demands the use of a wide-fronted shoe.

In general, a young adult with hallux valgus will eventually require operative treatment no matter what conservative techniques are tried, but it is important not to operate merely for cosmetic purposes if the foot is reasonably comfortable. The most satisfied patients after hallux valgus operations are those in which very marked discomfort and gross deformity are present.

Operation.—Local removal of the bunion together with the underlying exostosis, without interference with metatarsophalangeal joint, is not a very satisfactory operation because symptoms almost always recur, and a more radical operation has later to be carried out. There are perhaps exceptional cases in young people where the operation can be tried if the valgus deformity is only slight.

The standard operation for hallux valgus is the making of a pseudarthrosis by excision either of the base of the proximal phalanx (Keller) or the head of the metatarsal (Mayo). The Keller procedure is advisable in the younger patients, because the strength of the foot is not impaired,

but the Mayo operation has its place in older patients with very gross deformity.

After the operation, at least three months will elapse before the foot will tolerate an ordinary shoe, and the patient may not feel the full benefit of the operation for as long as six months.

HALLUX RIGIDUS

occurs as two distinct varieties.

(1) The adolescent type is due to synovitis of the metatarsophalangeal joint following injury, and is associated with muscular spasm. There are no radiological changes. It is relieved by wearing a metatarsal bar $\frac{3}{4}$ inch (2 cm.) wide and $\frac{1}{2}$ inch (1·25 cm.) thick (fig. 1692).

FIG. 1692.—Metatarsal bar.

(2) The adult type is nothing more than mon-articular osteo-arthritis, sometimes precipitated by injury. The limitation of movement is due to interlocking of osteophytes, and also to flattening of the metatarsal head (fig. 1693). Treatment is by operation, the Keller procedure being the one most widely employed. In this operation the painful rigid toe is replaced by a pseud-arthrosis at the metatarsophalangeal joint.

FIG. 1693.—Hallux rigidus.

HAMMER-TOE

consists in hyperextension of the metatarsophalangeal joint and flexion of the proximal interphalangeal joint (fig. 1694). Callosities form over the bony prominences, and in long-standing cases adventitious bursæ develop. Fascia and ligaments become secondarily contracted.

Hammer-toes sometimes develop from overcrowding, either by small or pointed shoes, or as a result of hallux valgus. Pes cavus, as an associated condition, has already been mentioned.

FIG. 1694.—Hammer-toe with callosity.

Treatment consists in correcting any predisposing cause and wearing a corrective splint.
If the deformity is established, operative intervention is required. The 'spike' operation (Higgs) ensures bony ankylosis, and consists of drilling the base of the middle phalanx and impaling it on the shaft of the proximal phalanx after shaping the condyles into a spike.

INFANTILE PARALYSIS (POLIOMYELITIS)

This condition occurs most commonly in the late summer months, and there is still a great deal which is not understood about the method of spread

S. L. Higgs, Contemporary. Orthopædic Surgeon, St. Bartholomew's Hospital, London.

of epidemics. Anterior poliomyelitis is a notifiable disease, and may be transmitted by nasal secretion or fæcal contamination of 'carriers.' It is now certain that the route of ingress is through the alimentary canal. The responsible organism is ultra-microscopic, passes through a porcelain filter, and can be transmitted to apes. The virus causes a meningeal reaction, the cerebrospinal fluid being under pressure and containing an excess of cells and albumin. The anterior horn cells in the cord are attacked and the corresponding muscles are paralysed. There is good evidence that undue muscular exertion during incubation can direct the paralysis to the exhausted muscle groups and also render more profound the resulting paralysis of these groups. Nevertheless rest is to be encouraged in the early stage of any febrile condition where the possibility of poliomyelitis is considered.

The disease is divided into three stages :

(1) *Stage of Invasion.*—The onset is usually sudden, and is characterised by a rise of temperature, pain in the head and spine, and usually more or less widespread cutaneous hyperæsthesia. Owing to meningeal irritation stiffness of the neck or back is constant and early—the 'spine sign.' Paralysis is evident after two or three days, and unless an epidemic is rife the true nature of the condition is frequently unsuspected until the paralysis is discovered. Lumbar puncture shows a preliminary rise in polymorphonuclear cells, followed by an increase in lymphocytes. In a severe paralysis the proximal muscles, i.e. shoulder and arm groups, hip and thigh, are usually more completely palsied than the distal groups controlling hand and foot. Spinal and abdominal muscles are frequently affected, the former leading to scoliosis. Paralysis is very variable in extent and distribution ; in severe cases the bulk of the skeletal muscles are initially affected, while in others merely one or two isolated muscle groups suffer.

(2) *Stage of Recovery.*—If a muscle group remains *completely* paralysed for four to six months, then paralysis is permanent, and further efforts to improve muscular tone are a waste of time. If there is a little voluntary movement after the acute phase has subsided, then continuous improvement in strength is likely for two or three years.

It is a matter of some consolation that the extent of the paralysis at the onset is not an indication of the final result ; some cases starting with almost total paralysis can be left with very localised and tolerable permanent disabilities, but in these cases the main recovery soon shows itself—i.e. in a few weeks.

(3) *Stationary Stage.*—This is approximately after the lapse of two years, but further slight improvement is possible. Shortening of the limb may result from inequality of growth.

Treatment.—(*a*) *Stage of Paralysis.*—Symptomatic treatment is all that can be attempted. The affected limbs should be splinted in the positions which place the joints in neutral position and so avoid undue stretching of paralysed muscle groups. Local treatment, such as massage or electricity, is harmful, in that the affected muscles require rest. But joints should be moved at regular intervals to prevent stiffness. Lumbar puncture is indi-

cated for meningeal irritation, and withdrawal of fluid under pressure gives relief.

No serum or antibiotic has yet been found with a proven effect on the virus. The use of serum from convalescent patients is no longer favoured.

(*b*) *Stage of Recovery*.—During this period three principles of treatment must be observed :

(i) Relaxation of paralysed muscles. If paralysed muscles are allowed to become permanently stretched, as by the pull of healthy antagonistic muscles or by the influence of gravity, any subsequent recovery of tone is neutralised by the ' slack ' which has been allowed to develop. Therefore splints, surgical boots, and other forms of apparatus must be worn to prevent over-stretching of affected muscles (fig. 1695). A plaster-of-Paris shell is required for spinal cases, to be succeeded by a jacket.

(ii) Maintenance of nutrition. Massage, electrical baths, radiant heat are all useful in stimulating the circulation and improving nutrition. Weak muscles must not be over-stimulated, and the limb is maintained in such a position as to relax affected muscles during treatment.

(iii) Exercise. As recovery occurs, active muscular contractions are encouraged, provided that the effort is well within the powers of the weakened muscle. Exercise beyond the point of fatigue does no good and may be harmful.

FIG. 1695.—Surgical boot—lateral iron to the knee, a valgus strap, and a toe-raising spring to correct talipes equino-valgus.

(*c*) *Stationary Stage*.—After a period of two years the value of the affected muscles can be assessed, although it should be remembered that further slight improvement is still possible. The principle of treatment is now to restore muscular balance, either by means of surgical apparatus or by operative procedures, with the advantage that appliances can then be discarded or simplified.

The following procedures may therefore be adopted :

(i) Tenotomy, which has little scope in the treatment of infantile paralysis, as muscles are already weakened and the contraction of stronger muscles should have been prevented.

(ii) Tendon transplantation, by which means the action of a stronger muscle is transferred to a weaker group, or the direction of muscular pull is altered so as to overcome deformity.

The following principles should be considered in connection with tendon transplantation :

(1) If possible the tendon is selected from muscles with the same innervation as those affected, so that re-education is simplified.

(2) The joint must be fully mobile, i.e. the transplant must not be expected to work against contractures which have not been abolished prior to the transplant.

(3) The path of the transplanted tendon should be as direct as possible.

(4) The limb must be relaxed before the tendon is fixed.

(iii) Tendon fixation (tenodesis) has been used in order to assist in the fixation of a flail joint. Thus in the case of the ankle joint the selected tendon

is fixed to the bone on either side of the joint in order to secure stabilisation. Results are disappointing, as paralysed tendons readily stretch when subjected to strain.

(iv) Arthrodesis is a useful procedure, in that it obviates the continued use of surgical apparatus devised to stabilise a flail joint. The operation consists in removal of the articular cartilage and securing bony union between the bones which comprise the joint. Arthrodesis is often combined with tendon transplantation.

In paralysis of the foot it is necessary to stabilise the tarsus so that a firm plantigrade foot is presented to the floor at each step and without any tendency to roll over into inversion as tends to happen if it strikes the ground while slightly inverted. The Naughton Dunn operation is widely used for this purpose.

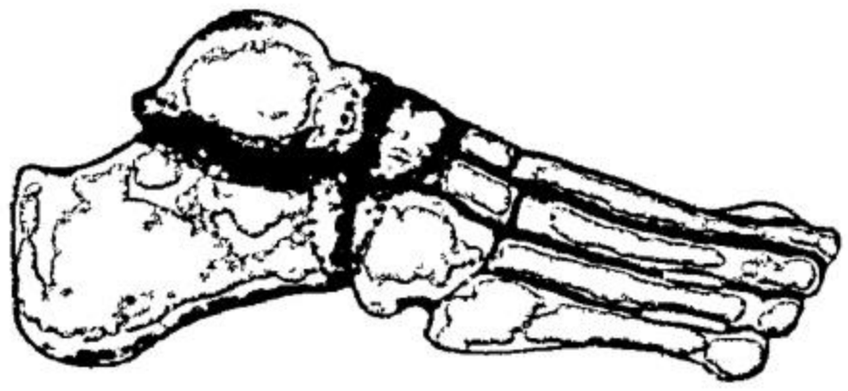


FIG. 1696.—The shaded areas indicate the bone to be removed in Naughton Dunn's arthrodesis.

Naughton Dunn's arthrodesis consists in excision of the subastragaloid and mid-tarsal joints. This includes, on the inner side, the scaphoid and adjacent parts of the astragalus and cuneiform bones, and on the outer side adjacent parts of the os calcis and cuboid (fig. 1696). The foot is displaced backwards, and becomes stabilised by ankylosis of the mid-tarsal and subastragaloid joints, but ankle movements are preserved.

(v) Bone lengthening is valuable in cases of shortening. The femur or tibia is divided obliquely and continuous skeletal traction will augment the length of the limb up to 2 inches (5 cm.).

Some surgeons prefer to excise a part of the femur in order to shorten the normal leg. Alternatively, in a growing child staples are driven into the bone to bridge the epiphyseal line and so prevent further growth.

Naughton Dunn. 1884–1939. Surgeon, Royal Cripples' Hospital, Birmingham.

CHAPTER LII

RADIOTHERAPY

ANTHONY GREEN

THE use of radiation in the treatment of malignant disease has now become so widespread, and its association with surgery so important, that it is essential for the student to have some knowledge of the principles of its use.

The following account must necessarily be condensed and dogmatic. It will be noticed that more attention is directed to the reactions and complications, though the latter are rare. This is because they may be seen outside a Radiotherapy Department and such entities are sometimes important in differential diagnosis. The technical aspects of radiotherapy are almost completely excluded.

ATOMS

Atoms may be regarded as minute solar systems, with a central nucleus consisting of protons and neutrons around which revolve planetary electrons. The protons have a positive charge and their number is exactly balanced by the number of negative electrons. The chemical behaviour of an atom is governed by the number of these outer electrons, thereby determining to which element it belongs. On the other hand, it is possible to vary the number of neutrons present in the atoms of a given element, these being termed ' isotopes ' of the element. These may or may not be stable structures.

RADIO-ACTIVITY

(*a*) Types of Radiation :

If the nucleus of an atom is unstable it will ultimately breakdown, or ' disintegrate,' ejecting part of the nuclear contents. Such atoms constitute radio-active isotopes. Three types of radiation are involved.

1. *Alpha* (α).—This particle consists of 2 protons and 2 neutrons (i.e. the nucleus of a helium atom). It is of little relevance as it is absorbed by a sheet of paper.

2. *Beta* (β).—An electron. If the ratio of neutrons to protons in the nucleus is too high, a neutron can turn into a proton and an electron, the latter being ejected at high velocity. The penetration depends on the energy given to this electron, termed a beta ray, and generally amounts to a few millimeters in tissue.

3. *Gamma* (γ).—This radiation is an electromagnetic vibration and generally carries off the excess energy available following the nuclear disintegration. Apart from their mode of origin, a gamma ray is identical to an X-ray. The penetration of this radiation depends on the energy carried, and may be very great. It ejects electrons from atoms sparsely in interacting with matter, thus producing long and low density ionisation tracks. The biological effects are low per unit length of track. The alpha and beta rays, however, have a short ' fiery ' path.

(*b*) Units :

The unit of radio-activity is the ' curie,' and is the quantity of a radio-active isotope in which $3{\cdot}7 \times 10^{10}$ of its atoms disintegrate every second. This curious number arises from a historical association with radium, but it now applies to any radio-active substance. It is too large a unit for most clinical purposes, ' millicuries ' (mc.) and ' microcuries ' (μc.) being more useful, these being a thousandth and a millionth of a curie respectively.

The definition does not specify the type of radiation involved, so that the dose delivered (see below) from a curie of a particular substance will depend on whether α, β, or γ rays are emitted and on their respective energies.

(*c*) **Natural Radio-activity :**

Some of the largest atoms occurring in nature prove to be too complicated for permanent stability. For example, a radium preparation contains naturally occurring radio-active substances. Such a preparation emits all three types of radiation. The beta rays penetrate 3–5 mm. of tissue, the mean energy being about 1·2 mev. (millions of electron volts). Their application in the treatment of rodent ulcers has been largely replaced by the use of low-voltage X-rays. They are adequately screened off by 0·5 mm. platinum for radium needles, though higher filters are used for larger radium tubes. The gamma rays emitted have a penetration similar to the X-rays from equipment operating at 2 to 3 mev. (see X-ray Therapy).

Another example is radon, which is a radio-active gas. This can be inserted into capillary tubing, which when cut into short lengths termed ' seeds ' can be inserted into tumours.

(*d*) **Artificial Radio-activity :**

It is now possible to make almost any substance radio-active by radiating it in either a nuclear reactor or a cyclotron. The bombardment suffered by the atoms of material irradiated may alter some of their nuclei, render them unstable, and hence radio-active. Examples of those in widespread use are ^{32}phosphorus, ^{198}gold, and ^{131}iodine, where the number given denotes the number of protons and neutrons in the nucleus of the element (the ' mass number ').

The concept of ' half-life ' becomes significant here. Radium has a half-life of about 1,600 years. This means that after that time has elapsed, it will have decayed to half its strength and in 3,200 years it will be only a quarter of its present value. In contrast to the relative constancy of radium, the half-lives of the above are shorter, namely fourteen days for ^{32}P, eight days for ^{131}I and 2·7 days for ^{198}Au.

The depth dose of the radiation emitted from particular isotopes depends on whether they are beta- or gamma-ray emitters, or both, and the energies entailed. The strictly local biological effect produced is much greater from the beta than from the gamma radiation as their absorption characteristics are different.

X-RAY THERAPY

(*a*) **Production of Radiation :**

Like the gamma rays which are emitted from the nuclei of atoms, X-rays are also electromagnetic vibrations. However, they originate from the field outside the nucleus of the atom, resulting from the loss of energy of high-speed electrons. They can be produced in an evacuated tube by accelerating a beam of electrons from a hot filament by applying a difference of potential between their source and a suitable target. X-rays are produced at the site of impact of electrons on the target, the interactions resulting in a whole range of energies with a mean value approximately two-thirds that of the applied voltage. Lower energy radiation is removed by a filter of appropriate sheet metals. This makes the beam ' harder ' or more penetrating. By the use of shielding and diaphragms, the X-rays can be applied in the form of a beam as required. Reflection and refraction are impractical with X-rays.

(*b*) **Depth Dosage :**

The dose delivered from a beam of X-rays penetrating tissue will diminish with increasing depth because of absorption. The dose received at any specified depth from the surface of a patient is generally expressed as a percentage of the dose maximum received at (or near) the surface. This percentage is influenced by the potential difference applied across the X-ray tube, the beam filtration (hardness of the beam), the target to skin distance (inverse square law effect), and the field size employed. For example, increasing the voltage from 250 kV. to 2 mev. for an average field size at typical treatment distance in both cases increases the 50 per cent. depth dose level from 8·5 to 12 cm. in depth. Scattered irradiation in the body contributes to the depth dose.

With mega-voltage[1] irradiation the scatter is predominantly forwards, yielding

[1] Millions of electron volts (supervoltage).

maximum dosage below the skin surface (build-up factor). This reduces the skin reaction but increases the subcutaneous biological effects.

In treating a deep-seated tumour, beams of irradiation are aimed at it through two or more separate ports of entry crossing at the depth. This ' cross-fire ' is used to concentrate the radiation at the site of the disease and minimises normal tissue damage.

(*c*) **Units of Dosage :**

Radiation interacts with matter, ejecting electrons from its atoms. In doing so the biological effects are initiated. This process of ionisation provides a unit of dosage termed the roentgen (r.), which is based on the quantity of ions produced in 1 G. of air. Small air ionisation chambers are used to measure this in practice, providing an index of the radiation energy available at the place of interest. The ' rad ' is the unit of absorbed energy. This is equal to 100 ergs per G. and is related to the biological effects.

(*d*) **Integral Dose :**

The total amount of radiation energy absorbed by the patient's body is known as the 'Integral Dose'. This is related to the general or constitutional effects of irradiation.

THE PRINCIPLES OF RADIO-BIOLOGY

Most tumours consist of a mixed-cell population—some differentiated and some undifferentiated, in varying proportions. Undifferentiated tumours usually have a high incidence of active mitosis. They are radio-sensitive, but not necessarily radio-curable.

There is a continual struggle for each cell to survive in the constantly changing active medium of the body.

When radiation reaches water the dissolved oxygen increases the chemically highly active radicles ($H.OH.HO_2$) which are produced. These cause radiation damage because they may :

1. Inactivate enzymes.
2. Interfere with the molecular structure of D.N.A. (desoxy-ribo-nucleic acid) which is required for nucleo-protein.
3. Alter the permeability of membranes.

The cell may recover or die outright. It may recover with one or more recessive mutations in its genetic structure. A lethal mutation will cause death later.

Most biological effects of radiation are ' recoverable ' and depend both on the amount of dose at any one time and the dose rate. The previous recessive damage, however, is independent of both and additive throughout life. (See personal protection from ionising radiations, p. 1351.) Immediate death is commoner with radio-sensitive tumours or with a high dosage. Delayed cell death occurs with less radio-sensitive tumours or a lower dosage. The effects produced are greater with a high dose rate.

The cell is most radio-sensitive before and early in mitosis, consequently divided doses of radiation are likely to prove more effective than the administration of a single dose.

On the other hand, malignant cells do not divide so readily in the presence of a ' shower of missiles ' from irradiation. Consequently, arrest of mitosis is commonly seen and the cell population may ' grow up.' An adult population with giant and bizarre forms may be produced and which are incapable of division. During a course of irradiation decline in the proportion of primitive and mitotic cells, and the increase in the adult and amitotic cells, is favourable. This is used as a prognostic sign in radiotherapy for carcinoma of the cervix. Serial biopsies are possible here and if there should be an unfavourable response, radiation may be abandoned in favour of operation.

The microscope under ordinary magnifications shows :

1. Arrest of mitosis.
2. Chromosome damage—clumping.
3. Swelling first of nucleus and then the cell.
4. Rupture of nucleus and then the cell.

Destruction of the tumour is completed by the action of the tumour bed. If it is very vascular, its effect is favourable (papillary carcinoma), and, conversely, in the avascular tumour bed (deeply fissured hard ulcer) the response is not good.

In very small doses radiation produces a favourable response in infections by liberating leukoproteases, other enzymes and antibodies from the destroyed radio-sensitive white cells. If larger doses are used, the infection is made worse. Infection interferes with the biological response to radiation, which aids the destruction of tumour cells. Hence infection is unfavourable to irradiation.

High doses of irradiation produce endothelial damage with obliteration of the blood vessels and do some tumour necrosis. Damage to the tumour bed at an early stage may be unfavourable. The presence of early œdema is a bad prognostic sign.

Cell damage and breakdown, together with the liberation of 'histamine-like' substances, encourage vasodilatation. This increased vascularity, together with leucotoxins from breakdown products, encourage local phagocytosis. The phagocytes help by devouring the damaged tumour cells. This is a most important effect of irradiation in all those tumours which are not highly radio-sensitive, and which constitute the majority. A high oxygen tension is favourable to the radiation response.

CLINICAL EFFECTS OF IRRADIATION

The desired effect is the destruction of the tumour with no undue reaction, and leaving relatively normal tissues.

General Effects :

These are related to the volume of tissue irradiated and the dose given (integral dose).

Toxic symptoms such as lassitude, anorexia, nausea and vomiting are now rarely troublesome with well-planned treatment and if persistent, usually have a pathological basis. Some adaptation to the effects of radiation usually occurs at the end of a week. The upset is greatest in upper abdominal irradiation, least in the limbs and is probably due to the liberation of the toxic products from cell damage. The platelet count provides an excellent guide. A practical index to the severity of the general effects of radiation is the reduction in the white cell count to 3,000 total, and 150 lymphocytes per c.mm. It is reasonable with great caution, if the patient feels well and the general condition is good, to reduce the total white cells to 2,000 if it is vital to complete the treatment. A marked fall in the platelets and white cells, especially the lymphocytes, is an indication for caution with radiation.

Immediate and active attention to general medical measures are important. The psychological aspects should be dealt with, pain relieved, and sepsis N.P. vigorously controlled. A high protein and a high calorie diet should be instituted.

The following vitamins are given : A. 25,000 international units per day
Tab. B. Co. b.d.
C. 200 mg. b.d.
Pyridoxine (B.6) 50 mg. t.d.s.

The latter is valuable in preventing radiation sickness.

In apprehensive patients the use of a tranquilliser [1] and an anti-histamine such as avomine may help. Cyclizine hydrochloride [2] (marzine) is useful. In cases of vomiting, intramuscular soluble phenobarbitone grains 3 (180 mg.) may be given. Prednisolone may possibly help to limit the effects of blood changes. The oxygen-carrying power of the blood is vital to the radiation response, so the circulation should be adequate, and hæmoglobin raised to 100 per cent. by transfusion.

Local Effects:

These are due to radiation damage of normal body cells. The latent interval is two weeks or more, but depends on :

1. The size and fractionation of the dose.
2. The volume of tissue treated.
3. Sensitivity of the part.
4. Individual sensitivity of the patient.

Skin.—Erythema or moist desquamation may occur.

The affected part should be rested, e.g. the groin, and kept as dry as possible. The application of surgical spirit and bland powders are useful. Irritation by friction, heat, sun and adhesive plaster are to be avoided.

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[1] Perphenazine is a powerful antiemetic.

[2] In calculating the amount of blood required, one pint gives a 7 per cent. increase of hæmoglobin, whereas packed cells give a 14 per cent. increase. The aim is 110 per cent. in males and 100 per cent. in females.

Mucosa.—Increased redness and fibrinous exudates sometimes result from radiotherapy. In the case of the upper part of the alimentary canal a soft bland diet is advisable, e.g. egg custard.

Scalp.—Moderate dosage causes temporary epilation, but heavy dosage may result in permanent epilation.

Lens of the Eye.—This is screened [1] in order to avoid cataract if the orbit is not involved. On the other hand, if the orbit is involved, and the eye is to be irradiated to full dosage, a cataract does not always occur. Such a cataract is amenable to the usual treatment. Low-penetrating radiation can be applied to the lids, e.g. beryllium window X-ray therapy with penetration of only 2 mm. (see p. 1349). The very superficial irradiation from the beta rays of radioactive strontium is useful for the treatment of malignant disease of the front of the globe, such as a melanoma.

Salivary Glands.—Dryness may be temporary, but sometimes lasts months or may be permanent.

Gonads.—Are radio-sensitive and of supreme importance in the young owing to the genetic effects produced. In general, the criterion is none or all (complete sterilisation). A relatively large dose is required to produce permanent sterility.

Growing Epiphysis.—Should be screened to prevent possible inhibition of growth.

Lungs.—Avoided as much as possible in order to minimise radiation pneumonitis.

Kidneys.—Excessive dose may result in radiation nephritis, uræmia and death.

Symptomatic Treatment.—Frequent normal saline mouth-washes for cleansing, and aspirin gargles for the relief of reaction in the mouth. Useful remedies are analgesic lozenges or insufflation in the throat, linctus codein for cough, and mist. kaolin et opii for diarrhœa due to small-gut irritation. In severe gut infections sulphasuccidine or an appropriate antibiotic is required. For radiation proctitis, 2 ounces (60 ml.) of arachis oil per rectum daily is useful. A soothing bacteriostatic ointment, spread generously on lint is used for moist desquamation on the skin. The occasional failure of a reaction to resolve means a radio-necrosis, which usually heals. If it fails to do so, the treatment is described under 'late complications.'

Cleaning of the Part :

Irrigation of the eye or nose. A drink of water is given after each feed when treating the mouth, throat and œsophagus, and copious fluids should be taken until 6 p.m. for bladder neoplasms.

Specific Treatment :

The cortisone group is valuable in the relief of pneumonitis and the prevention of fibrosis. It should be remembered that it is a dangerous drug requiring caution and care. It may 'light up' a mild infection or latent diabetes. Hence a urine previously clear of sugar must be retested. It should not be used if a peptic ulcer is suspected. It may be prescribed as buffered prednisolone mg. x q.i.d. for one to two weeks and 'tailed off.' An anti-cholinergic drug, e.g. probanthine 1 tab. t.d.s. is given, and an appropriate antibiotic may be used. Hydrocortisone (1 per cent.) combined with neomycin will relieve local reactions in the early stages, but the cost of this ointment is considerable. It is valuable in small areas of threatened radio-necrosis.

Immediate Complications :

1. Exacerbation of a 'latent' infection, e.g.
   (*a*) A deeply ulcerated carcinoma of the pharynx.
   (*b*) Acute diverticulitis from an unsuspected lesion either in the colon or the bladder.
   (*c*) Old tuberculosis.
2. The rapid autolysis causing a rise of temperature, or necrosis causing sudden swelling and pain in a large tumour, e.g. large cervical lymph nodes.
3. Rapid disappearance of growth producing a perforation in the viscus, e.g. the œsophagus (rare).
4. Reaction in the mucosa, e.g. small gut, causing superficial necrosis resulting in severe diarrhœa.
5. Very rarely an obliterating reaction in the blood vessels causing thrombosis and infarction. This may lead to severe gut ulceration, and perforation or a stricture may follow.

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[1] Screening may be done by sheet lead in front of the orbit or for 'low'-penetration radiation by using a lead 'contact lens' under the lids.

Late Complications :

Uncommon serious complications may be compared with those following a surgical operation, except that they usually occur some time after the completion of treatment. They are, in the main, much less common than, for instance, fatalities due to pulmonary embolism, which may follow an operation.

(*A*) **Vascular Effects** (and Direct Effects) :
These are, in the main, secondary to obliterating endarteritis.
1. *Skin.*—(*a*) Atrophic paper-like superficial scarring.
(*b*) Telangiectases.
(*c*) Mottled pigmentation.
(*d*) Epilation and dryness.
(*e*) Radiation dermatitis is a further stage of the above effects (see carcinogenic effects, p. 1347).
2. *Subcutaneous Effects.*—(*a*) Diffuse tissue fibrosis.
(*b*) Chronic œdema.

Fibrosis and chronic œdema are important in mega-voltage irradiation on account of the ' build-up factor,' i.e. higher subcutaneous dose than skin dose.

Groups 1 and 2 above are normal and common.

(*c*) *Tender subcutaneous nodules* may follow post-operative irradiation in the breast region. On biopsy these are tense ' rice grains ' of fat.

(*d*) *Necrosis.*—This may be the rare penalty for efficient treatment to full dosage. This risk has to be balanced where radiotherapy offers the best line of treatment, and where the disability is no greater than with radical surgery. Complete skin destruction may occur later following tissue trauma, strong sun, heat, chemicals, friction or local injury. Deep tissue necrosis may follow.

Treatment consists of rest of the part. Hydrocortisone and neomycin ointment is useful for small areas. Gentian violet forms a protective scab over a superficial skin ulcer.

In the case of sepsis, this should be dealt with first by eusol or an antibiotic after culture. Ragged tissue can be cleaned by varidase. Lotio rubra is useful to stimulate healing. Persistent failure to heal—radon ointment should be tried first, followed by excision and plastic surgery.

3. *Bones.*—(*a*) Necrosis—ribs or jaw. This is mainly a relic of cases radiated in the old days.
(*b*) Cartilage necrosis in ribs or larynx are becoming less common.
(*c*) Fractures, e.g. ribs, may occur after breast radiation. These are usually painless and often undiagnosed. Fractured neck of femur and other bones have been recorded, but bone complications are rare with skilled application.
(*d*) Epiphyses—early fusion with shortening of the limb—very rare.
4. *Central Nervous System.*—Variable effects due to gliosis. Transverse 'myelitis'—resulting in paraplegia—is usually due to excessive treatment.
5. *Alimentary Tract.*—Intense irradiation of the small gut may produce late necrosis followed by stricture or perforation and peritonitis.
6. *Peritoneum.*—The organisation of the fibrinous exudate between loops of bowel causes adhesions. This may cause partial or complete intestinal obstruction, often requiring a difficult operation because the obstruction is multiple.
7. *Lungs.*—Fibrosis may follow on pneumonitis if untreated.
8. *Bladder.*—Rarely, fibrosis and contraction or ulceration and bleeding follow high dose. This has been seen, in the main, with the use of fluid isotopes.

(*B*) **Specially Sensitive Tissue :**
1. *The Eye—Cataract.*—There is considerable variation in the sensitivity of the individual in irradiation (see p. 1345).
2. *The Fœtus.*—Irradiation during pregnancy is dangerous, especially so in the early stages when a series of abnormalities have followed but, fortunately, a miscarriage often occurs.
3. *The Gonads.*—The genetic effects of irradiation have been so widely stressed recently on account of the atomic bomb, as to require no additional comments. The actual clinical evidence is largely deficient at the moment, but may occur generations

hence. It would seem possible that the complex human mechanism may be able to protect itself in some measure against permanent detectable undesirable effects. Nevertheless, it is obvious how vital this is to the future of the population. Consequently, every attempt is being made to minimise the amount of irradiation to the gonads (see p. 1345).

(*C*) **Carcinogenic Effects.**—These are very alarming, but, fortunately, they are rare.

1. *Skin.*—The commonest type: rodent ulcers and squamous-celled carcinomas may follow the danger sign—hyperkeratosis—on a skin damaged as described above. Most cases are seen following X-ray epilation and continued irradiation of the neck, e.g. for thyrotoxicosis years ago.

2. *Soft Tissue Sarcoma and Bone Sarcomata.*—Sarcoma may arise in the mesenchymal tissue following a heavy course of irradiation in the past. Ingestion of radium and radioactive strontium which are deposited in the bones may cause sarcoma.

3. *Thyroid Carcinoma.*—Thyroid carcinoma may follow irradiation of the thymus gland in infancy, or frequently repeated irradiation of tuberculous lymph nodes sufficient to produce skin damage in adolescence.

4. *Blood.*—Myelogenous leukæmia follows in a very small proportion from irradiation of ankylosing spondylitis. This is not generally considered to be a strong contra-indication, but it calls for accuracy in diagnosing the bone condition to exclude conditions not requiring radiotherapy. Leukæmia may be an occupational disease, e.g. in radiologists.

Following X-ray pelvimetry—it has been suggested that leukæmia in the offspring may follow this procedure, but this is still under investigation.

METHODS OF ADMINISTRATION OF RADIOTHERAPY

There is a long list of methods of which only some examples are given for the sake of simplicity. It is strongly emphasised that the rôle of isotopes by *internal* administration has now, in the main, proved very disappointing in the *treatment* of malignant disease. Nevertheless, this sequence of methods of treatment has been followed because it seems more logical. The student should realise, however, that external radiation is the radiotherapy of choice for the vast majority of cases of malignancy.

(*A*) **Intracellular :**

^{32}**P** (a beta emitter).

Useful penetration is only about 5 mm. in depth.

(i) *Diagnostic.*—Malignant tumours have a high phosphorus nuclear metabolism. After injection of a tracer dose intravenously, a beta-ray counting probe can be used to define the limits of a cerebral tumour at craniotomy.

(ii) *Therapeutic.*—The relative tumour to normal tissue concentrations are rarely sufficiently favourable to permit effective treatment.

^{131}**I** (a beta and gamma emitter).

(i) *Diagnostic.*—A tracer dose is taken by mouth. This is concentrated in the thyroid. The radio-active iodine is used as a test for thyroid function because the amount of radio-activity in the thyroid gland can be measured by counting devices which respond to the radiation emitted from the gland through the skin (e.g. geiger counter). Over-active glands are avid for iodine, while under-active glands take little. The balance of the iodine is excreted in the urine via the blood-stream and a fractional counting method, based on fractions excreted, is of assistance in determining thyroid activity. Over-active thyroids hold it in the early stages and excrete it late ; with under-active glands excretion from the blood ' pool ' is early. This test is more accurate than the basal metabolic rate.

By a special counting method a fairly accurate contour can be made of the thyroid or of any accessory parts, e.g. substernal thyroid.

The nodules in the thyroid gland can be counted to differentiate between ' cold ' nodules, i.e. those which do not accept iodine and are therefore suspected cancer sites (20 per cent.) or those that are ' hot ' and take up a lot of iodine and are therefore

not so suspect. A large low contour area showing a deficiency of uptake may represent a 'space-occupying' lesion. This may prove to be a carcinoma of thyroid, especially if associated with a growing lump. It is vital to realise that this test is vitiated by the previous administration of antithyroid drugs, or by iodine-containing substances for a period of up to one month, e.g. cholecystography. Seafoods, especially kippers, have a significant iodine content.

(ii) *Therapeutic.*—For hyperthyroidism over the age of forty[1], recurrent post-operative cases, and those cancers of the thyroid gland and secondaries which accept iodine (less than 10 per cent.).

Should there be an uptake in a thyroid carcinoma, complete 'surgical ablation' of the thyroid is followed by radio-active iodine treatment to any residual areas of uptake. This is repeated after a period of myxœdema, because then the high T.S.H. output from the pituitary stimulates development of latent areas which may be destroyed by taking up radio-active iodine. At the completion of a series of highly technical treatments, thyroxine is maintained in dosage just short of toxicity in order to reduce the T.S.H. and to minimise thyroid growth and hormone-dependent recurrence.

In cases of exophthalmos, if chemosis is present, small doses of X-rays to the back of the orbit often relieves the condition.

(*B*) **In the Circulation :**

Radio-active albumen is used for the determination of circulation times.

(*C*) **Injected into the Tissues :**

Radio-active sodium injected in a tube graft will indicate to the plastic surgeon the degree of 'take.' The donor end is clamped and the 'clearance time' of the radio-activity noted. The clamp may be reversed as a control.

(*D*) **Internal Surfaces :**

Radio-active gold (a beta and gamma emitter) is applied to the bladder for dealing with bleeding or multiple papillomata. It is used in the abdomen and thorax to limit the formation of malignant effusions. The effusion is aspirated and the isotope injected. The result is not immediate and may be seen only after re-aspiration. It kills free and superficial malignant cells.

Dangers of Contamination.—It is of the utmost importance that these dangerous isotopes should never be handled except by trained personnel. A spill of unsuspected small radio-active isotope solution may result in persistent contamination and danger to staff and patients. The same precautions apply when taking 'samples' for pathology from highly radio-active patients. With skill and care there is no danger. This applies to all radiation hazards.

(*E*) **Implantation into Tissue :**

Radiufn needles implanted in the tissues may be compared to a number of electric-light bulbs placed in a large room. If two bulbs are close together, there is too much light in one place, i.e. too high a dose rate, which can result in radiation damage. If the bulbs are too far apart, there may be too little light in the space between, by analogy resulting in under-dosage and failure to cure. It follows that a dosage from radium must take two factors into account—first the rules of distribution to produce uniformity, and second, the total amount of energy absorbed, i.e. the dose. The dose rate from 1 mg. radium filtered through 0·5 mm. platinum measured at a 1 cm. distance is approximately 8·3 rads per hour. A set of complicated rules are used by the radio-therapist in treating patients. Fortunately, the soft tissues will tolerate a high dose over a very small volume without permanent visible injury. This makes possible the treatment of tumours by the implantation of radium needles, whereby a very high dose exists near the needle but a relatively uniform dose can be obtained at a distance of 5 mm. The normal tolerance of the tissues to radium irradiation is between 5,000 and 10,000 rads. At one end is a large volume of sensitive tissues and at the other a small volume of resistant tissue. An average dose employed is about 6,000 rads in one week.

(*F*) **Surface Irradiation :**

The technical difficulty in executing an ideal implantation has led to the use of radium spaced from the tissues on an appliance so that a uniform dose is delivered on the surface of the appliance near the tumour. This is a surface radium applicator. Unfortunately, it is not possible to use this in the tongue.

[1] The induction of possible malignancy many years later is feared in the young.

(*G*) **Intracavitary Irradiation :**

The same principles apply, whereby irradiation is delivered to the antrum or to the vagina. Surface irradiation is applied to the interior of the maxillary antrum after removal of the hard palate and evacuation of contents by diathermy. Radium is mounted in an acrylic appliance, which fills the cavity. This will give uniform surface irradiation of the interior of the antrum and is used usually after external irradiation. Antrostomy may be done before if infection is present. The interior of the uterus is very resistant to radiation and will stand a surface dose of 30,000 r. X-rays may be used in a cavity to treat accessible lesions by directing a beam of radiation down a cone placed directly on the growth, i.e. mouth.

(*H*) **External Irradiation :**

Radiation able to penetrate only the thickness of a sheet of paper or more than a foot of water may be obtained by varying the voltage of the X-rays from 10,000 to several million volts (megavolt therapy).

(i) **Beryllium Window X-ray Therapy.**—Low penetration (2 mm.) can be obtained by this apparatus used at 20 to 30 kV. It is useful for treating near the eyes and near the genitals to avoid deep damage.

(ii) *Superficial X-rays* (80 to 100 kV.) are used for skin diseases, rodent ulcers and superficial carcinoma.

(iii) *Middle-voltage X-ray* (140 kV.) is used for penetrating skin lesions and superficial lymph nodes.

(iv) *High-voltage X-ray therapy* (250 kV.) is the routine deep X-ray therapy of most hospitals. This is used to treat the breast and most deep-seated lesions.

(v) *'Penetrating' radiation* is undoubtedly the modern trend and superior results are claimed. The greater relative absorption in bone due to its calcium content is becoming less with highly filtered radiation generated at 250 kV, and is disappearing with a highly filtered 350 kV. beam.

'Supervoltage' radiotherapy is a term commonly used but this has given way to radiation described in mev., i.e. millions of electron volts. The advantageous depth dose is referred to on p. 1342. Installation of 1 to 2 mev. equipment is no longer novel. The radiation penetrates bone very readily and is equivalent in quality to that from radio-active cæsium (^{137}Cs., half-life thirty years) which is recovered from the waste products of the reactor ('pile').

Linear accelerators (4 mev.) have radiation slightly more penetrating than radio-active cobalt (half-life 5·2 years, emitted radiation 1·3 mev.) which has its radio-activity induced in the reactor.

Both cæsium and cobalt are housed in the big round end of an egg-shaped head protected with heavy metal. The beam emerges at an aperture at the small end which can be shut when the rays are not required. Supervoltage radiation can cover large volumes of the body and so produce efficient treatment for widespread disease, and is therefore valuable in palliation. The dose rate is high and this enables long treatment distances to be used to permit wide coverage from a limited aperture. The 'cobalt'-protected head rotates around the patient lying on a treatment couch.

Biological Effects.—The skin reaction is less owing to the 'build-up factor,' but a higher equivalent dose in roentgens is required to produce the same effects. This R.B.E. (relative biological efficiency) is upwards of 15 per cent. There is as yet no physical or radio-biological evidence to support the contention of the superiority of the radiation quality as such.

1. **Variants of Conventional Methods :**

Grid Therapy.—Radiation of advanced tumours through a lead grid or sieve has resulted in good palliative results on account of improved tissue tolerance.

Moving-beam Therapy (*Rotation*).—This may be crudely compared with a bicycle wheel, the tumour being the hub and the tyre the patient's skin. The moving beam of rays is always directed at the hub but passes through all the spokes in turn. Depending on the depth, a movement of 180° or 360° may be employed. This results in a very high depth dose—200 per cent. from 250 kV. and even more with penetrating radiation. An accurate concentration on the diseased site results from this method. Owing to the lower dose rates superficial to the 'hub,' the biological disturbance in normal tissues is reduced. Improved results are hoped for with expert use of the method.

PALLIATIVE TREATMENT

The object of palliative treatment is to obtain relief without producing undue distress from the treatment.

1. Secondary deposits. Relief of bone pain and often recalcification usually follows, e.g. with breast secondaries. Pain is occasionally made worse to begin with, but is almost always relieved in about two weeks. It should be realised that pain, segmental hyperæsthesia and sometimes tenderness to percussion may precede positive X-ray signs of neoplasms in bones by many weeks.

2. Control of hæmorrhage. Bleeding from carcinoma of the bladder stops within three weeks with adequate treatment.

3. Healing of ulceration. This is usually obtained by local irradiation of breast tumours (fig. 1697).

(*a*) (*b*)

Fig. 1697.—(*a*) Ulcerative recurrent carcinoma of the breast; (*b*) Result after external irradiation and skin grafting.

4. Limitation of discharge for advanced carcinoma of cervix invading the vagina.

5. Excessive salivation as in carcinoma of the mouth.

6. For the general relief of symptoms. Any or several of the following in the treatment of carcinoma of the bronchus, superior mediastinum obstruction, dyspnœa, cough, excessive sputum, hæmoptysis and pain. Deposits in the lung from the very sensitive seminoma may disappear in the not-too-ill patient.

APPLICATIONS OF THE METHODS IN RADIOTHERAPY TO THE SITE OF THE DISEASE

These are discussed under their relevant chapters.

WHAT CAN THE SURGEON DO TO HELP THE RADIOTHERAPIST?

(*a*) A joint consultation before any treatment. All malignant cases are best dealt with by an agreed plan.

(*b*) The hæmoglobin should be raised as near 100 per cent. as possible by transfusion, etc. A high oxygen carrying capacity increases radio-sensitivity.

(*c*) Infection should be cleared up by taking a culture of discharges and ulcers for antibiotic sensitivity. Infection combats the effects of radiation. Radiation in large doses makes infection worse. Conversely, a small tissue dose (100 r.) helps to combat infection, e.g. gas gangrene.

(*d*) If unexpected malignancy is found at operation, biopsy should be performed.

(*e*) If a deep-seated tumour is exposed at operation and radiation is contemplated, it is of assistance to insert metal markers either in or near the growth. These markers are invaluable in the bronchus, kidney, abdomen and bladder. If inactive radon

seeds are not available at the time, stout braided stainless-steel sutures or clips can be used. Radiographic localisation is then employed to provide a means of accurate direction of the radiation beam from the skin to the depth. Accurate radiotherapy is as important as precise surgery.

PRECAUTIONS REQUIRED WITH RADIOTHERAPY

(*a*) **Surgery Through Irradiated Areas :**

This should never be done without consultation with the radiotherapist, because following administration of high dosage, healing may never occur or the tissue may necrose.

On the other hand, pre-operative irradiation to the optimum dose is not attended by any increase in surgical difficulties. Surgery following the administration of irradiation to high dosage may be difficult on account of fibrosis, but with modern surgical techniques and the possibility of long anæsthesia, patience will usually result in a satisfactory operation. Absolute hæmostasis and careful non-irritating suturing technique is essential. Adequate antibiotic cover should be used, and firm pressure applied over the wound.

Stitches must not be removed before three weeks after a full course of irradiation, and then, alternately.

(*b*) **Secondary Radiation :**

When radiation strikes heavy atoms, e.g. iodine, secondary radiations are emitted and the reactions from radiotherapy are increased. The same happens with the zinc-oxide adhesive plaster. The use of transparent adhesives avoids this.

(*c*) **Reactions :**

Never operate when a reaction is present or expected. It is usually safe within a week of a single dose, or six weeks after the completion of full dosage provided the reaction has subsided.

PERSONAL PROTECTION FROM IONISING RADIATIONS

The dose received is the product of the dose rate and the time of exposure, i.e. D (dose = i (intensity) × t (time).

This means that if during an insertion four times the minimum quantity of radium is used, it follows that the dose received by the person is four times greater. It is also inversely proportional to the square of the distance, so if the operator stands eighteen inches away instead of nine inches away he will get a quarter of the dose. When using protection (absorber) a greater thickness is required for a penetrating radiation and for a less ' dense ' absorber. For a reduction of the quantity of radiation by 500 times, the thicknesses are :

For 0·1 mev. — 1 mm. of lead, or 8 cm. of concrete.
For 1 mev. — 6 mm. of lead, or 50 cm. of concrete.

No avoidable irradiation should be received. The answer to exposure is be quick, do not use more radium than is essential, and keep away. In addition to this, there is the need for using a protective barrier such as a lead container for radium and special walls for X-ray treatment rooms.

Measurement of Dose Received.—This is checked by wearing film badges in occupational exposure of staff, e.g. doctors and nurses. One part of the badge is covered with thin lead because it differentiates penetrating radiation, e.g. from radium, which will pass through the lead. The depth of blackening is a measure of the dose. Personal ' pen-type ' ionisation chambers may also be used. The dose received is read at any time by looking through the ' pen ' at the position of the fibre on the dose scale. Owing to the casing thickness, the latter is more useful for penetrating radiation, e.g. radium.

The total background or natural radiation received comes mainly from isotopes in the surrounding ' bricks and mortar ' and the ground beneath. This varies from place to place on the earth. A smaller quantity is received not only from the body itself in the form of radioactive potassium but also as cosmic rays from outer space. They average in all 2 milliroentgens per week. Hitherto an assessment of the hazards of radiation has usually been based on the assumption that 25 r. (10 to 20 milliroentgens a week) per generation would approximately double the mutation rate.

For radiation workers the maximum 'permissible' dosage is 0·3 r. in any one week, but the average is 0·1 r. per week, which is 200 r. in the normal working life.[1]

* * *

Kind and generous help was given not only by the physics and pathological departments, but also by the physicians and surgeons of the Royal Northern Hospital. Much assistance was afforded by other physicists, radiobiologists and radiotherapists, and finally by Prof. B. W. Windeyer, Dean of the Medical School, Middlesex Hospital, who read the final draft. To all of these grateful thanks are tendered.

[1] Details are given in the *Code of Practice for the Protection of Persons exposed to Ionizing Radiations*, Her Majesty's Stationery Office, 1957.

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