THE OSTEOPOROSIS OF IMMOBILISATION IN RECUMBENCY


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This study of immobilisation osteoporosis was undertaken when it was realised that the important observations of Gill (1944, 1947) upon epiphysial disruption and premature fusion at the knee were only a part of a much larger problem. The disturbance of bone growth associated with epiphysial fusion gave Gill's paper its immediate importance. However, prolonged recumbency also produces widespread skeletal changes which in the thorax and both lower limbs are often permanent. These changes have particular import in tuberculosis of the hip but are in any case the effects of an interference with the metabolism of the patient which ought if possible to be avoided.

That many of the present methods of treating skeletal tuberculosis necessarily exert an injurious influence upon calcium and nitrogen metabolism should be well known. The increased risk of urinary lithiasis in such patients, from raised calcium excretion and stasis,

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This text is accompanied by two figures (Fig. 1 and Fig. 2) which depict the skeletal changes observed in immobilised patients. The images illustrate the effects of prolonged recumbency on the knee joint, showing the difference in bone density and appearance between a child and an adult after treatment for tuberculosis.

Cuthbertson (1929) demonstrated the increased excretion of sulphur, nitrogen, phosphorus and calcium by immobilised patients. Howard, Parson and Bigham (1945) showed the prolonged negative nitrogen balance in similar circumstances. Beattie (1947) discussed the metabolic effects of immobilisation after injury, and Dietrick, Whedon and Shorr (1948) made a valuable study of the nitrogen and calcium balances and numerous other aspects of immobilisation in recumbency.

We are familiar with the pale, wizened, undersized, hunchbacked children seen after prolonged immobilisation for tuberculosis of the thoracic spine. They seem stunted by far more than the effect of the kyphosis. All efforts to fatten them fail. We suggest that just as
loss of calcium beyond a certain degree produces changes that are in part permanent, so also chronic disturbance of nitrogen metabolism eventually produces permanent tissue changes. Proof of this sequence awaits study in a metabolic unit, but the subject is mentioned here to emphasise the importance of the disturbances caused by the necessities of treatment.

This paper is confined to the following aspects: 1) The widespread effects of immobilisation upon the skeleton; 2) the additional effect of immobilisation and recumbency in patients with disease of long standing in whom porosis has not previously developed; 3) the uniformity of these changes in the lower limbs, whatever the reason for the immobilisation; and 4) the fact that immobilisation is the only factor common to the various situations where the effects are found.

MATERIAL

Eighty-five patients have been studied during five years (Tables I and II). About a third were seen after activity had been resumed and the remainder during immobilisation with bed rest. All had been or were being immobilised without suspension for at least three months, but a large proportion for one or more years. On account of the present general use in the hospital of compound pulley suspension of frames and plaster beds after the technique of Domnisse and Nangle (1947), it would now be difficult to collect a comparable series.

The points to which we wish to draw attention in this article will be illustrated by selected cases but it is stressed that none of the patients examined who had been immobilised in bed for three to six months failed to show evidence of osteoporosis in one or both lower limbs.

THE SKELETAL EFFECTS OF IMMOBILISATION

The widespread effects—Prolonged immobilisation, even when the limbs are entirely free from disease, produces both in children and adults gross radiographic changes in the lower limbs which illustrate clearly the disturbance of calcium metabolism (Figs. 1 and 2).

* Perthes disease was not originally included in this investigation as these patients are treated by Pugh’s traction and not upon frames at the Royal National Orthopaedic Hospital. However, a similar general porosis of the lower limbs has been observed in these patients.
Immobilisation of one lower limb, for example for disease of the tarsus, produces osteoporosis of the entire hind quarter (Fig. 3). The extent of immobilisation osteoporosis when disease is limited to the proximal part of a limb is well shown in Figure 4. The changes affect both feet, and in children and young adults leave results which may be permanent (Fig. 5).

**Figure 3**
Pelvis and hips of a man five months after he had been put to bed with a below-knee plaster for tuberculosis of the left subtalar joint. Osteoporosis affected the whole hind quarter.

**Figure 4**
Foot of a patient with a tuberculous hip after fourteen months on an abduction frame. Osteoporosis is marked. **Figure 5**—Contralateral foot of a boy aged eleven years who had suffered from tuberculosis of the hip. Radiograph taken two and a half years after remobilisation.

**The additional effect of recumbency and immobilisation**—Walking patients have also been seen in whom subacute tuberculous arthritis had been known to exist for months or even years without producing osteoporosis. The results of subsequent immobilisation with bed-rest provide an instructive means of comparing the effects of the disease alone with those of
the disease plus the immobilisation. A girl of twenty-three years with a four-year history of synovial tuberculosis of the knee showed no porosis. After four months' treatment in hospital a typical radiographic pattern had appeared. A man aged twenty-nine years with nine months' history of a tuberculous subtalar [subastragaloid] joint similarly showed porosis in the region of the lesion only after six weeks' immobilisation in bed in a below-knee plaster. A boy of fifteen years had a swollen ankle for a year but remained at school and played football. After that period of disease without immobilisation, radiographs showed very localised bone destruction of the subtalar joint but no generalised osteoporosis (Fig. 6). He was then rested with the foot encased in a below-knee plaster. At the end of six weeks there were marked radiographic changes throughout the tarsus (Fig. 7). Six weeks of rest did to the bones of the whole foot what a year of activity with a tuberculous subtalar joint had failed to do.

These were all proved cases and demonstrate the part played by immobilisation, necessary though it may be, in producing not only gross osteoporosis in regions and limbs remote from any infective disease, but also at the site of tuberculous disease itself.

**The uniformity of the changes, and immobilisation as the common factor**—The essential part played by immobilisation in producing the radiographic picture in the patients studied is proved by the following facts: 1) precisely similar patterns can be seen throughout the leg above a diseased tarsus, below a diseased hip, or in the other limb that has been immobilised; 2) these same changes will occur in both legs even when disease is limited to the spine (Fig. 2); 3) precisely similar changes follow immobilisation for tuberculous arthritis, Still’s disease, rheumatoid arthritis or traumatic synovitis; or indeed when the immobilisation is entirely involuntary as in extensive anterior poliomyelitis.

**Radiographic patterns**—There are three age-group patterns of this osteoporosis due to recumbency, namely under five years, five years to epiphyseal fusion, and adult. It is not proposed to describe the patterns in detail but the similarity of pattern in different conditions is illustrated by the radiographs of adult knees (Figs. 8 to 11). The pattern common to these can be well seen. It includes a generalised decrease of bone density, a zone of more intense porosis at the original site of the metaphysis, a narrower zone immediately deep to the cortex of the bone ends, and further irregularly distributed patches. The reason for the development of these areas is at present obscure. This series of adult knees illustrates the fact that, apart from bone or cartilage destruction, there is no way of distinguishing
Both knees of a woman aged twenty-five years treated for a tuberculous right hip for one year on a Jones double abduction frame. Note the pattern of osteoporosis.

Figure 9—Radiograph of the arthritic knee of a man with monarticular rheumatoid arthritis after one year in bed in a Thomas's splint. Typical pattern of osteoporosis. Figure 10—Radiograph of the left knee of a patient confined to bed for fifteen months with poliomyelitis.
radiologically between the bone pattern of immobilisation osteoporosis in a diseased joint and in an otherwise healthy joint.

Discussion—There is one immediately practical point arising out of this study. In the conduct of tuberculous arthritis, osteoporosis is taken for granted. Our evidence suggests that one factor, possibly large, in the production of this local osteoporosis is the general immobilisation. Intense local osteoporosis may even cause the radiographic disappearance of the head of the femur. Such porotic bone may reappear or may crumble and be irrevocably lost. There is evidence, however, that even in joints which radiographically appear most severely affected, the actual tuberculous process may be limited to the surface of the bone and two or three millimetres deep to it (Sissons 1950). In some cases the loss of cancellous bone may therefore be due far more to mechanical disintegration during the stage of intense porosis than to destruction by tuberculous granulation tissue. This point indicates the importance of obtaining the benefit of local rest but without an intense negative calcium and nitrogen balance. Recalcification at the site of disease, even while the region is still immobilised, is generally accepted as evidence of healing. The maintenance of a positive calcium balance should hasten healing by facilitating such recalcification and must help to prevent the mechanical collapse of osteoporotic cancellous bone.
SECONDARY DEFORMITIES FROM IMMOBILISATION OSTEOPOROSIS

Undesirable local results of this general loss of bone occur commonly and, omitting the epiphysial changes so fully described by Gill (1944, 1947), three of practical importance which occur in situations where there is no disease will be cited.

The thorax—When a child under ten years of age is placed upon the flat leather surface of a Jones double abduction frame for more than three or four months, the chest begins to flatten and the width to increase in comparison with the antero-posterior thickness. The measurements of the chests of 500 "normal" school children shown in roman numerals in Table III, from the ages of four to eighteen years, were taken at the level of the junction of the middle and

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TABLE III

CHEST RATIOS

Roman numerals—Ratios obtained by dividing the antero-posterior chest measurements into the maximal lateral measurement in 500 normal school children

Italic numerals—Ratios obtained in thirty-seven children treated on frames for six months or more

THE JOURNAL OF BONE AND JOINT SURGERY
lower thirds of the sternum, where the width is commonly greatest. The ratios are arranged in groups according to age and height. The actual figures are the average of each group and indicate the fairly narrow range of variation. The antero-posterior figure divided into the greater side-to-side figure gave an index varying from 1.3 to 1.5 at all ages. If children on frames are measured at intervals during their immobilisation a change can be watched. Some fifty have been measured and it is common to obtain an index between 1.5 and 2.0 indicating moderate to gross degrees of flattening (Stevenson 1951). Figure 12 is a photograph of a child with a ratio of 2.0. The effect on respiratory movements of the thoracic cage in severe cases is to bring the ribs down into the expiratory position; inspiratory movement of the ribs is reduced and breathing may even become almost entirely diaphragmatic. Inspiration then causes ballooning out of the upper abdomen with an almost motionless chest. Table III also gives the ratios (italic figures) of thirty-seven individual patients, arranged by the same method, all of whom had been treated upon abduction frames for six months to two years or even more.

The condition we refer to as “frame chest” we believe has two causes. The first is the weight of the intrathoracic viscera acting for a long time upon the thoracic cage in one position. The back is supported on a flat firm surface and the sides are completely unsupported. Just as a round table-jelly if laid on its side will tend to “flatten” and acquire an elliptical cross-section, so will the unsupported chest. The second factor is undoubtedly the loss of bone structure during immobilisation which makes such alterations in shape more easy.

For prevention of the deformity a moulded plaster bed for the trunk from the top of the buttocks upwards is necessary. The child would not then be lying on a flat surface and the sides of the chest would be supported. Breathing exercises are useful to prevent the extreme loss of intercostal movement with largely phrenic respiration mentioned already.
But they will not prevent skeletal deformity on a frame. It is the "under sevens" and especially the very young who suffer most. Children breathe well when doing it automatically. If one tries to teach a young child to breathe consciously it may get into difficulties: for instance, intercostals and diaphragm may work in opposition. Co-operation is not easily obtained. Breathing exercises in the young during prolonged recumbency are important, but they are only a very uncertain prophylactic against "frame chest."

**Fractures**—Minor falls during remobilisation of these children produce fractures distressingly often; indeed, they may even occur in bed (Fig. 13). It was easy in less than two years to collect a score of such incidents in patients at that time in hospital. Such fractures, most common just above or below the knee, usually heal well and sometimes provide an opportunity for the correction of fixed deformity. But an accident of this kind near the end of a long and tedious course of treatment is, to say the least, a most unhappy psychological setback to both child and parents.

**Unilateral coxa valga**—This deformity is readily produced in young children who have one lower limb immobilised for disease of the knee in a Thomas's splint. The entire limb becomes porotic and gradually the angle between the neck and the shaft of the femur...
increases. An example is shown in Figure 14. Six similar cases have been seen in the last three years. For this reason it is worth while taking radiographs of the hips of children under the age of seven years with disease of the knee who have been treated in a Thomas's splint for more than six months.

CONCLUSION

While it is not denied that immobilisation of a diseased joint may be essential, there is a growing mass of evidence that immobilisation in recumbency of the whole patient has severe effects both in the neighbourhood of the actual lesion and upon the skeleton as a whole. Further search for measures to counteract the undesirable skeletal effects of recumbency is much needed.

I am grateful to the surgeons of the Royal National Orthopaedic Hospital for allowing me to study their patients. Dr E. A. Allen, radiologist to the Hospital, has been unfailingly kind in discussing the radiographs. The Departments of Radiography and Photography have been most co-operative and their willing help has made this study possible.

REFERENCES