HETEROTOPIC OSSIFICATION IN PARAPLEgia
A Clinical Study

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This paper is based on study over twelve and a half years of 170 patients suffering from traumatic paraplegia or tetraplegia, of whom 162 survived for more than a month after injury, and of 103 patients with other lesions of the spinal cord. The patients in the second group were less suitable for analysis because in many the lesions were disseminated or incomplete: few could be compared with the patients with traumatic paraplegia, who generally had transverse and complete lesions with a well defined neurological level. Heterotopic ossification was found in forty-seven patients with traumatic paraplegia and twenty-five with non-traumatic lesions.

HISTORY
Towards the end of the first world war Déjerine and Ceillier presented to the Société de Neurologie in Paris a series of cases of heterotopic ossification in paraplegia, and published a comprehensive paper (1918c) containing a clinical and radiological study of the condition as observed at the Institution Nationale des Invalides. The following year Déjerine, Ceillier and Déjerine (1919) presented a paper on the anatomical and histological aspects of the disease, presenting sixteen anatomical specimens and a number of histological slides and colour photographs obtained from eleven patients. Little was known about the condition before these studies. After a prolonged search of the French literature for previously published cases of arthropathy in paraplegia, they were able to find only one unequivocal example (Chipault 1900). Geldmacher (1925) was unable to find records of more than four examples in the German literature (Riedel 1883, Israel 1920).

In the following years the condition was noted by other authors in traumatic and non-traumatic lesions of the central nervous system but was usually referred to as myositis ossificans. Geldmacher (1925) proposed the name ostiiasis neurotica para-articularis or paraossalis. Soule (1945) called the condition neurogenic ossifying fibromyopathy. Nevertheless the term ectopic bone or heterotopic ossification seems the most appropriate designation because it covers bone formed in muscle and in other soft tissues, whether of inflammatory or non-inflammatory origin.

MORBID ANATOMY
Little can be added to Déjerine and her colleagues' (1918a, b, c: 1919) description of the morphology of heterotopic ossification in paraplegia. The main feature is the formation of new bone in the vicinity of an unchange® hip or knee joint. Thus the pathological characteristics are completely different from those of osteoarthritis and of the arthropathy of an unprotected joint (Charcot 1868).

They divided their patients into two main groups: those showing the heterotopic formation of bone in close relation to joints and bones, and those in whom the bone formed under the aponeurosis of or inside a muscle and had no connection with the skeleton. Such heterotopic bone was in the form of long needles or blades. The hip was the most common site for para-articular formation of bone. Sometimes the joint became fixed by the completion of a bony arch growing between femur and the innominate bone. Parosteal formation of bone most commonly started in relation to the medial femoral condyle and progressed upward in the soft tissues on the medial side of the bone. The lower part of the heterotopic bone was compact and the upper part spongy. The whole mass was joined to the femur by two or three projections. Heterotopic ossification was not found below the knee or above the level of paralysis.
HETEROTOPIC OSSIFICATION IN PARAPLEGIA

HISTOLOGY

Heterotopic ossification consists of modified true bone, complete with Haversian canals, osteoblasts, blood vessels and oedematous bone marrow; in some instances there are also inclusions of cartilaginous tissue. Déjerine and her colleagues (1919) found no evidence of old or fresh extravasated blood or of pus. Where there is contact with the muscle, heterotopic ossification is separated from it by fibrous tissue, often dissociating the fascicles of the muscle. There is a perimuscular sclerosis often with atrophy of the muscle.

Déjerine (loc. cit.) did not find heterotopic ossification in the vicinity of pressure sores. However, Lhermitte (1919) found, on post-mortem examination, collections of pus and colonies of streptococci in one of his patients affected by bilateral and symmetrical heterotopic ossification.

Déjerine and Ceillier (1918c) did not observe heterotopic ossification in patients with neurologically incomplete lesions.

THEORIES OF PATHOGENESIS

Various theories regarding the formation of new bone in soft tissues in paraplegia have been put forward.

Déjerine and Ceillier (1918c) thought that there were two factors responsible for the formation of heterotopic ossification—a local one, and a central factor of neurogenic origin. The essential local factor was thought to be the lowering of the resistance of connective tissues by persistent oedema. Their failure to find heterotopic ossification in patients with incomplete lesions and their observation that heterotopic ossification was most frequent and extensive in patients with lesions sparing the intermedio-lateral column of the grey matter led them to the idea of a central, neurogenic, cause. They thought that toxaemia caused persistent irritability of the cells in this column which led to autonomic effects such as oedema hyperhidrosis and muscular fibrillation. The combination of the two factors was thought to cause heterotopic formation of bone. Charcot (1877) before them had blamed the anterior horn cell for the same influence.

Léri (1919), applying Wolff’s theory, believed that pressure and traction resulted in the formation of the tissue—bone—which was best able to meet the altered requirements. Lhermitte (1919) added a belief in the necessity of a superimposed factor of local infection. Israel (1920) put forward a similar theory of exaggerated reaction to pull and pressure.

Leriche and Policard (1918, 1926) suggested that heterotopic ossification in general develops in an ossifiable connective tissue near a depot of calcareous salts. This theory is based on Reichert’s (1845) concept of the non-specificity of the various types of connective tissue derived from the mesenchyme. Leriche and Policard thought of the transformation of mature connective tissue to bone as taking place in three stages: 1) the mature connective tissue reverted to a primitive state as a result of infection or trauma; 2) the connective tissue became infiltrated with a collagenous hyaline substance arranged in lamellae, to form osteoid tissue; 3) this pre-osseous substance was converted to bone by impregnation with calcareous salts. This last process was only possible in the area of an excessive concentration of calcareous matter, released, in their view, by hyperaemia and decalcification of the adjacent bone.

Several hypotheses have been put forward to explain the local precipitation of calcium and phosphorus. In the opinion of Armstrong-Ressy, Weiss and Ebel (1957), the reduction in the serum protein concentration due to marked negative protein balance following spinal cord injury, together with the lowered carbon dioxide tension caused by the lowered metabolism in the paralysed muscles tend to favour the deposition of calcium salts. The role of phosphatase (Robison and Soames 1924) has also been extensively discussed.

CLINICAL FEATURES

To establish exactly the natural history of heterotopic formation of bone it would be desirable to examine the potential areas systematically from the very onset of paraplegia:
this has not been done in all the patients in this series. In this Centre no heterotopic ossification was recorded during the first month after injury to the spine.

The hips and knees are the areas of predilection, the ischial tuberosity and the upper limbs in tetraplegics being less frequently affected. The changes may be unilateral or bilateral and are often multiple. Clinical signs are present only when the condition is advanced. In most cases the condition was discovered as an incidental finding when radiographs were taken for other conditions.

Thickening around the hips and knees may be seen and felt in advanced cases, most commonly after prolonged nursing in the prone position. There may be limitation of flexion of the hips and knees, and in fewer cases limitation of extension; the stiffening of the hips may be associated with a lateral deviation of both lower limbs to one side. In the region of the knee the mass of the bone is fixed; there may be a fair range of movement, pain being elicited when the limb is being locked in a walking caliper.

In advanced cases of ankylosis in extension the patient finds it difficult to sit comfortably in his chair. although later he often learns to compensate for the fixed extension by placing his buttocks on the very front of the wheelchair seat, his feet resting on the extended foot tray. Such a patient cannot use a toilet of the low-suite type, as the cistern is in his way. This writer has not seen a subluxation or dislocation of the knee in these cases.

Heterotopic ossification of a special nature may be associated with the paralysis caused by extension injuries of the neck in elderly patients. Shortly after the spinal injury these patients often complain of pain in their shoulders, elbows and hands, and of swelling of the hands. If they are not given adequate physiotherapy they develop stiff joints and later ossification may occur in the adductors of the shoulder, in the cubital fossa, or in the triceps tendon, with a fixed contracture of the joints.

**RADIOGRAPHIC APPEARANCES**

Heterotopic ossification does not appear in a haphazard manner, but follows certain patterns which may be seen in combination. One of the main features is that the condition is extra-articular and extra-capsular.

Déjerine and Ceillier (1918c) pointed out that there was usually osteoporosis in the adjacent bones, as if the calcereous matter used for the formation of ectopic bone had been borrowed from the vicinity. In the writer's experience even a moderate degree of decalcification is uncommon, and a local decalcification was only observed in one case in the bones of the knee joint. Perhaps the technique of microradiography and autoradiography with radioactive tracers as reported by Lacroix (1960) will provide us with more accurate means of assessing the presence and degree of decalcification.

**Ossification around the hip**—On the femoral side the bone usually forms in relation to the great trochanter (Fig. 1), less commonly in relation to the trochanteric crest (Fig. 2) or lesser trochanter (Fig. 3).

On the pelvic side the bone may form on the lateral side of the junction of the body and ramus of the ischium, and may then be associated with irregularity of the ischium (Fig. 4). It may also form in relation to the anterior inferior spine of the ilium (Fig. 5).

There seems to be a tendency for the formations to grow together from each side. Sometimes they fuse to bridge the joint, most commonly above it (Fig. 6) but also below it (Fig. 7). A complete extra-articular ankylosis may result (Fig. 8). The joint itself remains unaffected unless involved in infection introduced through a pressure sore (Fig. 9).

The bone is connected with the skeleton to a variable extent. In some cases it may appear radiologically to be continuous with the bones of the hip joint; in others it is clearly seen to be separate from them. In the latter group, most formations of bone seem to be in the gluteus medius, while others seem to be in the adductor muscles and the pectineus or in the quadriceps. Occasionally, bone seems to form in the tensor fasciae latae. In one case bone of a perforated
FIG. 1—Case 1. Man aged twenty-one with tetraplegia from transverse myelitis. Right trochanteric sore. Severe infection of urine; temporary loss of function of the left kidney. Note heterotopic formation of bone in relation to the great trochanter. Figure 2—Case 2. Man aged thirty-six with flaccid paraplegia below first lumbar segment from fracture-dislocation of twelfth thoracic on first lumbar vertebra. Bilateral trochanteric sores. Severe infection of urine; hydronephrosis. Nursed several months in prone position. Heterotopic bone arising from the trochanteric crests; needle-shaped heterotopic bone near the adductor origin from the ischium. Figure 3—Case 3. Man aged fifty-nine with spastic paraplegia below first lumbar segment due to vascular lesion of the cord. Left-sided trochanteric sore; patient bedridden in prone position for many months. Heterotopic ossification arising from the greater and lesser trochanters of the left femur; note the stalactite-stalagmite effect; contiguity but no continuity of the ectopic bone at the greater trochanter.

Figure 4—Case 4. Man aged fifty-four with flaccid paraplegia below eleventh thoracic segment from fracture-dislocation of eleventh on twelfth thoracic vertebra. Bilateral trochanteric sores; severe infection of urine; hydronephrosis; chronic uraemia. Patient nursed in prone position for many months. Heterotopic ossification at the junction of the body and ramus of the right ischium. Note contiguity, but no continuity; irregular outline of ischial tuberosity. Figure 5—Case 5. Man aged twenty-six with spastic paraplegia below sixth thoracic segment from extramedullary ependymoma. Right trochanteric sore; nursing in prone position. Heterotopic ossification arising from the outer aspect of the right ilium, at the level of the anterior inferior iliac spine.
Figure 6—Case 6. Man aged thirty-three with spastic paraplegia below ninth thoracic segment from fracture-dislocation of tenth on eleventh thoracic vertebra. Multiple pressure sores. Severe infection of urine. Prolonged nursing in prone position. Firm union between the right great trochanter and the outer ilium; bulky bony inclusions in the adductors; a small one in the right tensor fasciae latae. Figure 7—Case 7. Man aged thirty-seven with flaccid paraplegia below first lumbar segment from fracture-dislocation of twelfth thoracic on first lumbar vertebra. Ischial sore; prolonged nursing in prone position. Severe infection of urine; death from uraemia. Union between the lesser trochanters and the pelvis is taking place; slender bony needles near the adductor origins.

Figure 8—Case 8. Man aged twenty-one with spastic paraplegia below tenth thoracic segment from fracture-dislocation of ninth on tenth thoracic vertebra. Pressure sores over both greater trochanters. Severe urinary infection, chronic uraemia. Prolonged nursing in prone position. Complete bony ankylosis of the left hip in extension resulting from union in the upper and lower tier. Figure 9—Case 9. Man aged forty-two with flaccid paraplegia below tenth thoracic segment due to encephalo-myelitis. Dislocation of the right hip from septic arthritis caused through a trochanteric sore.
Case 10—Figure 10. Man aged twenty-seven with flaccid paraplegia from trauma on quiescent Pott's disease. Deep pressure sore over the right ischial tuberosity. Spongy new bone along the distal border of the right ischium. Figure 11—Ishium removed at operation. Note the lace-like appearance of the heterotopic bone; the line of separation between the ischium and the new bone can easily be distinguished. (Scale in centimetres).

ETIOLOGY OF HETEROTOPIC OSSIFICATION

It is possible to divide etiological factors into two main groups: those which remain beyond our control like the age of the patient and the level of the spinal injury, and those which depend on the type of treatment given.

Age—In this series the relative peak of spinal injury was in the fourth and third decades of life, whereas the relative peak of heterotopic ossification was in the seventh and sixth decades.
Level of spinal injury—In this series the most common level of injury was at the first lumbar vertebra. There was a gradual decline towards the twelfth and eleventh thoracic vertebrae, injuries at the thoraco-lumbar junction accounting for about 60 per cent of the cases. There was a lower peak of incidence at the cervical level, flexion and extension injuries together accounting for about 25 per cent. The lowest peak of incidence was at the thoracic region from the third to the tenth vertebrae, injuries in that region accounting for about 20 per cent of the total.

In contrast (Fig. 19), the peak incidence of heterotopic ossification was in patients with injuries at the eleventh thoracic vertebral level. The incidence diminished in the cervical and lumbar injuries, if extension injuries of the neck were excluded. In these, the incidence of heterotopic ossification was high.

Neurological lesion—The relative incidence of heterotopic ossification in patients with fractures of the first lumbar vertebra, who usually showed a flaccid paralysis, was in proportion to the relative incidence of spinal fracture. There was a steep decline of incidence in the patients with flaccid paralysis due to injuries of the second to fifth lumbar vertebrae.

In the group with thoracic vertebral injuries the incidence of heterotopic ossification was highest in patients with injuries of the eleventh thoracic vertebra and with consequent spastic paralysis. The incidence declined in the patients with spastic paralysis produced by higher vertebral lesions. There was in general, little difference in the incidence of ossification between those with spastic and those with flaccid paralyses.

Only those patients with heterotopic ossification following cervical extension injuries had neurologically incomplete lesions.
Figure 14—Case 8. Man aged twenty-one with spastic paraplegia below tenth thoracic segment from fracture-dislocation of ninth on tenth thoracic vertebra. Severe infection of urine; hydronephrosis; chronic uraemia. Multiple pressure sores but none over the affected knee. Apart from a massive ossification near the medial condyle and a small one at the medial margin of the plateau of the tibia, there is another ossification near the lateral condyle with a diaphysial sponge-like extension. Figure 15—Case 12. Man aged forty-eight with spastic paraplegia below fifth thoracic segment from fracture-dislocation of fourth on fifth thoracic vertebra. Multiple pressure sores, but none over the affected knee. Severe urinary infection; hydronephrosis. Ossification below the plateau of the tibia.

Figure 16—Case 13. Man aged sixty-one with incomplete tetraplegia from extension injury of the cervical spine. Inadequate physiotherapy in the early stage resulting in contracture in adduction of both shoulders and in flexion of the left elbow. Pressure sores; severe infection of urine; hydronephrosis. Note ossification in adductor muscles of shoulder. Figure 17—The left elbow. Note the ossification in the cubital fossa.
Management of spinal fracture—Most patients were admitted to the Centre some time after injury, their early treatment having been carried out elsewhere. The type of early treatment had some bearing on the incidence of heterotopic ossification (Table I).

Urinary infection and nephrolithiasis—In the present series the frequency of stone formation was about the same in those patients with heterotopic ossification and those without it. On the other hand, it was closely related to severe infection of the urinary system. It was also noted that the mortality from uraemia in the group with heterotopic ossification was much higher than in the other patients—26 as against 11 per cent.

Pressure sores—All the patients affected by heterotopic ossification had pressure sores.

Thus, ectopic bone at the ischial tuberosity was usually associated with a pressure sore on the adjacent skin. Similarly, sores were usually associated with heterotopic ossification in the coxo-femoral space. Four-fifths of the affected patients had sores on the ipsilateral or contralateral trochanteric areas, or both, and the remaining fifth in the other areas of the pelvic girdle, mainly over the sacrum or the buttocks. Heterotopic ossification in the region of the knee was rarely associated with a sore over the patella or one of the condyles.

TREATMENT

There is no effective treatment for heterotopic ossification. Excision of the bony mass has been tried (Miller and O’Neill 1949), also with reconstruction of the hip joint using a Judet prosthesis (Armstrong-Ressy et al. 1957). The operation very rarely led to a permanent arthrotic effect only, owing to tendency to re-formation of heterotopic bone and to infection. In this Centre intertrochanteric osteotomy was performed in a surgically clean case and led to increased and quick formation of new bone around the site of operation and union of the fragments. No pseudarthrosis could be obtained.

Several cases of acute septic arthritis of the hip were seen resulting from trochanteric sores and associated with formation of ectopic bone. The routine treatment used in these

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tbody>
<tr>
<td><strong>INCIDENCE OF HETERO TOPIC OSSIFICATION RELATED TO TYPE OF PRIMARY TREATMENT</strong></td>
</tr>
<tr>
<td>Method</td>
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<tr>
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</tr>
<tr>
<td>Skull traction</td>
</tr>
<tr>
<td>Open reduction and internal fixation</td>
</tr>
<tr>
<td>Open reduction alone</td>
</tr>
<tr>
<td>Laminectomy</td>
</tr>
<tr>
<td>Plaster-of-Paris, either alone or following open reduction or laminectomy</td>
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</tbody>
</table>
patients at one time was resection of the femoral neck and head. This almost invariably led to ankylosis in extension because of exuberant heterotopic formation of bone. Nearly always sinuses persisted. In all these patients disarticulation of the lower limb through the hip was ultimately necessary: amputation was followed by exuberant formation of bone on the outer aspect of the ilium (Fig. 20).

Thus, amputation of the leg seems to be the only dependable operation in surgically clean cases when a patient suffers from intolerable discomfort or when there are persistent sinuses resulting from excision of the head of the femur. Very few patients indeed will need this mutilating procedure.

Fleming (1957) reported a doubtful clinical improvement after treating two patients with ultrasonic waves.

**PROPHYLACTIC TREATMENT**

It is the writer’s experience that, with a few exceptions, heterotopic ossification in paraplegics results from failure to give these patients the best treatment from the first day of their disability. Severe concomitant injuries or an uncooperative attitude on the part of the patient may make ideal treatment impracticable. Heterotopic ossification tends to occur in association with other complications such as pressure sores. Severe urinary infection. Heterotopic ossification at the outer aspect of the left ilium after disarticulation through the hip.

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**Fig. 19**
Incidence of heterotopic ossification related to the bony level of injury. (Patients dying within the first month of injury have been excluded.)

**Fig. 20**
Case 15.—Man aged thirty-three with spastic paraplegia below ninth thoracic segment from fracture-dislocation of tenth on eleventh thoracic vertebra. Pressure sores. Severe urinary infection. Heterotopic ossification at the outer aspect of the left ilium after disarticulation through the hip.
TABLE II
INCIDENCE OF HETEROTOPIC OSSIFICATION RELATED TO TIME ELAPSING BETWEEN INJURY AND ADMISSION TO THE CENTRE

<table>
<thead>
<tr>
<th>Year of admission</th>
<th>Number of patients</th>
<th>Heterotopic ossification</th>
<th>Number of patients admitted within fourteen days of spinal injury</th>
<th>Heterotopic ossification (Patients admitted within fourteen days of injury)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of patients</td>
<td>Percentage</td>
<td>Number of patients</td>
</tr>
<tr>
<td>1947</td>
<td>17</td>
<td>4</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>1948</td>
<td>5</td>
<td>3</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
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</tr>
<tr>
<td>1959</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>47</td>
<td>29</td>
<td>54</td>
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hypoproteinaemia, anaemia, pressure sores and severe infection of the urinary bladder. Under ideal conditions the risk of heterotopic ossification may be substantially reduced, or even eliminated altogether (Table II).

Déjerine and Ceillier (1918c) in their study of seventy-eight paraplegics found thirty-eight to be affected by heterotopic ossification, an incidence of 48 per cent. The average incidence in the present series was 29 per cent. The incidence for 1948 was 60 per cent, but since then the incidence has been declining step by step with improving standards of treatment.

In 1951 this Centre began to admit paraplegics shortly after injury and it was hoped that none of these "fresh" cases would develop heterotopic ossification, provided the various predisposing factors were avoided. In the main this hope was fulfilled.

In 1954 there were three failures: two elderly men with extension injuries of the cervical spine developed heterotopic ossification in the upper limbs; in retrospect it is felt that they had not received as much physiotherapy as was necessary. One patient had on admission pressure sores and severe infection of the bladder. In 1955 there were again three cases: one patient had on admission pressure sores and a badly infected bladder, and two patients who had been discharged with a poorly controlled urinary infection were found on readmission to have pressure sores, hydronephrosis and heterotopic ossification. Finally, in 1957, a patient with cervical extension injury developed heterotopic ossification in the biceps; once more it seemed that this was due to inadequate physiotherapy.

In this Centre the following prophylactic measures have been applied with success.

**Maintenance of good general condition and avoidance of pressure sores**—It has been known since the works of Cuthbertson (1930, 1932, 1936, 1942, 1954, 1957) that there is often an excessive excretion of nitrogen in the urine during the period immediately following a fracture.
This in turn results in depletion in the body proteins. This occurs in most spinal fractures and the condition is made worse by severe concomitant injuries and early operative procedures. Diminished resistance of the skin to pressure and of the bladder to infection results. Pressure sores and urinary infection develop and lead to further loss of protein. Hypoproteinaemia leads also to oedema of the tissues. The negative nitrogen balance can be corrected to a certain extent by a high-protein diet but unfortunately most paraplegic patients display a considerable loss of appetite in the early stage of their illness and develop hypoproteinaemia with anaemia often lasting for many months. The writer considers that the most reliable method for avoiding and correcting the negative nitrogen balance is blood transfusion. Transfusion may have to be repeated frequently over a long period of time.

In the writer's opinion, oedema from hypoproteinaemia plays a considerable role in the pathogenesis of heterotopic ossification. Charcot (1868) and Déjerine and Ceillier (1918c) described oedema as a constant feature of paraplegia and in all probability what they were describing was a typical hypoproteinaemic oedema.

Constant change of position—Changing the patient's position in bed every two to four hours is fundamental to the treatment of paraplegia but, unfortunately, the principle had sometimes to be discarded in favour of a permanent or semi-permanent prone positioning of the patient in the event of pressure sores or thin scars over the sacrum, etc.

This is an unnatural position which involves shortening of the hip and knee extensors and stretching of the flexors, uncontrolled weight bearing by the anterior thigh muscles with a probable compression of the blood and lymph vessels. Almost all the patients affected by heterotopic ossification were nursed for periods of variable length in the prone position which often resulted in oedema of local origin restricted to the lower abdomen, inguinal regions, genitalia and the upper thighs, the parts of the body left clear of the proximal and distal sectional mattresses. It is this writer's experience that this was often associated with heterotopic ossification.

Early passive and active mobilisation—Frequent passive movements of the paralysed limbs were recommended a long time ago and this is the most dependable method not only for avoiding capsular and pericapsular changes but also for preventing shortening of one muscle group and stretching of the opponents, leading to the necessity for forceful and painful manipulation. This applied equally to the upper limbs in incomplete tetraplegia resulting from extension injuries where considerable shortening of the shoulder adductors and elbow flexors may take place over a period of a few days.

The importance of early mobilisation in a wheel-chair cannot be stressed enough. In case of a complete neurological lesion when no recovery of the lost functions can be expected the patients should be allowed out of bed as soon as the pain at the site of the spinal fracture and the condition of concomitant injuries do not stand in the way (Kerr 1956). In the neurologically incomplete lesions mobilisation in a wheel-chair commences as soon as the danger of increase in the collapse of the crushed vertebral body and of dislocation is over.

Early treatment of excessive spasticity—In the event of excessive spasticity of the lower limbs leading to flexion contractures of the hips and knees, anterior root section, from L.1 to S.1 inclusive, was the method of choice if the general condition permitted. Subarachnoid injection of alcohol was reserved for the poor operative risks. Both procedures were applicable in neurologically complete lesions and in the incomplete ones when the remaining neurological functions were of no practical value. In cases where the spasticity of the thigh adductors was the troublesome factor, an intrapelvic obturator neurectomy was performed. Care was taken to operate as soon as the spasticity had reached its presumable peak as the failure to deal with it early often leads to fixed flexion contractures and heterotopic ossification.

Avoidance of severe infection of the bladder—Practically every patient suffering from a spinal injury with neurological involvement has to go through a period of catheter drainage. Sooner
or later this causes infection varying in degree from a slight bacteriuria to a severe pyuria. It is necessary to do everything possible to prevent or limit this infection.

At the Southport Centre this has been successfully achieved by observing the following rules: 1) A "fresh" patient is admitted to a special post-operative ward where there is less chance of cross-infection and where he remains until the catheter is no longer required. 2) A long, polythene Gibbon catheter, connected directly to a Lane's bottle, is used as a closed-drainage system (Gibbon 1958; Ross, Gibbon and Damanski 1957). This catheter has the advantage of being non-irritant owing to its small size and chemical properties and there is no glass connection at the outer end near the bladder which, with other types of catheter, tends to facilitate cross-infection when the catheter is temporarily disconnected from the bottle. 3) Whatever the patient's method of voiding, either by abdominal straining or by reflex contraction of the detrusor of the bladder, it should be as complete as possible, with no or little residual urine. This is achieved spontaneously, at a certain stage of treatment, or by surgical procedures, mainly by bladder-neck resection (Ross 1951, 1956) or division of the external sphincter (Ross, Damanski and Gibbon 1957, 1958; Ross, Gibbon and Damanski 1957, 1958). The indications for these procedures are established after several urological examinations. In this connection cysto-urethrography is considered to be of great value (Damanski 1961; Damanski and Kerr 1957). 4) Periodical intravenous pyelography is the best method for assessing the effect of the infection on the upper tracts, and to find at the earliest possible moment hydronephrosis, ureteric reflux (Ross, Damanski and Gibbon 1960), loss of renal function or stones.

The writer believes that infected pressure sores and infection of the bladder are the main two factors in the pathogenesis of heterotopic ossification.

SUMMARY
1. A clinical study has been made of heterotopic ossification in 273 patients with paraplegia of traumatic and non-traumatic origin treated at the Liverpool Paraplegic Centre over a period of twelve and a half years.
2. The literature is reviewed and theories of etiology are discussed.
3. Etiological factors have been studied. Prominent among these is inadequacy of early treatment leading to urinary infection and to the formation of pressure sores.
4. It is concluded that there is no effective treatment for established heterotopic ossification.
5. The importance of prophylactic treatment is stressed. Special emphasis is placed on adequate primary treatment, correction of hypoproteinaemia and early mobilisation.

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