OBSERVATIONS ON TREATMENT OF FRACTURES OF THE FEMUR*

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OVER two thousand years ago Hippocrates wrote with reference to fractures of the femoral shaft that two strong men should suffice to make extension and counter-extension whilst a bandage was applied. The principle of preliminary reduction followed by fixation is probably as old as these fractures themselves. There is little record of any notable departure from that method until 1875. In that year, Hugh Owen Thomas applied the use of his bed knee splint to the treatment of this fracture, and evolved the principle of a sustained longitudinal force to stretch the muscles through the medium of extension plasters applied to the skin. By frequent and regular tightening of the tapes, the shortening could be overcome and the limb restored to its proper length.

At the beginning of the present century, the introduction of skeletal fixation by the Kirschner wire, the Steinman pin and the Pearson ice-tong caliper started the trend of continuous weight and pulley traction which was developed so widely during the 1914-1918 war. The weight was in continuous action and did away with the necessity for frequent and regular tightening of extension tapes, and considerable weight could be applied to tire out the strong thigh muscles, pull the fracture into line and hold it there. The principle of initial reduction tended to fall into abeyance with these methods of traction. Many modifications were elaborated mainly involving the suspension of the limb. The Pearson knee flexion piece was added to the original Thomas splint; Hodgen's splint, the simple sling of Hamilton Russell, Braun's frame, the hanging cast described by Farquharson—all provided support for the limb while the weight did its work.

A perusal of the text-books on surgery in general and fractures in particular shows that in the period between the wars the use of continuous weight and pulley traction was taught in the majority of schools and adopted in most hospitals as the method of choice. An occasional voice was heard from the disciples of H. O. Thomas faithfully preaching the principles of fixed skin traction which he had taught. But it was rather a voice in the wilderness. The continuous application of a heavy weight seemed much more attractive and efficient. Possibly Watson Jones may have evoked some surprise when he was found to state that most fractures of the shaft can be treated satisfactorily in a Thomas knee splint with skin traction.

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He does, however, recommend one departure from the original method of Thomas: he stresses the importance of adequate reduction under anæsthesia before the limb is put up in the apparatus.

The present observations are based on the experience of a large number of these fractures during the recent war, mainly in an Orthopædic Centre in the Middle East between 1941 and 1943. It was with a background of orthodox teaching that they were approached, and at first they were all treated by continuous weight and pulley traction. But as the battles waxed and the number of casualties increased, it became a common state of affairs to have twenty-five such cases in one ward, and the difficulties and shortcomings of the method soon made themselves only too apparent. Due to the influence of the late Brigadier Eastwood who was consultant orthopædic surgeon at that time, the principles of fixed traction in a straight Thomas splint were adopted as an alternative and certain modifications to the standard method were introduced. The difference was very striking both in the ease of management and in the ultimate results, and it gave much food for thought. Some of the views expressed here have already been published in a paper by Charnley (1944) who was associated in the treatment of some 130 of the cases, but they seem of sufficient importance to warrant reiteration.

The complications of fractures of the femur fall into three groups :—

(1) *Deformity.*—This includes shortening, lateral angulation, posterior angulation, or internal rotation of the knee and foot. These are the result of muscular action. Almost all the long muscles that pass from the pelvis to an attachment below the fracture lie obliquely to the femoral shaft on the medial side. In particular, the medial hamstrings and adductor magnus tilt the lower fragment medially. Gravity and the gastrocnemius draw it backwards. The upper fragment is influenced mainly by the glutei and psoas which tilt it laterally and forwards and may produce external rotation. The muscles are at first inhibited from voluntary motion and soon waste, so that in a week or ten days the bulk of the thigh is very much reduced and the power of the muscle pull correspondingly diminished. At first the hæmatoma does not give any support to the bone ends, but after two or three weeks early callus begins to fuse the fracture and movement of the fragments in a longitudinal direction is prevented. The callus is still plastic, however, and leverage easily produces angulation. At five to six weeks union is often firm enough to permit the leg to be raised from the splint, but repeated leverage will still slowly bend the bone. At this stage there is no pain and voluntary muscular activity has returned. Unless the bone is still protected, the preponderance of muscles on the medial side is very apt to produce a late angulation. There is no excuse for deformity. It is preventable by good treatment.

(2) *Interference with Union.*—In the straightforward case the femoral shaft has a natural aptitude for union which is often embarrassing to the surgeon. It may catch him unawares before he has achieved

his object in restoring length and line. Delayed union in the absence of infection is occasionally due to interposition of soft tissue, but much more often it is the result of distraction of the fragments or lack of immobilisation. Non-union is extremely rare. These complications are almost always the direct result of bad treatment.

(3) *Restricted Function.*—This is usually in the form of stiffness of the knee joint. It may be due to the original nature of the injury or it too may be due to treatment. It will be mentioned later. The particular pitfalls that treatment must be designed to avoid are too little or—more important still—too much extension, loss of line and strain on the knee joint.

When a case is treated by continuous weight and pulley traction, the pull of the weight is transmitted through the tibia to the long thigh muscles inserted into the tibial head. According to the amount of weight applied, the shortened muscles stretch out and then assume a state of postural tone which resists the pull. The greater the weight that is applied, the greater is the stretch and the stronger the resistant tone (Fig. 1). The quadriceps, as the main muscle of posture, probably plays a major rôle in striking an equilibrium with the weight. Theoretically it should be possible to apply to any particular case that amount of weight which will maintain the correct amount of stretch. The equilibrium must be an unstable one, however, as a suspended weight possesses inertia and can generate momentum, and any movement of the patient must alter temporarily the forces in operation. Over the course of two or three weeks the muscles waste and tone presumably lessens, so that the weight should be correspondingly reduced to allow for this. Each case differs from the next in the reaction of the muscles and in the rapidity of wasting and of bone union. There is no mathematical formula for determining the exact amount of weight required at any particular time, and adjustments must be made on a purely empirical basis guided by frequent X-ray examination for position. These are not merely theoretical arguments. In practice it was found that in a proportion of cases satisfactory equilibrium could be achieved, and by judicious adjustments of the weights length and line could be preserved throughout the treatment. But in other cases treated similarly the behaviour was quite different.

FIG. 1.—Weight traction. Distal extension of muscles.

Gnr. W. sustained a closed fracture of the femoral shaft among other injuries in an air raid. On 29th January 1942, after manipulation under an anæsthetic, twenty pounds weight was applied to a pin through the tibial

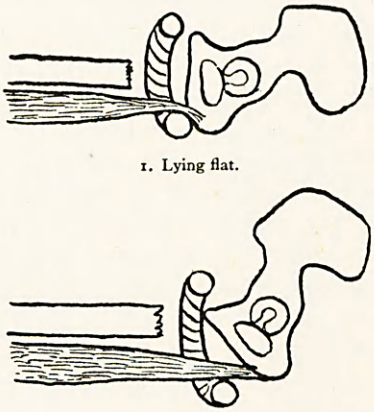
tubercle. The following day an X-ray showed good position and adjustment was not considered necessary. Five days later a further X-ray showed that the fracture was overpulled to the extent of half an inch, and the weight was accordingly reduced by half, to ten pounds. Two days later a third X-ray showed that not only had the gap closed but the fragments were overriding by half an inch and there was lateral angulation of about twenty degrees. The weight was increased again to fifteen pounds and a fourth X-ray, six days later and fourteen days after the injury, showed that although the overriding was now corrected, the lateral angulation persisted. Callus was faintly evident. Twenty pounds weight was attached once more and a pressure pad applied to the apex of the angle; but there was no change in the angulation after a further fourteen days, and a manipulation was necessary to straighten the limb. It has been remarked by Watson Jones that the correction of distraction often leads to angulation.

This case is not an isolated example. It represents a group of cases in which weight traction proved most difficult to control and led to the development of complications.

When weight traction is applied, the lower femoral fragment follows the tibia by virtue of the capsule of the knee joint. The only major muscle which is attached directly into it from a point above the fracture is the adductor magnus, and the tension in the knee joint ligaments is equivalent to the tone of this muscle and is relatively slight. When union has progressed sufficiently to fix the fractured surfaces and prevent movement in a longitudinal direction, no further traction is really necessary to maintain length. But unless a moderately strong pull is still applied the recovering medial muscles will angulate the bone. The transmission of the pull is now rather different. The lower fragment is anchored at the fracture and is no longer free to follow any further extension of the weakened muscles. Instead of being absorbed by the muscles, the pull passes from the tibia directly to the femur through the ligaments of the knee joint.

In the cases treated by weight traction in a Thomas splint with knee flexion piece, lateral angulation occurred with annoying regularity, and it often proved difficult to correct. According to the principle that any two sides of a triangle are longer than the third side, angulation necessarily implies some shortening, but in practice a moderate angle may produce so little actual difference in length that longitudinal traction cannot be entirely relied upon to prevent it, and will certainly not correct it unless an excessive pull is used. It was not so much during the early stages of treatment that the deformity asserted itself, as later on when weight was reduced in order to spare the knee. It is partly due to recovering muscular activity on the medial side and partly due to the position of the patient. With the hip and knee flexed the weight operates in the line of the femur at an angle of some forty-five degrees above the horizontal, and it expends part of its force against gravity. Reduction of the weight releases the action of gravity and the lower part of the limb slumps back into the splint and this promotes angulation.

The splint itself may also play an important part in the encouragement of angulation. It is not always fully recognised that the Thomas splint was designed to bear on the ischial tuberosity, but can do so only when the patient lies flat with the hip extended. In this position the tuberosity forms the most distal prominence of the pelvis and the hamstrings are relaxed (Fig. 2). If the patient sits up, the tuberosity rotates backwards away from the ring and the hamstrings tighten across it. At the same time the pubic ramus swings down and forms the point on which the ring bears. Pressure on this region can rarely be tolerated and the patient eases the ring down the thigh. The pelvis and upper fragment are then released and tend to tilt inward across the inner side of the ring which forms a fulcrum in the adductor region. A pressure pad with a purchase on the side bar of the splint is the usual method of correcting angulation. But if a pressure pad is used in these circumstances it simply draws the ring of the splint laterally into the adductor muscles and increases the pressure of the fulcrum. It does little to correct the angle. A pressure pad is reliable only when the whole limb, including the pelvis, bears a constant fixed relationship to the splint. This is impossible with Braun's frame or with any system of slinging the leg on a suspended splint. It is effective if the method of fixation in a straight Thomas splint is used.



1. Lying flat.

2. Sitting.

FIG. 2.—Relation of ischial tubercle to ring.

Late angular deformity was also encountered in cases treated by fixed extension when enthusiasm for early movements led to too early release of the limb.

Sgt. O. had an oblique fracture of the middle of the shaft due to a bullet wound. He was treated with fixed skin extension and good reduction was obtained and held. After seven weeks his fracture seemed quite firm and the extension plasters were removed and leg raising exercises started. Three days later he had developed twenty-five degrees of lateral angulation which necessitated a further four weeks of extension with strong leverage over a fulcrum for its correction. The temptation to go too fast in the recovery stage must be resisted.

Rotational deformity consisting of an inward twist of the knee and leg is not an uncommon end result. It is often associated with some lateral angulation, and in the position of knee and hip flexion both these deformities are very difficult to detect on routine clinical inspection. The position of the limb tends to mask them and precludes accurate assessment by comparison with the sound leg. The inward

twist may be discovered only when the patient starts getting up and it is then too late. It is due to the action of the glutei and psoas which externally rotate the upper fragment in some cases. When this happens it is impossible to control the upper fragment, and correction must be obtained by positioning the lower limb in external rotation. It is not easy to assess whether this is required. The position of the greater trochanter may be palpated, and if it lies further back than the trochanter of the opposite femur, some degree of rotation may be assumed. If an X-ray taken during reduction shows that apposition is not good, a second film should be exposed with the knee and foot externally rotated about thirty degrees. This may show more accurate reduction and give a clue as to the correct position in which the limb must be immobilised. Rotational correction is possible only with the limb almost straight; when the knee is flexed the leg can lie only in the antero-posterior plane.

The setting up of a fractured femur is not uncommonly treated as a minor procedure: perhaps an injection of morphia is given before applying skin extension, or a little pentothal or local anæsthetic for the insertion of a pin, and it is hoped that the weight will do the rest. Reduction can certainly be achieved by these means, but as the case of Gnr. W. shows, there is little time for gradual correction of deformities and a very close watch on the behaviour of the fracture is necessary. It is much simpler and much more reliable to carry out a definite manipulative reduction under full anæsthesia as the first stage in the treatment, to check the position by X-rays, and then to immobilise the limb in the splint. In two types of case such a manipulation is of prime importance: it is often possible to engage the ends of a transverse fracture, and if this is achieved, half the battle is won; secondly, there is the occasional case in which the upper fragment penetrates the quadriceps muscle, and only by a strong pull and manipulation can it be freed.

In the casualties arriving at the Orthopædic Centre, difficulty in restoring full length was hardly ever experienced, even in the closed fractures. In fact, when there was much muscle damage from shell wounds, a moderate pull might distract the fragments only too easily. These patients had lain for a few days in Tobruk splints with their limbs immobilised and muscles extended, before they reached the base. When they came to definitive treatment, the absence of muscle spasm was a notable feature and the limb pulled out easily. In a fresh fracture treated immediately, full length may be impossible to obtain, especially if the subject is powerfully muscled and there is much swelling in the thigh. But if the limb is pulled out as far as possible and held in this position in a splint for four or five days, a second manipulation at the end of that time will almost always succeed.

Supposing now that the fracture has been reduced and the limb placed in a straight Thomas splint with the ring in contact with the ischial tuberosity and the leg below the fracture fixed to the lower end

of the splint, what forces are in operation on the limb? This method of treatment is often referred to as "fixed traction," but the term is a misnomer. It arises from a conception of slow extension of the leg by repeated tightening of the cords. There is no traction operating in a direction away from the body; the force should be envisaged as acting in the opposite direction (Fig. 3). The lower leg should be regarded as a fixed point in relation to the splint, and the thigh muscles, acting from their insertion to the head of the tibia, exert a pull on the pelvis in a downward direction and press the ischial tuberosity against the ring.

At first, when muscle tone is strongest, the pressure on the tuberosity may be heavy and cause complaint. It is relieved by raising the foot of the bed and allowing body weight to pull in an opposite direction to the tension in the muscles. The actual pressure on the tuberosity then amounts to the force exerted by the muscles minus the pull generated by body weight; and provided that the latter is not the greater, the tuberosity remains in position and the mechanics in the limb itself are unaltered. Charnley has demonstrated that a nine-inch elevation of the foot of the bed produces in the case of a ten-stone subject a pull in the region of six pounds, and a twelve-inch elevation increases the pull to twelve pounds.

FIG. 3.—Skeletal fixation to splint. No traction. Muscle tone acts on pelvis.

With such a method of fixation the side bars of the splint act as rigid props between the lower limb and the pelvis, and the fracture is immobilised in a longitudinal direction. There is no movement to cause spasm of the muscles. There is no constant stretching force to engender reactive contraction. The tension is due to the tone of a muscle at rest and is much less than that in a muscle continuously subjected to stretch from a suspended weight. It is found that the tension diminishes very rapidly after the first two or three days until by the end of the third week it is very slight. When voluntary contractions of the muscle return they act between the pelvis and the head of the tibia—two fixed points—and so have little tendency to produce angulation of the femur. Throughout the whole process the main muscles in operation work between these fixed points and bridge the knee joint. At no stage can there be any strain on the ligaments of the knee joint.

The method of fixed traction is criticised on the grounds that skin extension is unreliable and that the strapping always slips. The objection is perfectly valid. Skin extension was given a thorough trial and slid down the limb in every case, especially during the early stages when muscle resistance was maximal but when it was most

important to maintain reduction. Sores on the dorsum of the ankle and over the tendo Achilles were prevalent despite all precautions. Possibly excessive perspiration in a warm climate checked efficiency. But in all descriptions of treatment by this method the necessity for regular tightening of the tapes in order to take up the slack is stressed (Diggle, 1942). There seems to be little point in performing a careful reduction under anæsthesia and then using an apparatus which allows the tension to slacken off at intervals afterwards. It is a remarkable fact that the advocates of the principles of H. O. Thomas have retained his original methods of applying them virtually unchanged. Fixed traction seems to be wedded to skin extension for better or for worse, and a weight seems to be the inseparable companion of a skeletal pin. There is no need to use skin extension. A pin through the tibial tubercle can equally well be adapted to fixed traction as it is to weight traction, by attaching it with cords to the lower end of the splint, and it gives far greater precision of control than skin extension. At the same time it leaves the leg below the knee unencumbered with bandages and removes the risk of pressure sores. Minor skin infection at the pin holes was the worst complication encountered in a large number of cases so treated.

The most serious and troublesome complication of a fractured femur is stiffness of the knee joint. In the absence of any obvious traumatic cause, such as laceration of the quadriceps, or damage to the joint itself in the original injury, stiffness still results. The pin, originally introduced into the lower end of the femur close to the capsule, was rightly condemned. But its removal to the tibial tubercle far away from the joint has not made any marked difference. A healthy knee joint does not develop more than a transitory limitation of movement if it is immobilised in a position of rest. It does so if weight and pulley traction is applied to it for any length of time, and the degree and permanence of the stiffness seems to be proportional to the length of time the traction is in operation. Watson Jones postulates that a constant stretching force acting on a ligament may cause an irritative reaction in the joint which results in adhesion formation. This pathological sequence is well recognised in the foot where repeated strain of the plantar ligaments leads to adhesions in the mid tarsal joints. It has already been shown that weight traction pulls directly on the knee ligaments as soon as the bone ends are anchored longitudinally, and it is a fact that this traction can actually stretch the ligaments if it is continued after union has commenced.

Cpl. B. had a severely infected compound fracture with slow union, and was treated with weight and pulley traction in a Thomas splint with knee flexion piece. The direction of the pull was in the line of the femur. After two months in this apparatus there was anterior subluxation of the head of the tibia of almost half an inch which was easily visible on inspection, and was due to stretching of the anterior cruciate and collateral ligaments.

Two other cases were noted in which this subluxation was evident, and several cases were seen in which there was demonstrable laxity of the collateral ligaments and an apparently loose knee, but at the same time limitation of flexion. Much can be done during immobilisation to prevent the development of stiffness. Daily passive manipulations of the patella are useful, and quadriceps exercises at an early date are of the greatest value. Movements will return far more rapidly if the muscles are strong enough to produce them. Once more the position of the leg in the splint is of importance. With the knee flexed the quadriceps tendon is stretched and the patella falls into the intercondylar notch. It cannot be moved appreciably either in an up and down, or side to side direction. Quadriceps contractions are difficult to perform with the knee bent, and are nothing like so strong or complete as they are when the knee is extended. Extension of the muscles by a weight seems to prolong the inhibition of voluntary contractions which return at a much earlier stage when the limb is fixed.

Continuous skeletal traction was abandoned then, in favour of the method of reduction under anæsthesia followed by skeletal immobilisation in a straight Thomas splint. The term "fixed traction" is omitted as it implies a false conception of the mechanics. A Steinman's pin passed through the tibial tubercle and fastened to the lower end of the splint was used to obtain fixation of the lower fragment. The limb was put up with a pad under the fracture and lower fragment to correct posterior angulation and produce some fifteen degrees flexion at the knee joint, and a lateral pad was applied to the site of the fracture and in some cases was reinforced with a pad against the medial femoral condyle. A cuff of plaster of Paris applied round the splint and limb and moulded in at the sides in the same way as in the Tobruk splint, and then cut away in front to leave a lateral and medial buttress, serves very well.

Perhaps the most striking feature which resulted from this change of policy was the ease of management of the cases in the wards. Constant checking of position by X-ray examination was no longer necessary. Provided that the line of the limb looks straight, the ischial tuberosity is in contact with the ring and the length of the limb by measurement is correct, nothing can be wrong. The foot of the bed, at first raised nine or twelve inches, can be gradually lowered as tension slackens. After the first few days a physiotherapist supervises daily active exercises of the foot, ankle and quadriceps, and carries out passive manipulations of the patella. As soon as the leg can be raised from the splint—about the fifth or sixth week in a straightforward case—the cords may be released for a short period each day and gentle flexion and extension exercises cautiously started under supervision. The apparatus should be carefully replaced afterwards. When the callus is no longer tender and lateral stress on the bone does not cause pain, the patient is ready for a weight-bearing caliper.

Unfortunately it was impossible to follow cases through to their conclusion and to obtain details of the functional end results. As soon as a man reached the convalescent stage he was evacuated to South Africa. However, the interim progress was noted in two small groups of comparable battle casualties, mostly with compound fractures. In the first group, treated by weight and pulley traction, the average length of time between wounding and reaching the stage of being up in a caliper and fit to move on, was eighteen weeks. In the second group, treated by the method outlined, the time was reduced to twelve weeks. One half of the latter group had by that time recovered eighty degrees or more of knee flexion.

Throughout this discussion two main themes run. The first concerns continuous weight traction. It has been publicly suspect (Girdlestone, 1943) for some time as a potentially harmful method of treatment. Theoretically it is illogical on both mechanical and physiological grounds. In practice it was found to be difficult of management, unreliable in result and even conducive to complications, to the prevention of which treatment should be directed. The second concerns the position of the limb. Flexion of knee and hip leads to many difficulties in the estimation and correction of deformity and does not favour rapid recovery of function. In the majority of cases the original Thomas splint, unadorned with any modification or attachment, is still the best available apparatus for the treatment of these fractures.

Smillie has classified fractures of the femoral shaft as the "Cinderellas of the surgical wards," since the introduction of the Smith Petersen nail promoted femoral neck fractures from that unenviable position. Perhaps if the method of continuous weight traction were finally discarded even these cases might lose some of that unattractiveness which renders them so much less desirable than their ugly sisters.

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