

FROM THE APELVIKEN COASTAL SANATORIUM, VARBERG
CHIEF: MED. DR. ROBERT HANSON
AND
FROM THE ORTOPAEDIC CLINIC OF THE KAROLINSKA INSTITUTET, STOCKHOLM
CHIEF: PROFESSOR PATRIK HAGLUND

ON DEFECTS IN THE
BONE-GRAFT AFTER ALBEE'S
OPERATION FOR
TUBERCULOUS SPONDYLITIS

BY

G. ODELBERG-JOHNSON

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TO MY WIFE

I N D E X

Introduction	7
Brief review of the anatomy and mechanics of the spinal column ...	8
The morbid anatomy of tuberculous spondylitis and its influence on the static conditions of the spine ...	13
The treatment of tuberculous spondylitis ...	23
The development of the bone-graft after transplantation ...	34
Defects in bone-grafts as described in the litterature ...	42
The authors histological investigations ...	50
The authors clinical material, reviewed with reference to the mode of production of the graft defects... ..	75
The clinical picture of the graft defect ...	108
Repair of graft defects ...	111
The significance of graft defects for the prognosis of the operated spondylitic process ...	120
Summary and conclusions ...	130
Case histories ...	148
Bibliography	207

PREFACE

The investigation, the results of which are submitted here, was carried out at the Coastal Sanatorium of Apelviken and in the Ortopaedic Clinic of the Caroline Institute, Stockholm, during the period 1931—34.

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Stockholm in March 1934.

INTRODUCTION

A frequent complication after an Albee operation is a defect arising in the periosteal bone-graft taken from the corticalis of the tibia and fixed into the split spinous processes. In the following, a clinically and roentgenologically demonstrable defect of that nature will be referred to as a *graft defect* whether it occurs in the original bone-graft or in the bone bridge replacing it after its reconstruction.

The author's clinical material comprises 37 patients treated at the Coast Sanatorium at Apelviken, Sweden (C. S. A.). 36 of these cases were operated on at this place; one patient had the Albee operation performed at the Linköping Hospital, and was subsequently under treatment at the C. S. A. Among a total of 278 patients with tuberculous spondylitis operated on by Albee's method during the period 1928—32 at the C. S. A. one or several graft defects were diagnosed in 36 cases. Had a complete after-examination been undertaken of the total number of operated cases, an additional number of graft defects would probably have been detected. For several reasons this had to be omitted. During the period 1928—32 there have thus been at least 12.9 % cases with graft defects among the operative material of the C. S. A.

In addition, the author has had the opportunity of perusing Dr. H. Waldenström's operative material, in part previously published by himself, from St. Göran's Hospital, Stockholm, and also a similar material from the Styrö Coast Hospital.

At St. Göran's Hospital the Albee operation was performed

for tuberculous spondylitis during the period 1911—32 in 205 cases. Defects in the inlaid bone-grafts were observed in 30 cases, thus in 14,6 %.

At the Styrsö Coast Hospital neither the technique of operation nor the graft material had been of uniform nature, wherefore this material cannot be fully compared with that of the author. With the therapeutic technique suggested by Waldenström, which has been employed in his material and also in the author's cases, such graft defects seem to be a common post-operative complication. It has therefore seemed to the author that a closer investigation of the subject would be well founded. The following are some questions demanding closer enquiry:

- 1) Under what circumstances does a graft defect arise and which are its immediate causes?
- 2) To what symptoms does a graft defect give rise and how does it affect the function of the spine?
- 3) What are the possibilities of union of a graft defect?
- 4) What bearing has it on the prognosis of the operated spondylitis?
- 5) How are graft defects to be avoided?

Chapter I.

BRIEF REVIEW OF THE ANATOMY AND MECHANICS OF THE SPINAL COLUMN

The spinal column is made up of two important main parts. Ventrally, the vertebral bodies with intervening cartilages form a coherent articulated pillar. Dorsally, arches and processes are connected through ligaments and intervertebral joints. This construction is well fitted for fulfilling the three main functions of the spine. (*R. Fick*).

a) The spinal column serves as a protective organ for the spinal cord. This is enclosed in the ventral portion of the spinal canal near the posterior boundary of the vertebral bodies. The spinal canal is limited ventrally by the vertebral bodies and

intervening discs, laterally and dorsally by the vertebral arches and the elastic ligaments expanded between them.

b) The spinal column is an elastic organ of support. Its supporting function is mainly exercised by the pillar of vertebral bodies with intervening discs. The elasticity is determined partly by the elasticity of discs and ligaments, partly by the two S-shaped curves of the spine, a large curve in the sagittal plane and a slight one in the frontal plane.

c) In conjunction with the muscles of the back and the trunk the spinal column serves as an organ of motion. It has been characterised by *Fick* as a synarthrotic chain. The relative mobility between any two adjacent vertebrae is slight but the summation of all such minor movements affords the spinal column as a whole a considerable range of mobility.

In the anatomical specimen the isolated pillar of vertebral bodies with intervening discs possesses considerable mobility by virtue of the construction of the intervertebral discs. The central portion of the disc is made up of a mucoid tissue under strong pressure and holding much fluid, the nucleus pulposus. Peripherally there is a system of lamellae, the annulus fibrosus, arranged concentrically around the nucleus pulposus and fixed to the end plates of the vertebrae. The lamellae are made up of fibrous strands interwoven crosswise with solitary elastic fibres and of great tensile strength. A change in the relative position of two adjacent vertebral bodies is rendered possible by fluid displacement within the nucleus pulposus with alteration of its position and shape. On flexion the fluid within the nucleus pulposus is shifted towards the convexity of the curve of flexion. The relative movements of vertebral bodies can only be carried out round axes through the nucleus pulposus. The relative displacability of the vertebral bodies is limited by the tension of the taut annulus fibrosus which checks and hinders every movement beyond a certain limit.—The relative mobility of the vertebral arches is modified by the tension of the ligaments between arches and processes, the tension of the capsules of the intervertebral joints, and by the form and position of the articular surfaces which vary in the different regions. Each pair of inter-

vertebral joints has a very small range of mobility limited by the tension of the joint capsules. Small movements can be carried out in different directions. These movements can be characterised as rotation, »parallel gliding« and »separation«. Each pair of intervertebral joint surfaces may be regarded as part of a large common hypothetic surface of rotation; small rotatory movements can take place round the axis of this common surface of rotation. Since the surfaces of the intervertebral joints are of different shape and position in different parts of the spine, the shape of the common surface of rotation and position of the axes of motion will also vary within the different regions.

In the undamaged spine the relative mobility of individual vertebrae is small. On the one hand only such movements can be carried out allowed by the nuclei pulposi without being hindered by the annuli fibrosi, on the other hand only such movements that are permitted by the intervertebral joints. Moreover is the mobility of the spinal column restricted by the shape of the processes, by the tension of ligaments and by the thorax. Individual vertebrae can thus perform minor movements round axes passing through the centres of the nuclei pulposi, movements which simultaneously do not exceed the range of movement of the intervertebral joints. The intervertebral joints allow not only small rotatory movements but also »parallel gliding« and »separation«. All movements beyond a certain slight extent are stopped and checked by the tension of the annuli fibrosi. By summation of such minor displacements between individual vertebrae the spinal column attains as a whole a considerable range of mobility. Yet the range of mobility of the undamaged spine is much less than that of the isolated column of vertebral bodies or the isolated row of vertebral arches.

The movements of the spinal column may be summarised as those of flexion, extension, lateral movement and rotation. Movements are rarely pure, the most common being a combination of rotation with other movements; isolated movements between individual vertebrae never occur, several vertebrae always taking part in the spinal movements. The only exception is the atlas, which is capable of large independent movements in relation to the axis.

Different regions of the spine have different ranges of mobility. The mobility of one section of the spine is in direct proportion to the height of the intervertebral discs and inversely proportional to the height and cross section of the vertebral bodies.

The mobility of the cervical region is considerable. The intervertebral discs here are high, the vertebral bodies low, the cross section small. The capsules of the intervertebral joints are wide and flaccid. Flexion and extension in the cervical region are possible within wide limits. The movements here take place round frontal axes through the vertebral bodies. Pure lateral flexion and rotation can only be carried out to a moderate extent but the two combined yield a wide range of mobility.

In the thoracic region the intervertebral discs are lower, the vertebral bodies higher and their cross section greater than in the cervical region; mobility here is much more limited. The intervertebral joint surfaces converge dorsally and cranially, they are cylindrically curved and form part of large cylindrical surfaces with central axes far in front of the spinal column. The cranial and caudal parts of the thoracic region permit of quite a considerable movement of flexion round frontal axes through the nuclei pulposi. Lateral movement is possible round sagittal axes through the nuclei. Forward and lateral flexion can be carried out through »separation« and parallel gliding movements in the intervertebral joints. Normally, extension can be carried out to complete straightening of the spine, further movement being checked by the high vertebral arches and the long tile-like downward-sloping spinous processes. Slight rotation can be carried out round mainly vertical axes of the intervertebral joints located far in front of the vertebral bodies. Rotation is limited by the tension of the annuli fibrosi, rotation and flexion movements are largely checked by the thorax.

In the lumbar region the intervertebral discs as well as the vertebral bodies are high and the cross section is great. The intervertebral joints are curved in a slightly cylindrical fashion, the axes are situated far behind the spinal column and the joint spaces have a vertical, almost sagittal position. On account of the shape and position of the intervertebral joints rotatory

movements are almost completely checked by the tension of the annuli fibrosi. Considerable extension and moderate flexion can be carried out round frontal axes through the nuclei pulposi, and considerable lateral movement is possible round sagittal axes. All these movements take place by parallel gliding and slight »separation« in the intervertebral joints.

On flexion and extension the length of the spine varies, increasing on flexion and diminishing on extension. This is particularly noticeable in the lumbar region. Combined movements of different kinds are also common in the thoracic and lumbar regions.

The spinal column is influenced by all the muscles of the trunk, but above all by the complicated musculature of the back. The uniform construction and innervation of these back muscles is particularly well adapted for their static and motoric functions. The tonus of the musculature is of decided importance for the equilibrium and stability of the whole spine. The movements of the spine, always involving large parts of it, are the result of a complicated interplay of muscles of the whole trunk. Isolated movements between individual vertebrae scarcely ever take place. Injury to the muscles of the trunk, and particularly to those of the back, causes the function of the spinal column to suffer. This applies to the static as well as the motoric function. Extensive injuries and paralysis of the back muscles will impair the spine as a supporting organ, will make it useless as an organ of motion and often fantastically deformed.

The spinal column can, in fact, be regarded as a synarthrotic chain. It is only when all the links of the chain are intact and capable of moving on one another that the spine can stand the stresses and strain to which it is exposed during work and rest. The normal function of the intervertebral discs is then of decisive importance. Damage to a single disc through disease or trauma will break down the whole system. The vertebral bodies above and below the damaged disc will then come to rest directly on one another. Even in movements otherwise physiologically sound a scraping friction will take place between those bodies. In order to prevent as far as possible the pains

and functional disturbances arising therefrom the back muscles contract; this causes a great part of the spine to be held as rigid as possible, and the damaged surfaces of the vertebral bodies and the remnants of the discs come to be pressed and fixed against one another. The contracture of the back muscles may persist for a long time, until the disturbed function of the spine is restored either by repair of the damage sustained to the intervertebral disc or through firm osseous or fibrous union being established between the vertebral surfaces above and below the destroyed disc. Destruction and collapse of a vertebral body likewise interrupts the continuity of the spinal column. In that case too large parts of the back become muscularly fixed with the view to restoring as far as possible the damaged continuity and maintaining the supporting function of the spine. If the adjacent discs remain intact, the function of the spine can often be materially restored after osseous union has been established between the remnants of the damaged body. If adjacent discs are destroyed primarily or secondarily, the static and motoric functions of the spine can be partly restored by solid union, fibrous or osseous, being established between the damaged vertebral body and its neighbours. Localised ankylosis will then result.

Chapter II.

THE MORBID ANATOMY OF TUBERCULOUS SPONDYLITIS AND ITS INFLUENCE ON THE STATIC CONDITIONS OF THE SPINE

Haematogenous tuberculous spondylitis is almost exclusively confined to the spongy cancellous part of the vertebral bodies. In the more compact arches and processes tuberculous ostitis is of rare occurrence. The localisation of tuberculous foci in the vertebral bodies is determined by the vascular distribution in the spine. The vertebral bodies are nourished by the vertebral, intercostal and lumbar arteries. The vertebral arteries give off spinal branches which in the cervical region enter the spinal canal via the intervertebral foramina. From the main stems of

the intercostal and lumbar arteries slender branches pass to the anterior surface of the dorsal and lumbar vertebral bodies. The main blood supply to these vertebrae is obtained from the spinal branches of the posterior ramifications of the intercostal and lumbar arteries. All the spinal branches pass through the intervertebral foramina and divide in the spinal canal into three branches. The posterior branch supplies the vertebral arch, while the middle branch supplies the meningi and spinal cord. The anterior branch divides into a cranial and a caudal branch, which enter into anastomosis with corresponding twigs from the spinal branches coming from the intervertebral foramina immediately above and below. In this way we get on the dorsal surface of the vertebral bodies two vertical vascular arcades, one on each side, connected by horizontal anastomotic branches. From these arcades arterial branches perforate the posterior surface of the vertebral bodies, ramifying in the cancellous part of the vertebral body (*Quain, Rauber-Kopsch, R. Hanson*). —The blood vessels of the intervertebral discs undergo degeneration and disappear in adolescence. The vessels in the nucleus pulposus disappear already shortly after birth, and latest about the age of 25 years the annulus fibrosus becomes devoid of blood vessels (*Übermuth*).

A tuberculous focus develops in a bone after infection of its vascular area with some tuberculous virus circulating in the blood. The exact course of events in the formation of a tuberculous bone focus is, however, unknown. Some artery in the bone may thus become obliterated through an embolus consisting of tubercle bacilli or of some tuberculous tissue. A haematogenous infection of the vascular wall with the formation of an obliterating and gradually disintegrating tubercle of the intima is also conceivable. Early tuberculous foci in the spine are generally located in the anterior half of the vertebral body, corresponding to the end branches of the anterior ramifications of the rami spinales. Such foci are often multiple, and at first run their course without giving rise to any clinical symptoms. Such symptoms only appear when the continuity of the supporting pillar becomes impaired. Sometimes central vertebral foci are

observed on skiagrams or on the post-mortem table. In many cases the tuberculous lesion involves the contiguous parts of two neighbouring vertebrae already at the onset of clinical symptoms. It often appears as if two vertebral bodies were affected simultaneously, one focus on the proximal, another on the distal side of the intervertebral disc. (*R. Hanson*). In the subsequent course of the process such foci break through the respective end plates and encroach upon the disc, causing destruction of this by damaging nutrient vessels of the vertebral body, and also by the invasion of specific granulation tissue. Isolated tuberculous foci in the intervertebral discs have been described by Morasca. The author has not met with any case of that nature.

The further progress of the foci in the vertebral bodies is characterised by liquefaction of the surrounding spongy tissue. The process often spreads ventrally, breaking through the anterior surface of the vertebral body, generally without damaging the periosteum or the anterior common ligament. At this stage the tuberculous process is checked ventrally by the periosteum of the bodies and the anterior common ligament. Cranially and caudally the process is checked by disintegrating spongiosa of the vertebral bodies, or by remnants of discs deprived of their nutrition. Dorsally, destruction may proceed right out to the dorsal periosteum of the vertebral bodies. One or more bodies may be entirely destroyed right out to the pedicles. It rarely happens that the tuberculous process encroaches upon the compact bone of the vertebral arches, and scarcely ever does it dorsally go beyond the articular processes (*Menard*). In the early stage of the process the diseased focus may be characterised as a larger or smaller tuberculous cavern at the site of the destroyed vertebrae, filled with granulations, caseous material and small sequestra. From this cavern the tuberculous infiltration and liquefaction extend into neighbouring vertebral bodies in the form of caries. Smaller embolic disintegrating foci communicate with the large cavern which becomes a depository of granulations, detritus and tuberculous pus. Gradually the pressure within the cavern increases and the periosteum on the

anterior and posterior boundary of the vertebral bodies will be under tension. In this way the periosteum of bodies above and below the focus may become separated from the bone. Between the periosteum and the anterior surface of the previously healthy vertebral bodies we get a paravertebral abscess forming. A perimeningeal abscess may arise in the spinal canal on the posterior surface of the vertebral bodies. The perivertebral abscesses may grow to a large size and thus cause the periosteum to become separated from numerous bodies above and below the original focus. The vertebral bodies stripped of their periosteum may be attacked more or less deeply by the tuberculous caries; the anterior parts of the intervertebral discs may also become damaged within the abscess area. A similar process is regarded by some authors as *spondylitis anterior superficialis*, and is stated to be caused by haematogenous minor foci in the anterior parts of the vertebral bodies brought there via the efferent small ramifications from the main stems of the intercostal and lumbar arteries. An intraspinal abscess often gives rise to paraplegia through compression of the spinal cord. Such an abscess may, like a perivertebral abscess, spread under the periosteum, causing superficial damage to vertebral bodies and intervertebral discs.

Collapse of a disintegrated vertebral body or destruction of an intervertebral disc after perforation of the end plate of the vertebral body will interrupt the continuity of the spine. In such an event the function of the spine as a supporting organ will be impaired or entirely inhibited, and can only be restored by establishing a secure connection between the cranial and caudal segments of the spinal column.

The injured part together with large neighbouring parts of the spine are fixed by contracture of the back muscles. This contracture aims at restoring as far as possible the interrupted continuity, the cranial segment of the spine being forced against the caudal segment in order to make good, in part or entirely, the defect in the spinal column. When the patient is in the erect position, the compression of the segments will be still further augmented by the part of the body weight above the diseased

area. The row of vertebral arches being maintained, the muscular contraction is usually unable to compress the damaged part of the spine in an axial direction. In order to cover the defect in the spine, and thus obtain a certain amount of stability, the spine, especially the dorsal region, must be bent forward. Since vertebral bodies and intervertebral discs within the damaged area are defective or entirely destroyed, this forward

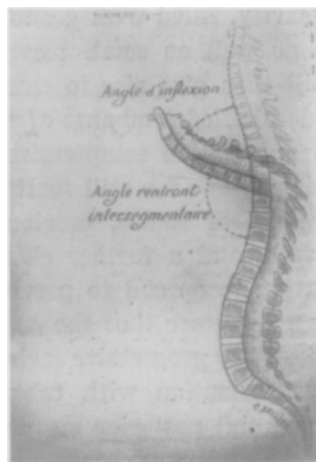


Fig. 1.
(after Menard)

bending will now take place round frontal axes through the intervertebral joints. *Menard* has called this kind of displacement »inflexion«. (By inflexion this author implies not only the movement itself but also the definite angulation between the cranial and caudal segments of the spine). In »complete inflexion« the caudal vertebral remnant of the cranial segment rests upon the upper surface of the cranial vertebral remnant of the caudal segment. In »incomplete inflexion« a space remains between the vertebral remnants of the cranial and caudal segments. By »inflexion angle« is meant the angle between the axis of the cranial segment in its normal and in

its inflected position. This angle becomes greater on increase of the inflexion (Fig. 1).

When the defect in the spinal column is caused by a tuberculous process, the destruction of the spongiosa is at first little localised. The remaining vertebral remnants in the cavity and its immediate neighborhood are infiltrated by tuberculous granulations and diffusely decalcified. On complete inflexion pathologically changed spongiosa will thus be compressed within the area of the cavity, filled with granulations and caseous material. Pressure as well as small movements between the contact surfaces will then give rise to mechanical destruction of the compressed decalcified remnants of the vertebral bodies, by *Menard* termed «ulceration compressive». This mechanical destruction makes it possible for still further inflexion to take place. Additional vertebral bodies, previously sound, may be forced into the cavern, and a further chance is afforded the tuberculous infiltration to spread to previously healthy spongiosa. It will be seen therefore that the original embolic focus becomes enlarged, firstly by progressive caries within the cavern, secondly by abscess formation with tuberculous, superficial caries of the anterior and posterior surfaces of the vertebral bodies, and, thirdly, by compression and mechanical erosion of the vertebral remnants on complete inflexion.

On collapse of the spinal column as a result of destruction of opposing parts of two adjacent vertebral bodies the upper damaged body falls down upon the lower. On this movement of inflexion, which takes place round a frontal axis through the intervertebral joints of the damaged vertebrae, the spinous process of the upper vertebra is shifted cranially, and the distance between the two damaged vertebrae is increased. On complete destruction of a vertebral body its arch is severed from its connection with the spinal column. In the thoracic region it may happen that a liberated arch of that kind on account of the shape and position of the surfaces of the intervertebral joints is forced out and dislocated dorsally and distally in relation to other vertebral arches. On complete destruction of several bodies several arches may be forced out of line backwards; the

gibbus formation will then become still more marked by the protruding spinous processes spread out in a fan-like fashion.

Thus by the above described processes the tuberculous lesion goes from bad to worse. New vertebral bodies are forced down into the cavern, and the inflexion is still further increased. In such way the tuberculous focus may go on spreading for years, steadily causing new parts of the spine to become destroyed. In the case of numerous bodies being involved the detached arches will be forced backwards into a »folding«. In spite of extensive destruction of vertebral bodies complete inflexion is thus rendered possible. Thus arise the large acute-angled humps in the thoracic parts of the back. In the case of asymmetrical lesions we may get a lateral angulation. Rotation between two vertebrae may occur in asymmetrical vertebral destruction, yet the rotatory displacement is never as great as, for instance, in rachitic kypho-scoliosis.

In the cervical region complete inflexion never occurs, since the broad articular and transverse processes here, situated on the lateral side of the bodies, only permit of incomplete inflexion. By contraction of the neck muscles the great possibilities of extension in this region can be utilized for counteracting the tendency to inflexion and thereby also to gibbus formation. The absence of one or two vertebral bodies may thus be entirely compensated by extension. Destruction of several cervical bodies cannot be compensated even by maximal extension with the closest possible compression of the low cervical arches. In such cases we get a small flat gibbus. In the upper and middle parts of the thoracic region the shape of the vertebrae and the construction of the intervertebral joints prevent any appreciable extension taking place. Destruction of a single vertebral body here causes complete inflexion and considerable angulation and gibbus, which it is impossible to compensate by extension. In the case of destruction of six or eight vertebrae the hump may become enormous. In the case of extensive destructions in the thoracic region the thorax sometimes prevents complete inflexion from taking place. In the distal part of the dorsal region the possibility of extension is greater, wherefore spondyli-

tis in this part need not give rise to as large a hump as a process of corresponding extent in the upper or middle thoracic spine. Destruction of one or two vertebral bodies in the lumbar region gives rise to complete inflexion. This inflexion may be reduced considerably by extension. The intervertebral joints permit of a certain amount of vertical displacement between the different vertebrae. A symmetrical destruction of the spinal column in the lumbar region may therefore be partly compensated by axial compression of the damaged vertebrae. A lesser destruction in the lumbar spine produces, despite inflexion, scarcely any gibbus, while a lesion of two or three vertebral bodies causes a rounded gibbus of fairly moderate size. Several spondylitic foci with multiple gibbositities in different parts of the back are of frequent occurrence.

In tuberculous spondylitis of the thoracic spine several vertebrae are often involved. The reasons for this are several. The cross section of the vertebral column in the thoracic region is rather small, bodies as well as intervertebral discs are low. Perivertebral abscesses here may spread under the periosteum and extensively erode the anterior surface. Because of the pronounced tendency to inflexion new healthy vertebral bodies are continuously being forced toward the tuberculous focus. In the lumbar region the cross section of the spine is larger, the vertebral bodies are more strongly built, and bodies as well as intervertebral discs higher. In this region perivertebral abscesses will soon communicate with the psoas sheaths and empty their contents into these.

Extensive subperiosteal abscesses on the front aspect of the vertebral column occur much more infrequently in the lumbar region than in the thoracic.

As in other tuberculous bone lesions (with the exception of *spina ventosa*) so in tuberculous spondylitis, the tendency to new-bone formation is slight. This is one of the reasons why recovery takes such a long time. Repair of the tuberculous bone destruction in the vertebral column is often preceded by bony union between the arches of the bodies affected. *Menard* has observed such bony union 2—3 years after

the onset of spondylitis, generally commencing with bony ankylosis of intervertebral joints. The osseous union may then proceed further from the intervertebral joints, ventrally between the pedicles and dorsally between arches and spinous processes. Such fusion of arches and processes may involve the entire diseased area or only part of it. Complete fusion of the arches belonging to all the damaged vertebral bodies is no guarantee against further enlargement of the hump with increase of inflexion. It is only when the tuberculous process in the bone has been arrested, and stability established in the column of vertebral bodies and discs by secure connection between its two segments, that the tendency to further gibbus formation ceases. The osseous union between the arches affords the damaged spine a certain amount of fixation, thereby possibly facilitating repair of the tuberculous foci in the vertebral bodies (*Menard*).

The formation of a hump is a natural sequence of normal and pathological factors. If left to itself, Nature will in many cases repair the tuberculous spondylitic process with the formation of a hump. The result will often be a firm spine, though deformed and of limited mobility.

The formation of a gibbus gives rise to considerable disturbances in the weight-bearing conditions of the vertebral column and the equilibrium of the body. Equilibrium can only be regained on disappearance of the widespread muscular contractures of the back, and when the patient has begun getting up from bed. Only then does the disturbed equilibrium of spine and body become troublesome. By maximal extension and compensatory lordosis of the undamaged areas respectively above and below the gibbus equilibrium is shifted in the vertebral column so as to enable the patient to move about more unhampered in the erect position. The compensatory lordoses affect the position and shape of the whole vertebral column, and the final result will be an equilibrium which reminds of that of the normal spine. As already mentioned, the cervical and lumbar regions possess the greatest possibilities of forming lordosis. Yet, particularly in children, the thoracic region and also the sacrum are able to partake in quite an unexpected degree in the

formation of compensatory lordosis. In the formation of lordosis the fluid in the nucleus pulposus is displaced ventrally; skiagrams show the intervertebral spaces to be increased in height ventrally and diminished dorsally. In childhood, the healthy vertebral bodies may in cases of maximal compensatory lordosis of the lumbar region assume quite a different shape, so much so that the height may even be twice the size of the sagittal diameter. (*Wullstein*).

Slight gibbus formations in the cervical region are compensated by extension in the atlanto-occipital joint and slight lordosis in the cervico-thoracic region. At a first glance these patients appear merely to have a strikingly short neck. The frequently large gibbositities in the upper thoracic region are compensated by maximal extension in the whole cervical region and a moderate extension in the atlanto-occipital joint, further by stretching and sometimes by mild lordosis of the lower thoracic region, and by lordosis in the lumbar region. In such cases the spinous processes all the way from the lower limit of the gibbus to the sacrum may form a regular, posteriorly concave curve. A gibbus in the mid-dorsal region is compensated by a maximal lumbar lordosis. The thoracic part above the gibbus is fully extended and may occasionally be slightly lordosed. The cervical spine is moderately extended. A gibbus in the dorso-lumbar region is compensated by maximal lumbar lordosis. The thoracic spine above the gibbus is extended so that the normal kyphosis is obliterated; children may occasionally develop a mild lordosis in this area. A gibbus in the middle or lower lumbar region is compensated by lordosis of the dorso-lumbar and lower dorsal region. The normal dorsal kyphosis is diminished, the remaining kyphosis only comprises the uppermost part of the dorsal region. The sacrum rotates with the apex ventrally; in children its shape is also changed, its curve is flattened out so that its normal kyphosis often entirely disappears. The pelvis accompanies the sacrum in its rotation, causing the symphysis to be raised. The patient must walk with his knees flexed in order thereby to shift the centre of gravity of the pelvis and the lumbar part of the back forward in relation to the feet. *McNard* main-

tains that none but wholly undamaged parts of the spine partake in the formation of compensatory lordoses. The formation of such compensatory lordoses in multiple gibbosities is exceedingly complicated.

What has been related above applies above all to tuberculous spondylitis in children. The gracile and delicate structure of the spongy bone in children, as also the lesser dimensions of the vertebrae, often lead to widespread vertebral destructions with considerable deformity. In children there are great possibilities of repair with bony ankylosis between the damaged remnants of the vertebral bodies. The soft skeleton of the child is more readily modified than that of the adult, and during its continued growth its shape may undergo considerable changes. As a result of this the vertebral column of the child has far greater possibilities of undergoing compensatory re-shaping than that of the adult. A spondylitis in an adult is usually of less extensive distribution and shows a far less marked deformity; the compensatory changes in the shape of the spine are much less apparent. On account of the less extensive distribution of the destruction the impaired function of the back will be less marked than in children. The tendency to repair of a tuberculous spondylitis is far less marked in adults than in children. The osseous block-formation often observed in children between vertebral bodies affected with tuberculosis is uncommon in adults although it may at times occur, even in advanced age (vide case 16). In adults the formation of periosteal bridges between the diseased and adjacent healthy vertebral bodies often adds to the stability of the back.

Chapter III.

THE TREATMENT OF TUBERCULOUS SPONDYLITIS

The treatment of tuberculous spondylitis must in the first place be directed against the tuberculous disease itself. As in all other forms of tuberculosis a treatment aiming at an increase of the bodily strength in general is indicated here, giving the body a chance of overcoming the infection. The attention should be mainly directed towards a hygienic-dietetic treatment with plen-

tiful and a great variety of food, light and air besides a long period of rest. Treatment with direct sun-light, or if this is not available artificial light of different kinds, is of great importance for patients whose general condition is sufficiently good to enable them to respond to these non-specific agents. Change of climate whether to the sea or to the mountains has been considered of particular benefit to patients with surgical tuberculosis, the abundance of ultraviolet rays contained in the sunlight at these places being one of the beneficial factors.

All therapy in surgical tuberculosis aims at repair of the process in the best possible position. During the acute stage of the disease, fixation and the taking off of the weight from the diseased part are the most important objects of specialised treatment; in later stages of the disease the damaged part is often able to bear weight, wherefore it is important then to prevent, by fixative appliances or other measures, faulty positions from arising. In tuberculous spondylitis radical operations have been tried with the view to removing the diseased foci in the bone but only in exceptionally favourable cases has such treatment led to a good result. By fixation, and by taking the weight off the part concerned it has been tried to prevent the tuberculous process from spreading, and at the same time to check the formation of a hump or other deformities. To this end different methods have been employed, and numerous specialised apparatus have been devised to fix the patient in a suitable supine position. Various methods of extension have been employed. Patients have also been placed in a permanent prone position. The plaster bed as suggested by *Lorenz* would seem to be one of the best and simplest fixation appliances for bed-ridden patients. A properly constructed plaster bed prevents lateral displacement and forces the vertebral column into extension, thereby diminishing the tendency to inflexion and gibbus formation. During the acute stage of spondylitis contracture of the back muscles is, however, often so pronounced that the gibbus gets larger in spite of the plaster bed. In a more advanced stage, when the contracture abates, the gibbus generally diminishes under treatment in plaster bed. By packing *v. Finck's* wadding-

crosses under the gibbus the extension effect of the plaster bed can be still further increased, and the deformity often considerably reduced. This reduction of the deformity is produced partly by direct lessening of the inflexion, partly by extension and lordosation of the healthy parts of the back immediately above and below the spondylitic area. Pressure on the prominent spinous processes and arches cause these to undergo atrophy, and may also in part cause them to become absorbed and reshaped, and consequently less prominent. Similarly, a gibbus can be modified by padding in plaster corset (*Calot*). *Calot's* manual correction in one stage has been given up long ago.

Orthopaedic appliances devised to enable ambulatory treatment to be carried out, such as corsets of plaster, leather, celluloid and so on, afford very incomplete fixation and weight elimination. During the acute stage of the disease such incomplete fixation cannot sufficiently counteract the tendency to inflexion. During the repair of the disease the chief object of such appliances is to retain as far as possible the extension of the vertebral column.

The aim of all treatment of tuberculous spondylitis should be in the first place, repair of the tuberculous process itself, in the second place reestablishment of the vertebral column as an organ of support, with a minimum of deformity. The commonest and most obvious deformity is the gibbus. By early, intent treatment the gibbus formation can sometimes be prevented, and in many cases be kept within moderate bounds. In a recent spondylitis, a gibbus already formed can be modified by prolonged continuous pressure; for instance, by the above mentioned correction in plaster bed with padding. In cases where no very firm union has yet been established between the segments of the spine reduction of the gibbus is attained by "diminishing the inflexion. In such cases it may be observed how the damaged vertebral bodies, which on earlier skiagrams were seen closely pressed together, after correction are distinctly separated. If the two segments of the spine have already become more firmly united, the angle of inflexion is not affected by the correction. The pressure in such cases forces the gibbus as a

whole in a ventral direction. The undamaged parts of the back immediately above and below the spondylitic area are then extended and lordosed. In the lordosed parts the skiagrams often show an altered shape of the intervertebral spaces, with increased height ventrally and diminished dorsally, owing to displacement of the fluid in the nucleus pulposus. The »para-gibbous lordosis« which may be obtained by correction in plaster bed or by plaster corset does not differ in principle from the compensatory lordosis earlier described. The lordosis resulting from the correction lies closer to the diseased area and is smaller in extent, with a smaller radius, than the compensatory, spontaneously arisen lordosis. The reduction of the inflexion, as well as the para-gibbous extension and lordosation, are extension movements, between which it is often impossible to draw any sharp line. Thus, the reduction of the inflexion in the peripheral part of a spondylitis involving many vertebral bodies can be of the same character as the para-gibbous lordosation (see Case 18 and others). Very often, the correction causes a reduction of the inflexion as well as giving rise to para-gibbous extension and lordosation. By the pressure exerted under correction, on the arches and spinous processes included in the gibbus, these become atrophied and decalcified. As a result of this the pressure may cause them to become reshaped and flattened, which may help to diminish the gibbus. Correction in plaster bed may also sometimes modify lateral deformities. As already mentioned, humps in the lumbar region may also sometimes be corrected by keeping the patient continuously in a prone position. It seems doubtful, however, whether humps in the upper and mid-dorsal region can be prevented or reduced by this method.

The importance of rest in recumbent position during the whole acute stage of spondylitis must be emphasised. The patient should not be allowed to leave his bed until the acute symptoms have disappeared and signs of repair have begun to be apparent; a suitable appliance for protection and support should then be fitted. It must be repeated, however, that even the best fitted corset is unable entirely to eliminate the weight-bearing effect and to prevent small movements taking place within

the diseased area. Thus *Menard's* »ulceration compressive« cannot be entirely prevented by a corset, still less can tuberculous caries in the periphery of the diseased focus be relieved by it.

Through consistent general treatment carried out for a long time, and by suitable treatment of abscesses and other complications, the tuberculous disease can very often be arrested, and in many cases repair of the process be attained. By orthopaedic treatment we are able, in early cases, to restrict the gibbus formation to a minimum. In more advanced cases we can often by correction directly diminish the gibbus, in others it may be rendered less prominent. These measures do not enable us, however, to restore the impaired continuity of the vertebral column. Particularly in those cases where a defect persists in the row of vertebral bodies, the stability of the back becomes insufficient and can only in part be made up for by the permanent wearing of a corset. Yet a corset of that nature cannot, generally speaking, prevent the corrected inflexion from recurring, wholly or in part, or the gibbus from reforming. Repair of the tuberculous spondylitis with consolidation of the vertebral column is inconceivable unless a firm osseous, or possibly fibrous, connection is established between the two segments of the spine. The greater the defect in the vertebral column, the less is the chance of obtaining a firm connection between the segments at the site of the defect.

For a long time past, surgeons have tried by operations of different kinds to establish a firm connection between arches and processes, resembling the fusion sometimes spontaneously occurring between the processes and arches of the damaged vertebrae. The defect in the column of vertebral bodies resulting from tuberculous destruction would thereby become of no importance, and the column, as an organ of support, be replaced by a secure ankylotic pillar of arches and processes. *Wilkins*, in 1886, thus tried to establish fixation by connecting the vertebral arches by means of wire ligatures. Neither he nor any other operator has seen any appreciable results from this or similar methods. *Lange* believed that by applying splints of steel and

celluloid at the sides of the spine he had efficiently aided the stability of the spine. *Calot* and numerous other surgeons, above all *Hibbs*, have connected the processes and arches by pedicled periosteal bone grafts from spinous and articular processes and vertebral arches in order thereby to replace the impaired pillar of vertebral bodies.

Brckett, Albee, Whitman, de Quervain, Henle, Halstead and many others have tried to establish a firm connection between the arches and processes of the diseased or damaged part of the spine by free bone grafting to the latter. *Henle* applies the grafts at the sides of the spinous processes; *Halstead* removes the spinous processes in one lot, fells them sideways and lays the grafts on the cut-off bases.

The spinous processes are then replaced on the top of the inlaid graft. *Albee* splits with a chisel the spinous processes of the diseased vertebrae, two above and two below the affected part. In the lumbar region he contents himself with splitting one healthy process above and one below the affected vertebrae. The halves of the processes he levers to one side, and in the gutter thus produced he inserts a powerful periosteal bone graft cut from the inner surface of the tibia. In the case of a straight back he applies a straight graft, in the case of a small gibbus an angulated one. If the gibbus is considerable, he uses a graft split longitudinally into four thin bone lamellae,—»a bundle of reeds«. The thin lamellae permit of considerable bending without any fracture resulting. The graft is fixed by strong interrupted sutures through the interspinous ligaments. The ends of the graft are often secured by small transverse bone grafts placed behind the main graft and inserted at the sides into the interspinous ligaments. *Albee* maintains that the operation carried out in this way, in difference to the methods employed by *Hibbs* and others, effects immediate fixation of the diseased part. He claims that through the tibial graft the spinous processes come to possess a high degree of »osteogenetic power«. The graft shall moreover serve to conduct freshly formed blood vessels from the healthy spinous processes to the spinous processes and bodies of the affected vertebrae. Kyphosis in cases of acute spondylitis he corrects prior to the operation. In many

cases a gibbus formation is carefully corrected during the operation and the graft fixed in the spinous processes under tension. *Albee* makes this operation on any part of the back, and on patients of all ages. His only contraindications are fever due to secondary infections, and sinuses within the field of operation. The presence of paraplegia and abscesses widens the indications for operation. *Albee* stresses in particular the importance of operation on children with acute spondylitis in whom respiratory movements exist between the vertebral segments. In such cases a strong free bone graft, secured into the spinous processes, in difference to the soft bone-periosteum grafts used by *Hibbs* and other operators, effects immediate fixation to the diseased part. *Albee* keeps his patients in bed for six weeks after the operation. Adult patients are then allowed to get up without any fixation appliance, children wear for 4—6 months a »Taylor's spinal brace«. Paraplegic patients, however, are not allowed to leave bed until the paralysis has disappeared. He warns against the following errors in the technique: placing the graft in the wrong spinous processes, and using either too short a graft or too thin a one. In the two former events fixation will be insufficient, in the last case the graft may readily be fractured, and the fixation lost in consequence.

Albee gives a summarised account of 865 operated cases of spondylitis, of which 33 % were complicated by sinuses, abscesses, compression of the spinal cord, tuberculosis of lungs or joints, and one case of fracture of a bone graft previously applied. In most of the patients the disease had lasted more than twelve months at the time of operation. The period of observation after the operation varied between one and nineteen years. The therapeutic results were »excellent or good« in 90 %, by which *Albee* means that the patients were free from symptoms and able to work. These results have been criticised from several quarters.

Albee's operative method has been taken up in numerous clinics all over the world, in its original shape or modified, and has given rise to numerous publications describing the experiences of different operators with its use. The method has many

enthusiastic advocates and many decided opponents. Scarcely anywhere to-day are the indications for operation given so wide limits as those originally stated by *Albee*. Many authors advise against using the *Albee* operation in the case of children, not only because the primary results obtained are often not very good, but also because as has frequently been observed, spontaneous bony repair between the damaged vertebral bodies will occur much more readily in children, as compared with adults (*Sorrel, Delchef* and others). It is a generally recognised fact, referred to again and again in most publications, that even a correctly placed and well united *Albee* graft is unable to prevent the tuberculous lesion from encroaching upon healthy spongy bone and previously undamaged vertebrae. It stands to reason that the operation as such is unable to relieve a compression of the spinal cord. In progressive vertebral destruction an *Albee* graft cannot entirely prevent increase of the inflexion. Nor can the graft alone always counteract a recurring inflexion in those cases where the latter was already established prior to the operation, and has been reduced or inhibited by correction. The necessity of careful and prolonged after-treatment of the operated patients, not only with generally strengthening measures, but also with suitable orthopaedic supporting appliances has been emphasised from many sides.

Waldenström aims at complete correction of deformities before the operation. This correction he attains by padding in plaster bed by *v. Finck's* method. Complete correction often takes a very long time, sometimes even as much as two years. When the gibbus has been so much corrected that a straight tibial graft can be laid into the split spinous processes, then *W.* considers the advisability of operation. He stresses the importance of postponing the operation if the patient's general condition is not all that may be desired. Open sinuses, paraplegia, acute abscesses are contraindications to operation. *W.* says that his aim with the operation is to fix the back in the corrected position obtained by redressment. Operation should not be performed until the active stage of disease has come to an end and when no further vertebral destruction is likely to

occur. The difficulty of arriving at a decision on this point is very great. It may be assumed that the tuberculous process in the bone begins to localise itself at the earliest $1\frac{1}{2}$ —2 years after the onset of first symptoms. By the operation W. aims at fixing the impaired vertebral column—in which the disease has been arrested or at best repaired—in the position obtained by the correction. In this way he can allow his patients to discard their supporting appliances earlier than if no operation had been carried out. Thus W.'s patients are not operated upon until the deformity has been as far as possible corrected. After the operation, mainly carried out in accordance with Albee's technique, the patient is kept on his back in plaster bed for 7 weeks—3 months. After that he is allowed to be up and about for 2—3 months provided with a plaster corset. By padding through a window cut in the corset the field of operation can during this time be kept under continuous pressure. During the following twelve months after the operation patients have to wear an orthopaedic corset of leather, celluloid or webbing fortified with metal stays.

At the Apelviken Coastal Sanatorium, during the period Jan. 1 1928—Jan. 1 1933, a total number of 278 patients were treated and operated on for tuberculous spondylitis mainly in accordance with *Waldenström's* principles and operative indications. In no instance was operation decided upon until the clinical and roentgenological evidence gave basis for assuming that the tuberculous process was arrested or in the process of repair. In no case was the operation undertaken earlier than twelve months after the onset of the first symptoms of spondylitis. In the majority of cases the clinical history was a much longer one. In cases of a past paraplegia, where recovery had been complete, this was deemed an additional indication for operative fixation of the spondylitis. In only one case was an Albee operation carried out on a patient with a psoas abscess and open sinus in the groin. This patient died ten months after the operation from secondary infection of the abscess. Descending abscesses in an acute stage have also been considered as contraindication to operation. Great importance has been at-

tached to general treatment before as well as after the operation. As a rule the gibbus was, before the operation, corrected sufficiently completely to enable a straight tibial graft to be fitted into the split spinous processes, with the periosteal side either turned dorsally or to either side. Sometimes, however, it was impossible entirely to obliterate the gibbus by correction in plaster bed. In such cases, use was made of a bow-shaped tibial graft placed with the periosteum facing either side. In a few cases the gibbus was so prominent at the time of operation that it was found necessary, in order to make the graft follow the curved shape of the back, to fracture the graft subperiosteally. The seat of fracture was then, if possible, placed inside a split spinous process. The grafts were taken from the inner surface of the tibia, usually on the left side. In patients under 10 years of age the crest of the tibia was in many cases included. The graft was cut out either by means of a motor-driven saw or by chisel and mallet. Before application, the superficial fibrous layer was removed from the periosteum of the graft, and into the remaining deep periosteal layer numerous incisions were made close to the bone, with the view to stimulating a more rapid invasion of blood vessels (*Arxhausen, Waldenström*). The graft was generally placed into the spinous processes of the affected vertebrae, besides into two processes above and one below the affected part. In the lumbar region we have in many cases been content with getting an anchorage into one healthy process above and one below the destruction. In a few cases where two lumbar vertebrae have been the seat of slight destruction the operation has been carried out according to *Galland's* method, with a short graft into the spinous processes of only the two damaged vertebrae. After the operation, in uncomplicated cases, the patients have been kept in plaster bed for 7—8 weeks. They have then been provided with a plaster corset and allowed to get up. The field of operation is subjected to firm pressure by padding through a window cut in the corset (*Waldenström*).

Four-five months after the operation the plaster corset is replaced by a removable corset of leather or celluloid, which is worn day and night for at least twelve months.

On the earliest skiagrams, taken about 2 months after the Albee operation, the graft appears as a thin, sharply defined bone shadow and within it its original osseous structure can often be observed, though blurred and indistinct. Gradually, united within the spinous processes, the graft is surrounded by periosteal deposits. In children considerable deposits may appear already 3—4 months after the operation, in adults they are of less extent and appear at the earliest after 5—6 months. In antero-posterior pictures the periosteal deposits appear as seams along the contours of the graft. In a lateral picture we gradually find »arcades« of new bone passing over from the spinous processes to the ventral surface of the graft. By and by a denser shadow is obtained of the graft as well as of the surrounding deposits, probably owing to increased calcification. The original contours and bony structure of the graft can be discerned for a long time but gradually disappear. Finally, after $1\frac{1}{2}$ —2 years, the graft can no longer be discerned in the bone bridge that has formed in its place.

As no complete after-examination has been made of spondylitis cases operated on at the Apelviken Coastal Sanatorium, the therapeutic results cannot be surveyed. In some cases, however, the spondylitis was found after the operation to have encroached upon previously sound vertebrae. In these cases inflexion had increased after the operation, and the Albee graft had bent in a bow-shaped manner over the gibbus. A similar condition has also been observed in a few other cases where the tuberculous process after the operation had showed no signs of progress. A course of that nature is more common in children than in adults and has often been described in the literature. The cause is to be found partly in the greater tendency of the child's pliable back to gibbus formation and changes of other kinds (compensatory lordosis etc.), partly in the smaller dimensions, greater elasticity and pliability of the tibial graft in the child. In other cases, particularly in adult patients with powerful grafts, these retain their shape during the reconstruction, in spite of considerable defect in the vertebral column. The gap in the vertebral column may gradually be filled up with bone, causing the development

of a massive block formation between the vertebral bodies next to the gap.

The commonest postoperative complication among the operative material at C.S.A. has been a defect in the tibial graft inserted in the spinous processes or in the bone bridge formed in its stead. In the list of clinical cases only such cases have been included in which a defect in the graft had been clinically and roentgenologically verified. As already mentioned, one or several graft defects were observed in 36 patients among the 278 cases composing the C.S.A. operation material during the period 1928—1933, and besides these one other patient was under treatment at C.S.A. for a graft defect, who had had an Albee operation performed at the Linköping Hospital. Had the total number of operated cases been after-examined, still further instances of graft defects would probably have been found. Among the operated cases at C.S.A. there are thus graft defects in at least 12.9 %. Waldenström's operated material at St. Göran's Hospital, Stockholm, during 1911—33 comprises 205 cases. Among these a defect in the graft was observed in 30 cases, thus in 14.6 %. A few graft defects have also occurred among the operated material of the Styrsö Coast Hospital. As the operative technique at this hospital varies, and the graft material is not of uniform nature, the material cannot be directly compared with those of C.S.A. and St. Göran's Hospital.

Chapter IV.

THE DEVELOPMENT OF THE BONE GRAFT AFTER TRANSPLANTATION

It has been known for a long time that a fresh auto- or homoplastic bone graft is capable of uniting with an osseous bed especially prepared to receive it. The progress of this fusion has been the subject of numerous investigations. It is assumed by *Ollier* that an auto- or homoplastic periosteal bone graft is able to unite and fuse with an osseous bed without its vitality being jeopardized. Also heteroplastic grafts may occasionally unite; but they undergo necrosis, and are replaced by new bone formed

from the osseous bed. His experiments show that auto- and homoplastic grafts unite firmly in the bone bed, are invaded by blood-vessels, and increase in thickness; on these facts he bases his assumption with regard to the retained vitality of the graft; it is not based on any histological examinations. *Ollier* ascribes to the periosteum of the graft a decisive rôle for the union; without periosteum the graft is rapidly absorbed.

Contrary to *Ollier*, *Barth* maintains, backed by a series of histological investigations, that an auto- or homoplastic graft undergoes necrosis on being transplanted. In spite of this, an auto- or homoplastic, occasionally even a heteroplastic graft, may unite with a mammalian organism. The necrotic graft is gradually absorbed and replaced by new living bone. The new bone is deposited on the surface of the graft, and is also formed, around its Haversian canals, by osteoblasts which invade these canals together with the vessels. The invading osteoblasts absorb the necrotic bone substance and immediately replace it by new bone. Even if no connection with living bone tissue has been established, new bone develops in the bone canals of the graft and on its surface. The transformation of the necrotic bone of the graft is termed a »*schleichender Ersatz*«. Originally *Barth* believed that the periosteum of the graft was serving no useful purpose in transplantations; he thought he could transplant with equally good results heteroplastic grafts sterilised by heat. In a work published in 1908 he points out, however, that autoplasmic periosteal bone grafts yield the best practical results. He quotes *Lannelongue* and *Vignal*, who have shown that sterilised dead bone can unite with living bone substance. The necrotic bone is gradually absorbed and replaced by new living bone deposited on the surface of the graft and around its Haversian canals. *Bidder's* histological investigations into the question of transplanted ivory pegs show that the union of ivory grafts follows a similar course. *Barth's* own experimental transplantations of macerated sterilised bone show absorption of the graft which is replaced by new bone deposited on its surface and around its canals. Thus the rebuilding of the graft takes place mainly in the same way in autoplasmic transplantation as in transplantation of macerated bone.—*Marchand* main-

tains that the periosteum of the graft in autoplasmic transplantations is able to survive the transference and that at least in transplantations into soft parts it can take part in the formation of new bone.—In autoplasmic bone grafting, the periosteum as well as the endosteum of the transplant take part, according to *Axhausen*, in the formation of new bone. The substitution of living bone for necrotic takes place from the periosteum and endosteum of the graft, as well as from the bed of the latter, if this has any bone-forming capacity. The new bone is deposited on the surface of the graft and around the vessels of the Haversian canals. Bone formation in the Haversian canals takes place without visible absorption of surrounding necrotic bone. Lacunar absorption is not observed to any noticeable extent in the Haversian canals.

Lewer has described in detail the fusion and reconstruction of the autoplasmic bone graft. He maintains that the osseous tissue of the graft, with the exception of solitary small well-nourished parts, undergo necrosis, and that periosteum and endosteum partly survive. The necrotic bone is rapidly vascularised through minute vessels growing out from the graft bed and penetrating into the Haversian canals of the dead bone. If the graft is lying in a bony bed it rapidly fuses with surrounding bone tissue. Fairly soon the necrotic bone begins to decalcify, and the »Kittsubstanz« to become absorbed, the bone then softening and losing its strength. Lacunar absorption is observed on the bone surface, in the medullary spaces, and also in the Haversian canals. This »atrophic stage« of the graft extends over a long a time, at least 3—4 months. During this time the strength and elasticity of the graft, especially with regard to bending stress, is much reduced. The »atrophic stage« is followed by the »lebender Umbau«. During this stage considerable deposits of living bone are formed in a concentric fashion on the surface of the necrotic bone, as well as in its medullary spaces and Haversian canals. The necrotic bone is thus covered by living bone, and its mass pervaded by living Haver's systems. Instead of the absorbed material fresh lime salts and fresh »Kittsubstanz« are deposited, »Kittlinien« demarcate the bound-

ary between dead and living bone. During this stage of regeneration the strength of the graft is again increased. The necrotic bone having been largely replaced by living bone of the »funktioneller Umbau« of the graft is then set on foot, its structure being altered in accordance with its new functions.

Leriche and *Policard* maintain that bone tissue is formed by the depositing of specific substances and lime salts into connective tissue; metaplastic bone formation in cartilage may also occur. The periosteum has no specific bone-forming property, osteoblasts are regarded as a specific form of connective tissue cells appearing when new bone has to be formed. *Leriche* and *Policard* state that the greater part of an auto- or homoplastic bone graft will undergo necrosis on being transplanted. In spite of the necrosis its bone nuclei will stain for a long time.

The graft is originally fixed in the bone bed through fibrin deposits. A connective tissue rich in cells invades the fibrin and the bone canals of the graft, causing the latter to become fixed to the surrounding bone through fibrous tissue. The minute vessels and connective tissue extending into the bone canals bring about absorption of necrotic bone, mainly through »osteolysis« and only in part by »osteoclasia«. Gradually the necrotic bone is replaced by new living bone formed by the connective tissue that invades and surrounds the graft. The periosteum of the graft generally survives the transplantation and facilitates the primary fibrous union of the graft. The hard fibrous superficial layer of the periosteum may sometimes delay the penetration of vessels into the canals of the graft, thereby delaying its osseous union as well as its reconstruction. For the formation of new bone the deeper layers of the periosteum are of some importance, since their connective tissue cells are already adapted for bone formation.

The formation of new bone always takes place around a transplanted bone graft, whether this be placed subperiosteally or subcutaneously. *Orell* has shown this to be the case also when the graft has been killed by boiling. He was thus able to demonstrate in man periosteal new-bone formation on the surface of a graft, killed by boiling which had been placed in the

subcutis. The formation of new bone in this case took a long time, however, and was of slight extent. Bone grafts put into soft parts are generally completely absorbed in spite of the formation of new bone.

It would seem to be generally held to-day that an autoplasmic bone graft will undergo necrosis when transplanted. The periosteum and endosteum of the graft survive the transplantation entirely or in part. Small superficial areas in the bone which have undergone rapid vascularisation may also retain their vitality. Several authors state that the cell nuclei of the necrotic bone may retain their staining capacity for some time. Thus, *L. Mayer*, for instance observed numerous stainable bone nuclei, as much as 63 days after the transplantation. *Troell* has seen numerous stainable bone nuclei in the graft 213 days after the transplantation, and is therefore led to the conclusion that the graft in his case on account of favourable vascular conditions had largely survived the transference. He has also shown experimentally that bone-grafts in cats will ultimately undergo necrosis and regenerate from the surrounding bone. 141 days after the operation no rests from the original graft are to be seen.

In comparing investigations made on human beings with those undertaken by way of experiments on higher mammals such as dogs and rabbits it will be found that on the whole the same rules apply as regards the course and progress of bone grafting. In the dog, however, the reconstruction of the graft is much more rapid than in man. *Hoessly* transplanted periosteal bone-grafts from the tibia to the spinous processes on a number of dogs by Albee's method. In so doing he found that the osseous tissue of the graft invariably underwent necrosis. Already three weeks after the operation the »insidious reconstruction« was in full swing. After 5—8 months the graft had undergone firm osseous organisation, and the bone tissue showed stained nuclei everywhere. *L. Mayer* examined an Albee graft from man 9 weeks after operation and another after twelve months. In the former case, a patient aged 37, he found a necrotic graft with partly stainable cell nuclei. The bone marrow showed normal staining capacity. New bone was forming from the

cambium layer of the periosteum and from the endosteum, and also in the surroundings of the Haversian canals. In the latter case, a patient aged 8, the graft had been rebuilt into a tubal bone with corticalis and spongiosa. Nowhere could necrotic bone be seen.

In discussing these matters *Albee* follows *Ollier*, and in his publications of 1913 and 1914 he states that an autoplasmic or homoplasmic bone graft immediately unites into the split spinous processes without necrosis or cell degeneration, to be gradually rebuilt later for its new task. He supports this view by animal experiments, as well as by observations after operations on human beings. *Albee* transplanted into the spinous processes of 15 dogs, firstly, fresh autoplasmic periosteal bone material, secondly, fresh homoplasmic ditto or such as had been kept for some time in normal saline, and, thirdly, heteroplasmic periosteal bone tissue. The auto- and homoplasmic grafts united without difficulty. In five cases the grafts were examined under the microscope. In one of these cases the graft showed no signs of degeneration 14 days after the operation. An autoplasmic graft showed firm bony union 40 days after the operation. »No evidence of degeneration or cellular death could be found«. A homoplasmic graft which had been kept in a refrigerator two days before the operation, and was examined 6 weeks after the transplantation, showed complete vascularisation, »no dead bone cells, no cartilage«. An autoplasmic graft was examined 4 months after the operation. »The graft has lost its identity—bony union—no evidence of cellular degeneration«. Still another graft was examined 5 months after the operation. Osseous union with the spinous processes was found. A transverse section depicted in the paper shows that the graft had united with the spinous processes and was under the process of reconstruction. According to *Albee* »no dead bone cells are seen in these specimens«. The sections »fail to show degeneration of that part of the graft which has become united«.

No cartilage could be detected in the sections. From operations on man *Albee* describes among other things a graft examined 6 weeks after the operation. This was firmly united

with the spinous processes and surrounded by new bone. The graft »had increased in size«. Macro- as well as microscopic examination showed living bone everywhere. Macroscopic examination of grafts 3, 4, 5 and 7 weeks old showed proliferation of the periosteum, and that they were vascularised, with the exception of their extreme ends. In later publications he states that the graft may undergo necrosis, later to be rebuilt from the periosteum and endosteum, the graft serving as a »scaffold« for the osteoblasts.

Albee's microscopical examinations related here furnish us with no definite proof regarding his statements concerning the surviving bone grafts. The data he gives are too summarised to permit of any definite view being expressed. It is by no means certain that bone nuclei staining some weeks after the transplantation are living. In *Albee's* experiments, in which the graft was examined 4—5 months after transplantation, it seems likely, in the author's opinion, that the necrotic bone remnants may have been small enough to have escaped observation, or may have been entirely absorbed. According to *Hoessly's* investigations, the graft in a dog may be largely rebuilt 4—5 months after the transplantation.

Kornew has experimented with bone grafting on dogs and rabbits, and in so doing he found that the medullary tissue of the graft showed evidence of degenerative changes and cell disintegration as early as 5—10 days after the operation. The staining capacity of the bone corpuscles is clearly reduced after 10—20 days, and is retained longest in the centre of the graft.—Bone grafts fixed into the spinous processes of rabbits were entirely rebuilt in 63 days; at the seat of a thin corticalis-graft a tubal bone with compact and spongy bone tissue had developed, and of the original graft there were no signs. Grafts inserted into the spinous processes of young rabbits and puppy dogs had grown with the back. (In some of the experimental animals, defects in the inlaid grafts can be seen on the skiagrams published). In *Kornew's* opinion the added length of the grafts is due to the traction caused by the growth of the back; this lengthening of the graft was most marked when it was located

at the base of the spinous processes, less so when placed near the tips of the processes.—In another series of experiments on rabbits, *Kornew* grafted pieces of fibula or ulna into defects of the ulna. On histological examination of these grafts the above described degenerative changes appeared also there. In one of the experimental animals examined 48 days after the operation, part of the corticalis of the graft had united with the newly-formed corticalis of the ulna, which filled up the defect. In this graft-remnant the original lamellar structure partly remains, the staining capacity of the bone corpuscles is reduced, some of the lacunæ are empty, the bone corpuscles being entirely absent. The remnant of the graft is pervaded with bone, whose nuclei stain well, and which is concentrically arranged around the Haversian canals.—According to *Kornew*, the bone graft is to serve as a prosthesis in a bone defect, stimulating to new bone formation in the surroundings. It is also assumed to fuse, completely or partially, with surrounding bone with maintained »Lebensfähigkeit«. *Kornew* maintains that the degenerative changes observed in the graft on histological examination do not prove that it is dead. He thinks that the vitality of the transplanted bone tissue is impaired, that the bone is severely diseased. Under favourable conditions of stress and circulation the vitality of the diseased bone may be reestablished, so that parts of the transplanted bone together with the surrounding new bone may eventually become an integrating, living part of the organism. In his other experiments he showed how every trace of the original graft had disappeared. Referring to *Kornew's* Experiment no. 25 the author maintains that the union of corticalis of the graft, after 48 days, with the new-formed corticalis does not signify any definite stage. In the illustration shown it will be observed how the ground lamellæ of the graft are perforated by thin, interrupted Haversian canals surrounded by a slender ring of new bone. In the author's opinion this picture shows a progressive reconstruction of the fused part of the graft and he furthermore does not think that *Kornew* in any of his experiments have proved that the graft has become united, totally or partially, with its vitality retained.

Camitz, Holmgren and Johansson have studied the fusion and reconstruction of the graft by means of an experimental series of autoplasmic transplantations on dogs. These authors, too, found degenerative changes in the graft; 60 days after the operation they found in the osseous tissue »pyknose nucleaire; la disposition lamellaire présente un caractère diffus«. In one of the experiments they found at the site of the graft, 120 days after the operation, a small area of bone, the lamellar system of which was built in another direction than that of the surrounding bone; its lacunæ were moreover largely empty, and its few remaining nuclei small and pycnotic. In another experiment there were no signs of the graft 196 days after the operation. The above named authors agree with *Kornev's* view related above. They consider that »les parties conservées du transplant sont celles qui se trouvent bien ajustées et disposées de telle sorte que leur propre structure concorde avec l'architecture de l'os receuteur. Les autres par contre, subissent une fonte, sous l'action des osteoclastes qui se sont formées«. 196 days after the operation C. H. and J. were unable to find any signs of the original graft. In the author's opinion C. H. and J. have in no case been able to demonstrate any surviving portions of the bony tissue of the graft. Their experimental results regarding the time of complete reconstruction of the graft in the dog agrees with that obtained by *Hoessly*, who has shown that a bone graft in dog is completely rebuilt after 5—8 months, and that the bone formed at the site of the graft at that time shows normal staining capacity of the nuclei everywhere.

Chapter V.

DEFECTS IN BONE-GRAFTS AS DESCRIBED IN THE LITERATURE

Numerous authors have described fractures, pseudarthroses, »Aufhellungszonen« and other defects in bone-grafts. It is maintained by all of them that such defects arise from mechanical causes. *Bier* describes cracks and gaps in bone-grafts applied in operations for pseudarthrosis of the long bones. These defects

arise at the same level as the interarticular space of the operated pseudarthrosis. *B.* emphasizes that besides mechanical factors, others, such as the effect of hormones, may contribute to the production of pseudarthrosis. He further states that live normal bone and bone-grafts behave in the same manner in the formation of pseudarthrosis.—*W. Müller* has studied, clinically and experimentally, »akuter Umbau« of long bones which takes place as the result of an abnormally powerful mechanical strain. According to *Müller* this acute reconstruction is caused by increased bone absorption and increased formation of new bone in the form of apposition at the seat of an increased, persistent or intermittent local strain. In such cases reconstruction with change of shape of the bone area concerned is completed in a short time. Sometimes a defect in the bone with pseudarthrosis arises in the reconstructed area. *Müller* compares pseudarthroses of this nature with »Loosers Umbauzonen« in rickets and osteomalacia, drawing attention to the pathological conditions of calcification present in these conditions. He has tried on dogs and rabbits to bring about ankylosis of the talo-crural articulation by fixing a bone graft, para-articularly, in the tibia and tuber calcanei. In a great number of animals the graft inlay had united with the calcaneus and the tibia, and considerable periosteal deposits had formed in the neighbourhood of the graft. In one case a typical oblique fracture was found in the graft 41 days after the operation. In all the other cases a transverse defect through the graft was discovered 25—106 days after the operation. The defect is located at a level with the interarticular space of the talo-crural articulation. In one case, the defect in the callus tissue round a graft, cast off on account of ostitis, proved on microscopical examination to be filled up with hyaline cartilage. In the cartilage small cavities filled with fluid were observed. At the boundaries between bone and cartilage, the cartilage cells were arranged in rows running at right angles to the surfaces of the bone ends, in the longitudinal direction of the bone bridge. The arrangement resembles the ossification zone in a normal epiphyseal line. In several cases *Müller* was able to obtain complete anky-

losis of the talo-crural articulation by the para-articular application of a bone-graft. In no case however did a coherent bone bridge persist between the tibia and the tuber calcanei. In *Müller's* opinion graft defects are caused by the continuous mechanical irritation in one plane to which the graft is exposed, and which arises on minor movements in the talo-crural articulation. This localised mechanical strain would produce local absorption of bone; on account of the inability of the graft itself to form new bone the absorbed bone substance would be replaced by connective tissue growing in from without, and pseudarthrosis would then gradually arise. The graft defects would not have the character of fractures; the always blurred outlines on skiagrams would go against such an assumption. *Müller* maintains that the bone defects in an Albee graft described by various authors are not fractures, but pseudarthroses arisen in the manner described above. He draws attention to the resemblance between these defects and bone defects »auf den Scheitelpunkt starker Knochenverbiegungen«.

Frangenheim and other workers have tried to produce ankylosis of the talo-crural articulation by driving a peg of corticalis right through the calcaneus, talus and the distal portion of tibia. When this was done, a transverse defect nearly always arose through the graft within the talo-crural interarticular space. In many instances the talo-calcaneal joint became ankylosed without the graft showing any defect within its interarticular space.

Cramer and *Lasker* have tried to produce ankylosis of the talo-crural joint in man by applying a para-articular bone-graft. In many cases they then found transverse defects through the graft, on a level with the interarticular space. *Lasker* has shown that these defects frequently became repaired under the formation of strong periosteal callus, so that the ankylosis aimed at has gradually been attained. Contrary to *Müller*, *Lasker* is of the opinion that it is a question, in these cases, of fractures of the graft, favoured by lime absorption in the necrotic graft. He puts these graft fractures in the same category as the defects observed in the bone graft after Albee operations.

In cases of rachitis and osteomalacia, *Looser* describes under the name of »Umbauzonnen« (U. Z.) certain gradually arising, transverse attenuated bands on the long bones visible on skiagrams. These U. Z. produce no, or slight, clinical symptoms, and give rise to no malposition. The skiagram gives one the impression of a transverse fracture without displacement and with a slight amount of callus formation. From the point of view of morbid anatomy they are regarded as an insidious form of callus formation. They are supposed to arise through »acute reconstruction« of the bone »an Stellen chronischer Irritationen«, probably as a result of crack formation in the corticalis. The bone marrow is transformed into fibrous marrow growing into the crack and absorbing the lamellar bone. In the defect a new undifferentiated spongiosa is formed. On account of disturbed calcium metabolism in rickets and osteomalacia this new bone cannot be calcified in the normal manner but retains its character of osteoid tissue. Such osteoid tissue yields a much thinner shadow on a skiagram than lime-containing bone. The reconstructed part will therefore for a long time present the appearance of a ribbon-shaped defect in the long bone. On recovery of the original disease the U. Z. are generally rapidly calcified and rebuilt into lamellar bone. The production of U. Z. would thus be occasioned by mechanical irritation, probably with crack formation, of a pathologically changed bone substance deficient in lime salts. Its appearance on skiagrams is determined by the disease concerned with its attended disturbance in the calcium metabolism of the skeleton, which takes the form of halisteresis and absorption of bone with new formation of osteoid tissue.

Læxer maintains that a bone-graft in a short time undergoes almost complete necrosis. In the necrotic bone a great deal of the lime salts and the »Kittsubstanz« are gradually absorbed, and the Haversian systems loosened. During this »atrophic stage« the strength and elasticity of the bone are markedly reduced, particularly is its bending stress much impaired. *Binswanger* has shown that the bending stress of the bone-graft, 9 weeks after the operation, is only half that of the normal

live bone. Particularly is it markedly reduced during the third and fourth months after the operation. Only when the mass of newformed bone within and around the graft can lend sufficient support to it are its strength and elasticity again increased. During the atrophic stage, when the necrotic bone is decalcified and its Haversian systems loosened, transverse cracks may arise in the bone substance on too heavy loading. Such cracks may arise on instantaneous increase of the load, as also on intermittent stress applied at the same point and permanently in the same direction. The crack may at once pass right through the graft as an »acute« fracture with secondary malposition and diastasis. In other cases only small local cracks are formed. Connective tissue and vessels grow into these, absorbing the surrounding bone. Further small cracks may form, and in this way a defect may gradually arise right through the graft, a so-called insidious fracture. A fracture of a periosteal graft unites with callus on sufficient fixation being observed. This also applies to fractures of bone-grafts embedded in soft parts. In the case of crack formation in a graft complete fracture may often be entirely prevented by fixation for some time to give the bony injury a chance of forming callus and to consolidate. If a graft fracture is insufficiently fixed, pseudarthrosis often arises at its site.

Leriche and *Policard* point out that a graft during the stage of absorption is often so soft that it can be cut with a knife, and that its strength is consequently reduced. As a result of this, »tassements« (depressions) and spontaneous fractures often arise in such grafts. The decalcified and fairly abundantly vascularised tissue has a great ability to form callus, wherefore such fractures unite with callus formation if no displacement is present.—In another relation *Leriche* and *Policard* give their experiences concerning the union of fractures. Connective tissue rich in cells grows into the fibrinous reticulum of the blood-clot surrounding the seat of fracture, absorbing the coagulum and uniting the fracture ends. In conjunction with a lively absorption in the ends of the bone the connective tissue callus is gradually transformed into bone. On complete fixation of the

fragments no cartilage is formed in the callus. In the case of incomplete fixation some parts of the connective tissue callus, particularly those subjected to minor tangential movements and varying pressures (scissor movements), may be transformed into cartilage. Pseudarthrosis is formed: 1) on account of a small haemorrhage at the seat of fracture, 2) in the case of interposition of muscle, 3) on infection of callus with sclerosis of the connective tissue.

The numerous authors who have described defects in the osteoperiosteal graft applied in *Albee's* operations have expressed different views upon the nature and genesis of these defects.

Albee considers that the bone graft put into the spinous processes *may sustain a fracture* if insufficiently stout and strong. In such cases he recommends another operation, with insertion of a new graft, sufficiently long, parallel with the old one, covering the defect.

Baer maintains that the bone-graft may be fractured as long as two years after operation. In the case of graft fracture the vertebral column may at once prove insufficient to its task as an organ of support owing to inhibited fixation.

Bressot mentions the occurrence of graft fractures, and in such cases recommends another operation.

Calvé and *Galland* also mention the occurrence of graft fractures. These are always located between the spinous processes of tuberculous vertebrae.

Delchef states that the inlaid bone-graft becomes very much weakened through absorption. This is the case in children far more than in adults. The in themselves thinner and weaker bone-grafts in children therefore sustain fractures very much more readily than the stout and more powerful grafts used in adults. He states that graft fractures are a rare occurrence in adults and relatively common in children.

Fromme is of the opinion that fractures of the graft easily arise, and relates a couple of cases of that nature.

Gonzales mentions the occurrence of graft fractures.

Henle describes fractures of grafts applied paraspinally, located level with an undamaged intervertebral disc.

Hoffmann maintains that fractures and pseudarthroses of the necrotic graft may arise on »arthrogenous stress«. In order to prevent fractures he has made use of stout bone-grafts. In some cases he has inserted pedicled rib grafts into the split spinous processes. He has observed graft fractures even in such cases, however.

Sven Johansson describes a graft fracture united with periosteal callus. His clinical material includes two more cases with defects in the bone-graft.

Nussbaum has performed the *Albee* operation on a number of dogs, and there observed fractures of the graft. He states that these fractures either unite with callus or are transformed into pseudarthrosis with fibrocartilage and connective tissue. In one dog he was able to carry out an after-examination six years after the operation. Two paraspinous graft inlays had been applied into the spinous processes of D XI—L IV. On this distance there were four bone defects, each level with an intervertebral disc. On skiagrams the defects gave the impression of being »Aufhellungszonen«. There was distinct mobility between the vertebrae within the fixed part of the spine. The bone defects proved to consist of a 2—3 mm. broad layer of fibrocartilage, resembling the graft pseudarthrosis after para-articular arthrodesis of the talo-crural joint as described by *W. Müller*. In six years the graft had grown 4 cm. longer.

Sorel and *Rocher* draw attention to the risk of graft fractures in the *Albee* operation. To protect the graft as far as possible from undue stress their patients are not allowed to leave bed until six months after the operation.

Waldenström describes 14 »graft fractures«. Most of them were diagnosed during the first twelve months after the operation, one case as late as three years after the *Albee* operation. In a few cases the fracture had arisen as a result of trauma of various kinds. In others the fracture appeared without any known cause. Several of the patients had clinical symptoms in the form of pains and a weak back. The gibbus obliterated through correction again appeared. *Waldenström* maintains that the routine treatment of graft fractures should be reoperation

with application of a fresh bone-graft. Some of his patients recovered under conservative treatment. He further holds that graft fractures can be largely prevented by letting the patient wear a corset for a long time after the operation. He strengthens the fixation of this area still further by padding over the field of operation through a window cut in the corset.

Biesalski has found numerous »Aufhellungszonen« in the inlaid bone-graft and in the spinous processes. These attenuations may be observed during the first few months after the operation, partly in the form of thinner spots, partly as attenuated bands through the inlaid graft. In *Biesalski's* opinion these »Aufhellungszonen« correspond to *Looser's* U. Z. These attenuations may either be rebuilt and unite with normal bone tissue, or be transformed into pseudarthroses. The latter would be the case were the area concerned exposed to mechanical irritation. In addition to this, *Biesalski* mentions »eine tatsächliche Fraktur« of a graft. His autoptic material includes several cases of defects of the Albee graft. He ascribes these to mechanical irritation of a »Aufhellungszone«, which may then pass over into a pseudarthrosis, and maintains that such a development is common at a level with an undamaged intervertebral disc or with a lesion of vertebral bodies where false mobility exists between the remnants.

Denk, König, Mau, Roos and *Sträter* also describe defects in the inlaid bone-grafts, verified by roentgen examination. They identify these defects with *Looser's* U. Z.

Läwen describes an autoptic specimen with a defect in an Albee graft. He is of the opinion that »Abbau und Einknickungen« occur in the graft, at a level with the maximum point of the gibbus formation.

The defects developing in the bone-graft fixed in the spinous processes in an Albee operation are thus labelled fractures by *Albee, Waldenström* and others. *Biesalski* and others liken these defects wholly or in part to *Looser's* U. Z. (*Biesalski* emphasizes that local mechanical irritation is necessary for transformation of U. Z. into a bone defect). *W. Müller* maintains that defects

in the bone-graft may develop through acute local bone absorption on mechanical irritation.

Defects in an Albee graft develop either at a level with a lesion in vertebral bodies with false mobility between the remnants (*Biesalski*), or, in the case of »arthrogenous stress« (*Biesalski*, *Hoffmann*) at a level with an undamaged intervertebral disc.

The author's own investigations into the defects occurring in an Albee bone-graft will be presented in Chapter VI. In connection with this he will discuss the views expressed in the literature concerning bone-graft defects and their genesis.

Chapter VI.

THE AUTHOR'S HISTOLOGICAL INVESTIGATIONS

The author's histological material is incomplete, and some examinations with specific dyes etc. though desirable, had to be omitted. As, besides, the number of cases investigated is small, it must be admitted that the material possesses only slight value as basis for a specialised inquiry into the reconstruction of the Albee bone-graft. In the main, the author agrees with the views expressed by *Lexer* and *Leriche-Policard* regarding the reconstruction of the bone-graft; on the whole, his results coincide with theirs. The terminology usual in surgical graft literature has been used also in the present work. As the material presents a good many details of interest, and on important points supplements the experiences gained by clinical and roentgenological examinations, the author has considered it not out of place to review briefly his histological investigations despite the incomplete state of the material.

With the view to finding out something more in detail about the progress of union and reconstruction of the Albee bone-graft in man, as well as about the time occupied by these processes, the author has examined histologically a number of Albee grafts of different ages:

A.—Specimen from a pointed portion of the graft removed 2 months after the Albee operation.

B.—Post-mortem specimen from a patient who died 7 months after the Albee operation.

C.—Post-mortem specimen from a patient who died 10 months after the Albee operation.

D.—Post-mortem specimen from a patient who died 17 months after the Albee operation.

E.—Post-mortem specimen from a patient who died 2 years 2 months after the Albee operation.

F.—Post-mortem specimen from a patient who died 8 years 1 month after the Albee operation.—

A.—In a boy, aged 12, the proximal prominent point of the graft was removed 2 months after the Albee operation. The skin over the prominent point was intact, and the pointed part was covered by a bursa. Six frozen sections were made stained with Weigert-Htx-v. Gieson.

In the centre of the section there is an elongated thin bony part consisting of a long and a short fragment. In these fragments nuclei do not stain and the lacunae are empty. The fragments are surrounded by a tissue varying in type and rich in cells. Around the larger fragment there is a richly vascular tissue which seems to cause erosion of the denucleated bone under formation of Howship's lacunae. In some parts the tissue shows a cartilagenous structure with the nuclei arranged in rows at right angles to the bone surface. In one or two places there appear in the tissue, rich in cells, next to the denucleated bone, brownish-yellow formations resembling bony trabeculae. The cell nuclei are lying in cavities in the trabeculae which surround small portions of tissue with numerous nuclei strongly stained. Within the denucleated bone fragment in one of the sections an obliquely cut Haversian canal is observed containing vessels and fibrous bone marrow with nuclei staining normally. The bone canal is surrounded by two lines of concentrically arranged elongated nuclei, embedded in ground-substance and with normal staining capacity. This part of the bone with stainable cell nuclei is sharply demarcated from the surrounding denucleated bone by bluish lines. The small denucleated bone fragment is markedly eroded by the surrounding tissue, its contour shows

numerous Howship's lacunae with giant cells resembling osteoclasts. At some distance from the larger denudeated bone fragment there is seen in most of the sections an irregular group of typical bone and osteoid trabeculae. These trabeculae surround medullary spaces of smaller size containing young medullary tissue with lines of osteoblasts. The bars have a yellow-brown colour, the margins are partly red. In the surroundings there are numerous cells resembling osteoclasts. In one or two places these osseous trabeculae pass over without any sharp demarcation into the surrounding tissue rich in cells.

B.—Post-mortem specimen from a male patient, aged 27, who 7 months earlier had had an Albee operation for spondylitis of D VI—VII and who died of miliary tuberculosis. The graft is firmly united with the spinous processes of D IV—VIII. Three sections were examined from the graft: B 1, horizontal section through the graft and the spinous process of D V; B 2, horizontal section of the graft between the spinous processes of D VII and D VIII; and B 3, vertical section through the right half of the graft and the base of the VIII spinous process. The sections were embedded in celloidin and stained with Htx-Eosin, Weigert's Htx-v. Gieson and by Hansen's method.

B 1.—Horizontal section of the graft within the V. spinous process. Towards the side of the section the fairly massive graft is seen pervaded by moderately dilated Haversian canals and all round surrounded by spongy bone with wide medullary spaces containing wide blood-filled vessels, fibrous bone marrow or myeloid tissue. The spinous process is built up of a finely reticular spongy bone with a myeloid medullary tissue rich in cells. In the bone marrow of the spinous process there are solitary tubercles with giant cells. The graft is sharply demarcated from the spongy bone of the spinous process. The nuclei over large areas of the osseous tissue of the graft fail to stain and the lacunae within these parts are empty. In the bone canals there are everywhere well blood-filled vessels. In the centre of the graft the Haversian systems seem to be fairly much the same, the canals are narrow and surrounded by thin concentrically arranged rings of nucleated bone. This bone is partly demarca-

ted from the denucleated bone by blue lines. In the periphery of the graft the bone canals are wider and take a less regular course, also here the nucleated bone has a concentric arrangement around the canals, it is more widely distributed here than in the centre. On the boundary between the graft and the spongy bone surrounding the spinous process nucleated osseous trabeculae from the spongiosa of the spinous process pass directly over into the denucleated bone of the graft. In the centre these trabeculae show denucleated bone peripherally lined by seams of nucleated bone.

B 2.—Horizontal section through the graft in addition to spongy parts from the base of the VIII spinous process. The microscopical appearance is on the whole the same as in *B. 1.* The nucleated bone has somewhat less distribution in the centre of the graft.

B 3.—Vertical section through the graft and the base of the VIII. spinous process. Most of the graft is here denucleated. Its dorsal surface is covered by a tissue rich in vessels and cells, dorsally passing over into fibrous tissue. The dorsal contour of the graft is mainly formed by denucleated bone, it is sharp but irregular and shows numerous Howship's lacunae, containing cells resembling osteoclasts.

C.—Post-mortem specimen from a male patient, aged 31, who ten months earlier had an Albee operation for spondylitis in L. II—III and who died as a result of secondary infection of a psoas abscess. Sections were made as in the previous cases. For the sake of comparison a transverse section was made from the corticalis of the patient's right tibia. This section includes the inner surface of the tibia with periosteum as well as central spongiosa. The bone-graft inserted into the spinous processes is composed of corresponding part of the left tibia. The tibial section shows a corticalis of average thickness with cell nuclei stained everywhere. The Haversian systems are well developed, the bone canals being possibly somewhat wider than normal.

C 1.—Horizontal section through the graft and the proximal part of the spinous process of L II. On three sides the graft is surrounded by soft parts, on the fourth it has fused with the

spongy bone of the spinous process. Over considerable parts of the graft nuclei fail to stain, the lacunae here being empty. The Haversian canals vary in breadth and are stouter than in the control specimen from the right tibia. They are also wider than the Haversian canals in the graft of case B. The canals enclose blood-filled vessels and medullary tissue mainly of fibrous type. Groups of myeloid cells also occur. The Haversian canals are surrounded by concentric rings of nucleated bone. These rings are of various breadth, being fairly wide around the bigger canals. Around many of the small canals the ring of nucleated bone is quite thin, comprising only a couple of lines of concentrically arranged bone nuclei. The nucleated spongiosa of the spinous process opens up with wide medullary spaces rich in cells towards the graft, the spongy bone trabeculae of the spinous process pass over uninterruptedly into the denucleated bone. The boundary between nucleated and denucleated bone is generally sharply defined, marked in parts by blue lines. Underneath the periosteum of the graft there is a broad layer of nucleated bone with canals, cut transversely and lengthwise, directly coherent with, but sharply demarcated from the underlying, mainly denucleated, osseous mass. On two sides the graft presents on the whole a straight contour (the cut surface from cutting out the graft from the tibia). The surrounding tissue poor in cells shows no reaction at the contour of the graft.

C 2.—Horizontal section through the graft and the spinous process of L III. The graft is placed edgewise in the split spinous process, and is surrounded ventrally and laterally by the spongy bone of the spinous process. Dorsally its contour (cut surface) is covered by a tissue poor in cells; the outline of the mainly denucleated bone is sharp and regular. In this section, too, the graft presents rings of nucleated bone around the Haversian canals. Around the Haversian spaces on the boundary between the spongy part of the spinous process and the graft there are broad seams of nucleated bone. The boundary between nucleated and denucleated bone is everywhere sharply defined and in parts marked by blue lines. At one side the spongy part of the spinous process is separated from the graft by a narrow band

of connective tissue poor in cells, consisting of the retained periosteum of the graft. Between the largely denucleated graft and the periosteum there is a layer of nucleated bone pervaded by numerous Haversian canals. In this area there is no bony union between the spongy part of the spinous process and the bony mass of the graft.

D.—Post-mortem specimen from a male patient, aged 30, who 17 months earlier had had an Albee operation for spondylitis of L II—III; died of pulmonary tuberculosis.

The section includes a horizontal section of the middle portion of the graft, in addition to spongy bone from a spinous process. The spongy bone of the spinous process forms thin nucleated trabeculae, the medullary spaces are filled with myeloid tissue. The tibial graft presents narrow Haversian canals as well as wide Haversian spaces containing blood-filled vessels. In the Haversian spaces there are plenty of red and white blood corpuscles, and possibly also some myeloid tissue. Canals as well as Haversian spaces are everywhere surrounded by narrower or broader concentric zones of osseous tissue with obviously stainable nuclei. Between these zones the lacunae are empty over large areas. Nucleated and denucleated bone is generally separated by thin blue lines. The boundary between the spongy bone of the spinous process and the graft is but vaguely defined; the osseous trabeculae of the spinous process pass over uninterruptedly into those of the graft remnant. The graft is sharply defined from surrounding soft parts, there is no sign of erosion of the bone surface anywhere, nor are there any obvious signs of reaction in the connective tissue. Seams of osteoblasts occur neither on the bone surface nor in the Haversian spaces.

E.—Post-mortem specimen from a female patient, aged 15, 2 years 2 months earlier operated on for spondylitis of L III—IV; died of amyloid degeneration. At the operation a thin corticalis graft, about 1 cm. broad, was inserted into the spinous processes; the graft was taken from the inner surface of the left tibia, the crest was not included.

E 1.—Horizontal section from the graft and the spinous process of L III. At one side of the tip of the spinous process

the graft remnant is observed pervaded by Haversian spaces so wide that it has assumed the character of coarsely trabecular spongy bone. In the central parts of these coarse trabeculae the lacunae are empty. In the periphery of the trabeculae there are thinner and broader zones of nucleated bone, arranged concentrically around the Haversian spaces. There is a sharply defined

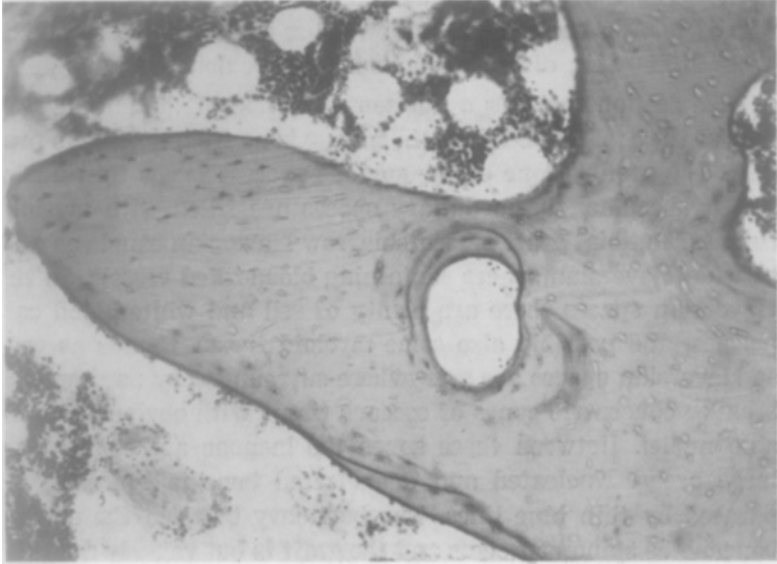


Fig. 2.

E.2.

The lacunae of the bone trabecula are to a great extent empty. Stained bone nuclei are present, concentrically arranged around the Haversian canal as also in the periphery of the trabecula. The denucleated and the nucleated bone are separated in parts by thin blue lines.

demarcation between nucleated and denucleated parts of the bone, in many places marked by thin blue lines. The Haversian spaces are filled with active red bone marrow; the boundary between the spongy part of the graft and that of the spinous process is everywhere vaguely defined, the trabeculae passing over into one another. At one place a narrow zone of collagenous connective tissue, poor in cells, extends between the graft remnant and the spongy bone of the spinous process (?periosteum).

In other parts the spongy bone of the spinous process presents thin nucleated trabeculae and a myeloid bone marrow rich in cells.

E. 2.—Horizontal section through the bone bridge between the spinous processes of L IV—S I, on a level with the spinous process of L V, which has no contact with the bone bridge. The transverse section of the latter forms an equilateral triangle with a side of 1 cm. The peripheral parts of this section present to some extent the structure of compact bone; cell nuclei take up the stain here. The central parts of the bone bridge are composed of spongy bone with relatively coarse trabeculae. (Fig. 2). The graft remnant, which in this section can only with difficulty be demarcated from the rest of the bone tissue, seems to occupy one of the lateral areas of the transverse section. The graft is mainly made up of spongy bone with coarse osseous trabeculae and wide Haversian spaces. The bone is denudeated in the central parts of the trabeculae, their peripheral parts consist of nucleated bone arranged concentrically around the Haversian spaces. The medullary tissue in the Haversian spaces of the graft is poor in cells and in some places contains myeloid elements. In the central parts of the section the bone tissue has chiefly the character of spongiosa with coarse bone trabeculae; in the medullary spaces there is in some areas plenty of myeloid bone marrow.

E 3.—Vertical section of the graft and the spinous process of L V. Farthest ventrally irregular spongy bone is observed, with bone marrow rich in cells belonging to the spinous process. Ventrally and dorsally, the bone bridge presents a layer of fairly compact bone with stained cell nuclei. Parts of the Haversian spaces in the centre are cut longitudinally and contain fatty marrow here and there. The central bony trabeculae present in the centre large areas with empty lacunae, surrounded by broad layers of bone with stained nuclei.

F.—Post-mortem specimen from a male patient, aged 17, who 8 years 1 month earlier had been operated on for spondylitis of D XI, D XII and L I and died of renal tuberculosis. The section is taken horizontally through of the middle portion of

the graft. Embedded in celloidin, stained with Htx-Eosin, iron-trioxi-haematin-v. Gieson and by Hansen's method.

The sections show a spongiosa with fairly coarse trabeculae, on three sides surrounded by coarser bony parts which on two sides form a layer of stout trabeculae, on the third side compact bone with Haversian systems. The bone marrow is fairly vascular and consists of fatty and myeloid bone marrow. The spongy part as well as the more compact parts of the bone present a fairly regular concentric arrangement around Haversian canals and spaces. Nowhere can any bone with empty lacunae be observed; in the spongiosa as well as in the more compact parts of the bone there are nuclei which stain, though in some parts the staining is rather weak.

It is quite possible that the specific technique adopted in the production of histological sections of bone may alter and destroy the staining capacity of the cell nuclei of the bone. To check the technique, control sections should therefore have been made, by the same methods, from the patient's own healthy tibial corticalis. This could have been done in the autptic cases. Unfortunately, control specimens were only made in case C. In that case the control section shows good staining capacity of the cell nuclei of the bone tissue, and empty lacunae are only observed here and there. On the other hand we find the graft united with the spinous processes presenting considerable areas without any stained cell nuclei, thus with empty lacunae. Also in cases A, B, D and E stained cell nuclei are lacking in considerable parts of the graft. In the following, the author, like other workers (*Barth, Marchand, Lexer, Leriche* and *Policard*) proceeds on the assumption that bony tissue in which the nuclei stain badly, or do not stain at all, or which shows empty lacunae, is necrotic.—In cases A and B the necrotic bone has a wide distribution. Case A shows the picture of an entirely necrotic graft under absorption two months after operation, the new-bone formation in the neighbourhood of the graft can probably be ascribed to the bone bed, possibly also to the periosteum of the graft. Around a Haversian canal a narrow ring of nucleated bone is seen, and all evidence goes to show that it

is new bone formed within the necrotic graft. In case B the graft is 7 months old. There is a considerable amount of nucleated bone, concentrically arranged around the Haversian canal in the centre as well as around the Haversian spaces in the periphery of the graft, on the boundary toward the spongy part of the spinous process. This nucleated, concentrically arranged bone seems to be newly formed within and around the necrotic graft. In case C, where the graft is ten months old, the new bone is similarly arranged, but has a wider distribution. The Haversian canals of the graft are wider than those of the control section, a fact which points to a certain amount of bone absorption. Between the retained graft periosteum and the necrotic, main mass of the graft there is a broad layer of nucleated bone of irregular structure, entirely demarcated from the spongy bone of the spinous process by the fibrous periosteum. In cases B and C the graft has retained its original form and is clearly defined from the spongy bone of the spinous process. The Haversian canals are widened. Outside the nucleated new-formed bone considerable remnants are observed of the now denucleated necrotic, original Haversian systems. In cases D and E the remnants of the graft can only with difficulty be demarcated from the surrounding spongiosa. In case E the graft has been transformed into spongy bone with coarse trabeculae, in the centre of which are seen large necrotic remnants of the graft, now of the character of intermediary systems. The nucleated new-formed bone is concentrically arranged around wide Haversian spaces. Case E shows how a powerful bone bridge has developed, with a triangular transverse section between the fixed spinous processes and around the originally narrow thin graft. The bone bridge consists of a new-formed corticalis surrounding spongiosa with coarse trabeculae. As late as 2 years 2 months after the Albee operation, large necrotic remnants of the graft are seen on one side of the bone bridge.—Cases A—E show, in a consecutive series, instances of the »living reconstruction« of the graft. In case F the graft is seen to be entirely rebuilt into a bone bridge resembling a long tubal bone, in which the bone shows stained nuclei everywhere.

The results of histological examinations recorded above accord with those obtained by numerous other research workers. That in case E a great deal of necrotic remnants from the bone-graft were still found 2 years 2 months after the operation is a striking circumstance. In one case, however, *Lexer* found necrotic remnants of an autoplasmic osteo-periosteal graft put into the defect of a long bone $3\frac{1}{4}$ years after the operation.

Ollier's hypothesis, quoted by *Albee*, concerning the immediate union of the graft with its vitality intact is contrary to the results of nearly all histological investigations. As already stated, *Albee's* own investigations cannot be taken as full evidence of proof in this case; nor has he in subsequent publications maintained his original theory regarding the union of the graft.

With the view partly to finding out the mode of production of the graft defect, partly to studying the further progress and conditions of healing of the latter, sections from clinically and roentgenologically diagnosed graft defects, were subjected to microscopical examination. The sections were taken in connexion with reoperations made for the purpose of covering the defect by a fresh bone-graft.

I. Specimen from a patient who nearly 2 years earlier had had an *Albee* operation, and who 15 months ago was operated on for a graft defect. After a slight trauma a fresh graft defect was discovered. A fortnight after the onset of symptoms another operation was performed, on which occasion the specimen was secured. (Case S. T. I.).

II. Specimen from a patient who $2\frac{1}{2}$ years earlier had had an *Albee* operation; a graft defect was discovered 6 months before the specimen was taken. (Case 5).

III. Specimen from a patient who 12 months earlier had had an *Albee* operation performed and in whom a graft defect was found 6 months before the specimen was taken. (Case 36).

IV. Specimen from a patient who 15 months earlier had had an *Albee* operation performed and on whom a graft defect was found about 12 months before the specimen was taken. (Case 2).

V. Specimen from a patient operated on by *Albee's* method

3½ years earlier. At the time when the specimen was taken, the graft defect was probably 15 months old. (Case 23).

Specimen I. (Case S. T. I.).—At the operation the previously diagnosed graft defect, which appeared as a narrow transverse slit through the graft, was laid bare. Respiratory movements caused a slight displacement between the fragments of the graft. The defect was filled up with a black-red mass resembling

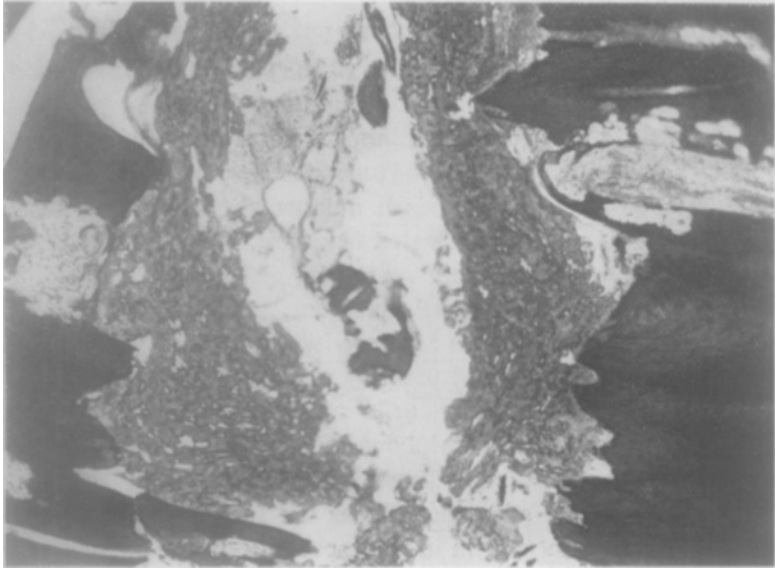


Fig. 3.

S.T.I.

General view of the defect. In areas bordering on the defect the graft fragments show empty lacunae, in other parts bone nuclei are well-stained. The defect is filled out with blood-clot through the centre of which passes a slit containing detached denucleated bone fragments and red blood-corpuscles. The Haversian spaces contain fibrous marrow rich in cells, the outlines of the bone trabeculae show numerous Howship's lacunae.

a blood clot.—The defect together with its bony boundaries on both sides cut out by two somewhat convergent transverse sections. The bony specimen thus obtained consists of a transverse wedge from the dorsal portion of the graft. It consists of two thin bone lamellae with an intervening blood-

stained defect. The sagittal section of the specimen is wedge-shaped, the base of the wedge corresponds to the dorsal surface of the graft.

The microscopical slides were prepared from sagittal sections from different parts of the specimen embedded in paraffin and celloidin. The sections were stained with Htx-eosin, Weigert's htx-van Gieson, Weigert's fibrin- and Hansen stain. Most of the sections are wedge-shaped, and include the dorsal part of the graft defect with surrounding bony parts from both sides.

The defect is filled up with a denucleated amorphous mass of coarsely reticular structure, staining red by eosin, yellowish red by v. Gieson. On fibrin staining, a network of coarse violet-coloured strands appears in the amorphous mass. Right through the amorphous mass there is a narrow slit containing blood corpuscles and small denucleated fragments of bone (Fig. 3). In the amorphous mass, for the most part close to the outlines of the bone, are embedded small, irregular, denucleated fragments of bone. From the fibrous marrow in the medullary spaces of the surrounding bone, and possibly also from the periosteum, a cellular tissue with large cells and fairly large nuclei is tending to invade the amorphous masses. The invading tissue has mainly the character of embryonic connective tissue. Smaller portions of the amorphous mass are found enclosed in the invading tissue. In certain areas, especially on the boundary to the amorphous contents of the defect, the invading cells resemble osteoblasts. In close relation to these osteoblastic cells there are small tissue strands staining red or yellowish red with v. Gieson's stain. In other places the invading tissue presents cells of considerable size with pale protoplasm and well-stained nuclei. On one side of the defect there is a large area of bone with fairly coarse osseous trabeculae for the most part resembling compact bone pervaded by Haversian canals and Haversian spaces of moderate size. The bony part is limited on the outer side by a straight regular line, the cut section. On the other side of the defect there are small portions of bone unconnected with one another, also these are limited on the outer side by the cut section. The nuclei in the osseous tissue are on the

whole well stained. In the bony parts bounding the defect there is an area of varying breadth in which there are no stained nuclei, but empty lacunae. The contour of the osseous trabeculae facing the defect is torn and irregular. Over the areas where this contour borders directly on the amorphous mass it is torn and indented; in the mass outside the contour there are small denucleated fragments of bone. In these parts of the contour

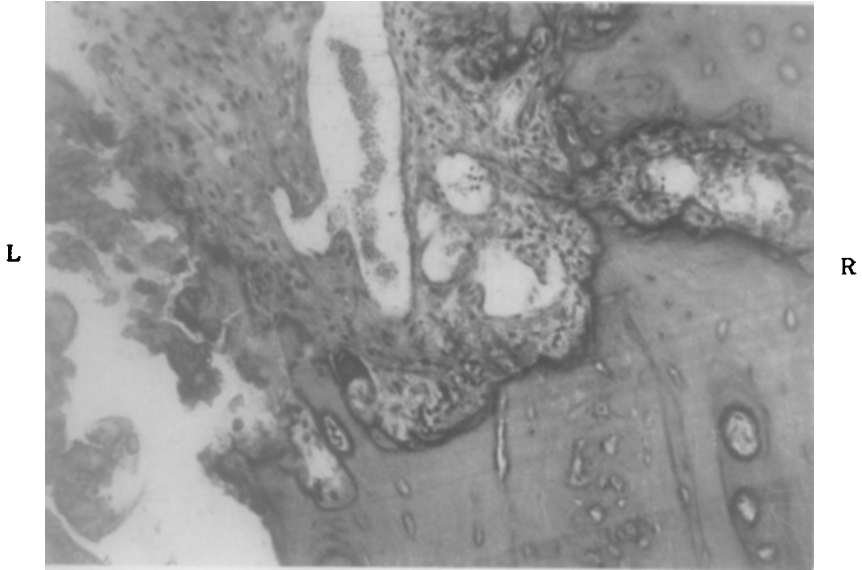


Fig. 4.
S.T.I.

In some areas lacunae are empty, in others the bone shows well-stained nuclei. To the left blood-clot, to the right fibrous bone marrow is growing into the defect, eroding the contours of the bone.

there are no Howship's lacunae. The medullary spaces are everywhere filled up with a fibrous marrow, rich in cells, here and there they are lined with close lines of osteoblasts. Where the nucleated and denucleated bony tissues come up against the cellulated medullary tissue their contours are irregular and excavated (Fig. 4, 5). This irregular form of the contours, due to numerous closely packed Howship's lacunae, is found also in the Haversian canals, in Haversian spaces, and in the bound-

ing line between the osseous trabeculae and the defect over those areas where these are in contact with the invading cellulated medullary tissue. Osteoclasts occur sparingly, the lacunae usually contain cells of osteoblastic type. Here and there the osseous trabeculae show narrow seams of well demarcated bone with numerous nuclei, probably new bone.

The blackish red appearance of the amorphous mass between

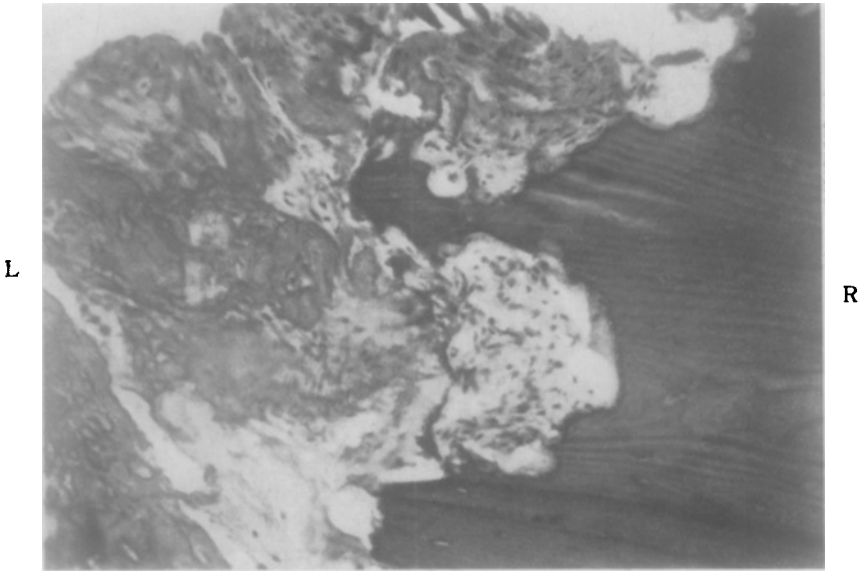


Fig. 5.
S.T.I.

Blood-clot with invading fibrous bone marrow. Bone nuclei for the most part stained. The bone outline down to the left is torn and rent. Bone contour in the contact surface bordering on the medullary tissue is more even, with Howship's lacunae holding cells resembling osteoclasts.

the fragments, visible to the naked eye, its property of staining red with eosin and yellow to yellowish red by v. Gieson, the coarse reticular structure apparent on fibrin staining,—all these factors support the view that the mass is chiefly made up of old blood-clot. The main part of the bone tissue visible in the section is nucleated, it is only the parts located close to the

bone defect whose nuclei fail to stain. This shows that the inlaid graft within the area examined has been rebuilt.

The form of the bone defect, with irregular torn and rent contours, especially in areas not affected by invading tissue, the detached necrotic bone particles partly embedded in the clot, the superficial necrosis of the bony parts limiting the defect and, finally, the blood clot filling up the defect,—all these factors suggest a sudden interruption of the continuity of the rebuilt bone graft. This is borne out by the patient's reference to a sudden pain in the back in conjunction with a slight trauma a fortnight before the operation, a pain which subsequently persisted unabated. Here, then, we have to do with a true fracture of the Albee graft rebuilt at least in its dorsal part.—The age of the lively bone absorption of lacunar type, apparent in the sections, cannot be exactly determined. It is thus impossible to say for certain that the bone absorption within the investigated portion of bone had not been going on already prior to the slight trauma causing the fracture. In that case the fracture would have occurred within a previously weakened area.

Specimen II (case 5). Specimen from a male patient, aged 23, who had had an Albee operation 2½ years earlier. At the time when the specimen was taken, the graft defect was 5—6 months old. At the operation a white fibrous band between the two graft fragments was observed at the seat of the defect. No respiratory displacement was noticed in the defect. Sagittal sections were made from the lateral part of the defect, including the above described white band with surrounding bony parts.—Frozen sections, stained by Weigert's Htx-van Gieson. The microscopical sections show two areas of spongy bone, separated by an irregular blue-coloured band. The spongy trabeculae are fairly coarse with irregular, mainly nucleated structure. The medullary spaces contain a fairly vascular fibrous bone marrow rich in cells. Here and there are seen rows of osteoblasts. The blue-coloured tissue is made up of typical cartilage and cartilaginous tissue, at one margin of the section of coarse collagenic connective tissue. At the boundary between the spongiosa and the cartilage, the medullary spaces of the former open

towards the latter, causing irregular depressions into the cartilage outline. Here and there it may be seen how the vascular medullary tissue has extended into the empty cavities after degenerative cartilage cells. Around the medullary spaces, in the periphery of remaining cartilage trabeculae, there are narrow well defined seams of nucleated bone and osteoid tissue. In one or two places near the boundary of the spongy bone the cartilage cells tend to have a pillar-like arrangement. In the spongy trabeculae next to the cartilage the nuclei are rounded and irregularly arranged. In several places are seen remnants of blue-coloured tissue enclosed in the osteoid and osseous trabeculae. In other parts of the section the cartilaginous tissue is also seen here and there to pass over into osteoid tissue and bone.

The section shows a bone defect in the reconstructed graft. The defect is filled up with cartilage and cartilaginous tissue. In the contact surface against the bone a slight formation of new bone is going on from cartilage as well as from cartilaginous tissue.

Specimen III (case 36). Specimen from a boy, aged 8, with an Albee operation twelve months earlier. When the specimen was taken, the defect was at least six months old. Three sagittal sections were made through one of the two defects with surrounding bone. At the operation respiratory displacement could be observed in the defect between the fragments and the spinous process of L IV. Frozen sections, stained by Weigert's Htx-van Gieson.—The sections include two areas of spongy bone, one with coarse, irregular trabeculae, the other with thin trabeculae. Between these there is a blue-coloured band cleaved by a slit. The blue-coloured band is made up of hyaline cartilage.—In the central area of the compact bone there is a smaller part with empty lacunae, demarcated from surrounding nucleated bone by thick dark lines. On the line bordering on the cartilage there is a system of coarse, spongy trabeculae. The intervening medullary spaces contain a fibrous bone marrow rich in cells, and in places open towards the cartilage. Around these medullary spaces there are layers of small nucleated seams of bone in the

periphery of remaining cartilage trabeculae. Near the boundary toward the bone, the cartilage cells show a pillar-like arrangement.—Through the middle of the cartilage band there is a deep slit partly filled by brown-coloured amorphous masses. On each side there is a row of large chondrin balls, with numerous nuclei, arranged along the defect. On the outer side of these chondrin balls cartilage cells are arranged in regular arc-shaped

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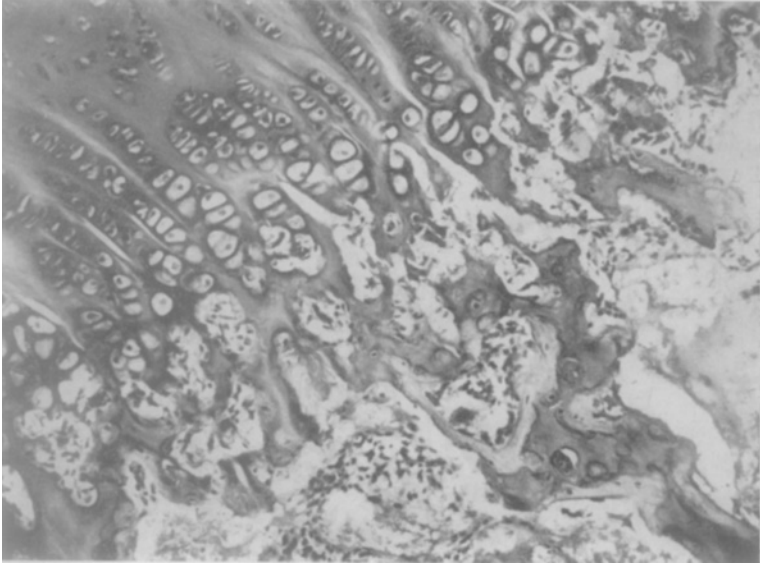


Fig. 6.

Case 36.

Cartilage cells show a pillar-like arrangement; the ground-substance is dark-coloured (calcified). In the bone-cartilage boundary there are thin bone trabeculae surrounding medullary spaces filled with blood vessels and fibrous marrow. Down towards the right are seen remains of calcified ground-substance surrounded by seams of new-formed bone.

rows, on the whole parallel with the defect.—On the other side of the cartilage band there is spongy bone with narrow trabeculae. Near the cartilage, the bone-marrow is fibrous and rich in vessels and cells, farther away from the cartilage it is of myeloid character. Near the boundary between cartilage and bone, the cartilage nuclei show a typical pillar arrangement.

The transition between cartilage and bone has in all essentials the same appearance as that of a somewhat irregular epiphyseal line.

The defect in the bone graft is in this case filled with hyaline cartilage. Transversely through the cartilage there is a slit which, to judge from the arrangement of the chondrin balls, had been present during life and not made in cutting out the sections. On the boundary between bone and cartilage a typical enchondral formation of new bone, of the same type as in a normal epiphyseal line, is going on on one side. On the other side, the new-bone formation from the cartilage is insignificant, but also here it has the character of enchondral new-bone formation. (Fig. 6).

Specimen IV (Case 2). Specimen from a female patient, aged 30, who had had an Albee operation 15 months earlier. The graft defect was 12 months old when the specimen was taken. At the reoperation the defect was seen to be covered, dorsally, by a thin layer of bone. The defect was filled out by a yellow-white fibrous mass.—Frozen sections, stained by Weigert's Htx-van Gieson. The specimen includes several fragments from the bone surrounding the defect, besides the fibrous tissue of the latter.—The sections show numerous irregular fragments of bone adjacent to tissue of fibrocartilaginous character. Large, fairly massive bony parts show an absence of stained nuclei and empty lacunae; other parts, particularly the thinner trabeculae, show well-stained nuclei. The medullary spaces are filled with fibrous marrow rich in cells. Around the medullary spaces as well as on the line bordering on the cartilagenous tissue, the denucleated bony parts show seams of bone with numerous stained nuclei. Around the Haversian canals of the denucleated bone there is nucleated lamellar bone. In numerous places there are signs of lacunar absorption of the necrotic as well as of the nucleated bone.

This specimen shows necrotic remnants of the graft on the point of being reconstructed. The defect is filled up with a fibrocartilaginous tissue. On the boundary between this tissue and the graft fragments bone absorption as well as new bone formation are going on.

Specimen V (Case 23). Specimen from a male patient, aged 36, who had had an Albee operation $3\frac{1}{2}$ years earlier. The graft defect was probably 15 months old when the specimen was taken. At the reoperation a white line, 1 mm. broad, was observed at the seat of the defect, passing transversely through the graft and surrounded on both sides by bone. No respiratory mobility between the graft fragments could be observed. Sagittal sections

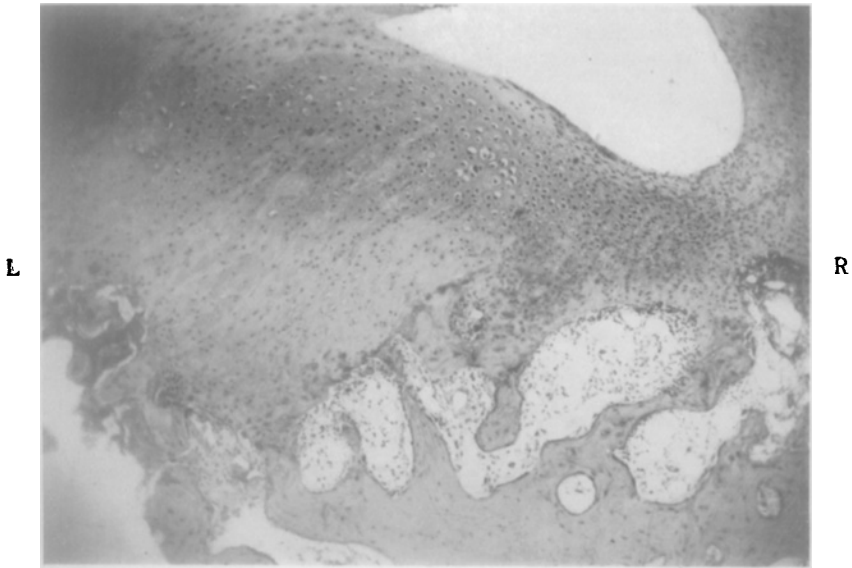


Fig. 7.
Case 23.

Above, cartilaginous tissue with a rounded cavity; below, bone tissue. The cartilage cells show tendency to pillar-like arrangement towards the osseous boundary. In the Haversian spaces a very vascular fibrous bone marrow.

were made through the lateral part of the graft defect. Frozen sections, stained with Weigert's Htx-v. Gieson.

The sections comprise two areas of spongy bone separated by an irregular band of bluish tissue. A compact portion of bone shows fairly large areas with empty lacunae. As this portion is pervaded by nucleated bone tissue concentrically arranged around Haversian canals, it would seem that the denuded

bone corresponds to some necrotic graft remnant. The spongy trabeculae in the other parts of the section are coarse and irregular; nuclei well-stained. The Haversian spaces of the spongy bone are filled up, peripherally, by myeloid bone marrow, next to the »transverse band« the medullary tissue has the character of a vascular fibrous bone marrow; the Haversian spaces are here and there lined with osteoblasts. The »transverse band«

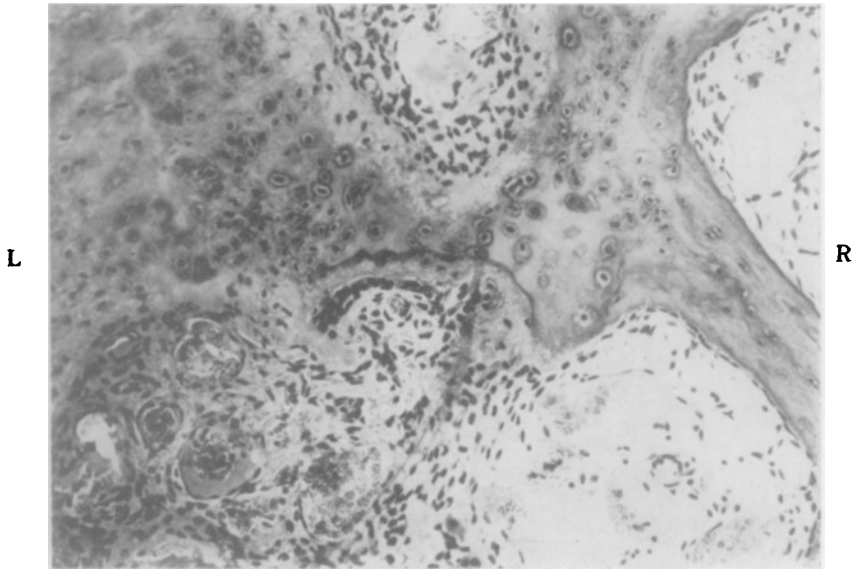


Fig. 8.
Case 23.

Above and to the left, degenerative cartilage. In the centre of the picture there is a seam of osteoblasts, above this a seam of new-formed bone, and to the right a bone trabecula. In the Haversian spaces fibrous marrow and blood-filled vessels.

consists of cartilage and cartilaginous tissue. Some areas show no stained nuclei, in other places cavities are observed, some of which contain blood. In one or two places the cells of the cartilaginous areas tend to have a pillar-like arrangement towards the bone boundary. The medullary spaces of the spongy bone open up extensively towards the cartilaginous band. They are filled up with a highly cellular fibrous bone marrow with wide,

blood-filled vessels. Around these medullary spaces there are narrow, well delimited, probably new-formed bony seams. The impression formed is that the cartilaginous tissue is disintegrated by the highly cellular fibrous bone marrow, whereupon new bone is formed concentrically around the medullary spaces. Centrally, the new-formed bony trabeculae enclose areas of cartilaginous tissue, in places containing stained nuclei. Some trabeculae show a narrow seam of osteoid tissue. Here and there lacunar absorption of new-formed bone trabeculae is observed.

The section shows a defect in a partly necrotic Albee bone-graft. The defect is filled up with cartilage and cartilaginous tissue. Within the defect there are necrotic areas and a few small cavities. On the boundary between the defect and the spongy bone new bone is being formed from cartilage and cartilaginous tissue.

In summary, then, specimen I shows a fracture, about fourteen days old, of a reconstructed Albee graft with superficial necrosis of the ends of the fragments and a blood-clot in the slit between them. It is impossible to state definitely for how long the lively progressive lacunar bone absorption has been going on, it may have started already before the fracture was sustained. Callus has begun to form, fibrous bone marrow is growing into the blood-clot, and there is also a slight amount of new-bone formation.—None of the specimens II—V give any definite idea as to the mode of origin of the graft defect. Nor could this be expected, seeing that the specimens were removed between 5 and 15 months after the defect had arisen. Specimens II, III and V include the defect as well as surrounding bone. In specimens II, IV and V (adult patients) the defect is filled up with an irregular mass of cartilage and cartilaginous tissue, in specimen III with hyaline cartilage.—In specimens II, IV and V new bone is being formed from cartilage and cartilaginous tissue on the boundary between the defect and the spongy bone. Specimen III shows a typical enchondral new-bone formation on one of the boundaries between the defect and the spongy bone; the line of demarcation between cartilage and bone has the appearance of an epiphyseal line. On the other boundary of the

defect the new-bone formation is insignificant. The pillar-like design of the cartilage cells, characteristic of a growing epiphyseal line, can be seen on both sides of the defect, on the line bordering on the spongy bone. A similar design of the cartilage cells is indicated in specimens II and V. Lacunar bone absorption of slight extent occurs in specimens II, IV and V.

The appearance in specimen III is the same as in cases of pseudarthrosis described by *W. Müller*. In a young rabbit he had fixed the posterior surface of the tibia to the tuber calcanei by means of a bone-graft, with a view to ankylosing the talo-crural articulation. The bone-graft was cast off, but around it a bone bridge had formed between the tibia and the tuber calcanei. This bone bridge shows a pseudarthrosis at a level with the talo-crural joint. This pseudarthrosis, like one which occurred in another case, shows, between the bone ends, a zone of cartilage with small central cavitations. The microscopical picture shows how the cartilage cells are arranged in a pillar-like manner towards both boundaries between cartilage and bone. The picture shows »eine auffallende Ähnlichkeit mit der Verknöcherungszone einer Epiphysenlinie«. Small capillaries have grown into the centre of the cartilaginous band, and around them small bone trabeculae can be seen.—*Nussbaum* describes defects of the grafts in a dog operated on by *Henle's* method. The defects are filled out with a fibrocartilaginoid tissue.

In callus around incompletely fixed fractures of the extremities one often finds larger or smaller areas of cartilage, particularly in those parts of the callus where the mobility is greatest. As a cause of transformation of connective-tissue-callus into cartilage *Leriche* and *Policard* suggest repeated small movements, especially of a tangential kind,—»scissor« movements between the fragments. Specimens II, III and V show a defect in the bone of the graft filled out with cartilage and cartilaginous tissue. The abundant cartilage formation in the callus tissue formed between the fragments may possibly be explained by the steadily repeated minor displacements between the graft fragments arising on respiratory movements and other involuntary small movements within the spine.—In these cases the

histological appearance does not contradict the assumption of a graft fracture in the process of callus union. It is evident from the commencing formation of new bone in specimen I, as also from the clearly evident formation of new bone of various types in the other specimens, that the graft defects investigated have a tendency to spontaneous union.

The result of the author's histological investigations may be summarised as follows:—

1. The reconstruction of an Albee graft in man takes place in a manner described by *Barth* and others. It takes a long time for the corticalis graft, which undergoes necrosis after the transplantation, to become completely absorbed and to be replaced by living bone. In children this may take longer than 2 years and 2 months, in adults more than 3½ years. The transplanted periosteum takes part in the formation of new bone.

2. Fracture may occur in a largely rebuilt Albee graft.

3. Defects in an Albee graft have a tendency to spontaneous union. At the seat of the defect a highly cartilaginous callus tissue may form. The boundary between cartilaginous callus and bone may in children present the appearance of an epiphyseal line with enchondral bone formation.

The entirely or partly necrotic bone graft can neither biologically nor mechanically be likened to the living though pathologically changed rhachitic or osteomalacic bone. It seems therefore hardly correct to use the term: *Looser's* »Umbauzonene« when speaking of a bone-graft. Nor can defects in the necrotic bone graft be likened to fractures and fissures in living healthy bone tissue.

Lexer maintains that during its atrophic stage the strength of the necrotic bone graft is reduced, particularly with regard to flexion stress, and that exposure to strain easily causes cracks in its bone substance. Sometimes these cracks pass transversely through the graft, immediately producing a break in the continuity with obvious malposition and diastasis. In the case of smaller and incomplete cracks, vessels and connective tissue may grow into them and absorb the surrounding bone, with the result that the strength is still further reduced. New cracks form, and

finally a complete defect in the continuity develops also in such cases, an »insidious fracture« being the result.

The circulation in the united necrotic bone graft is at first insignificant, and confined to the narrow Haversian canals in the compact bone of the graft. The necrotic bone substance can therefore only be absorbed in the contact surface between the graft and surrounding tissue and in the Haversian canals. *W. Müller* considers that a graft defect may arise as the result of local »mechanical irritation« at some point of the graft, through increased bone absorption there with diminished formation of new bone. In the author's opinion this explanation of the production of a graft defect is insufficient. It would hardly seem probable that vessels and connective tissue would at one single point grow into a coherent, mainly necrotic, corticalis graft and cause a defect of this. On the other hand, *Lexer's* explanation of the production of an »insidious fracture«, as illustrated in his publications by numerous cases, seems to be satisfactory.

Biesalski mentions »eine tatsächliche Fraktur« of an Albee graft. The author's specimen I likewise shows the picture of a graft fracture. Several of *Waldenström's* and the author's cases show the clinical and roentgenological picture of a instantaneous graft fracture. One cannot disregard the possibility that the graft in some cases has become more than usually impaired by generalised bone absorption. Such a condition may conceivably contribute to the production of a graft fracture.—Numerous cases in the literature, as well as among *Waldenström's* and the author's material, present the picture of an »insidious fracture«. In the production of *Looser's* U. Z. mechanical factors take part and cause cracks in the corticalis of the long bones. These cracks are invaded by fibrous bone marrow, which absorbs the surrounding bone. There is considerable analogy between the formation of U. Z., the production of »insidious fractures«, and pseudarthrosis in necrotic bone grafts, and also certain cases of insidious formation of pseudarthrosis in healthy living bone tissue (*Bier, W. Müller*).

Chapter VII.

THE AUTHOR'S CLINICAL MATERIAL REVIEWED
WITH REFERENCE TO THE MODE OF PRODUCTION
OF THE GRAFT DEFECTS

Albee states that the partially periosteum-covered bone graft inserted into the split spinous processes and fixed there by firm interrupted sutures provides good fixation to the injured spine already from the start. This fixation is strengthened still further when the graft shortly after enters into bony union with the spinous processes. *Albee* emphasises the value of immediate fixation in those cases where the tuberculous destruction has caused complete interruption of the vertebral column with respiratory displacement between the upper and lower segments of the spine. In such cases, the persistent wear on the fragments of the vertebral bodies due to respiratory movements would immediately be brought to cease by the operation. It would seem that *Albee* also to some extent operates on early cases of spondylitis. It is particularly in such cases that he considers his operative method to be superior, on account of the immediate fixation obtained, to other methods by which soft osteo-periosteal grafts from processes and arches are united with one another (*Hibbs* and others). In the latter methods osseous union between the arches of the diseased vertebrae is obtained only gradually.

It is quite evident that the bone graft united in the spinous processes cannot prevent the tuberculous infiltration from spreading further in the vertebral bodies. In cases of spondylitis operated on in an early acute stage there is frequently, after the operation, a progressive destruction of the vertebral bodies; and often, in spite of operation, a terrible deformity develops, with considerable alteration in the shape of the graft. *Waldenström*, *Sorrel*, and others lay stress on the importance of postponing the operative fixation till a time when the tuberculous bone destruction has come to an end, or has become quiescent. To determine this is a matter of exceedingly great difficulty.

With the patient in supine position there is only one factor which may create a certain amount of strain on the damaged part of the back; namely, contracture of the back muscles. With

a patient who is thus fixed in plaster bed or otherwise, the fixation brought about by the Albee operation is in the majority of cases sufficient to prevent movements within the diseased part of the back.—In those cases where an inflexion originally present has been corrected through redressment there is a defect in the column of vertebral bodies and intervertebral discs at the seat of the tuberculous lesion. In the erect position the body weight above the defect is striving to force together the segments of the spine, thereby filling up the defect in the vertebral column and reestablishing the interrupted continuity. The bone graft fixed in the spinous processes is intended to make up for the lost stability of the column of vertebral bodies and prevent a renewed inflexion movement. It is only after repair or encapsulation of the tuberculous process in the bone that the defect in the vertebral bodies is gradually filled up with new-formed bone or firm connective tissue; and only then is the column again able to sustain a weight, thanks to this firm, supporting tissue. Until then, the series of arches and processes in the damaged part of the spine, connected together by the Albee graft, must carry out the function of the spine as a supporting organ.

When the vertebral column of a patient with spondylitis is put to the strain of sustaining a weight in erect position there is thus immediately a tendency to inflexion; the cranial segment of the spine will tend to fall down upon the caudal one. The bone destruction usually has its greatest distribution in the anterior parts of the vertebral bodies, their dorsal parts as a rule maintaining a better condition; articular processes and arches are generally intact. In the case of more widespread destruction in vertebral bodies and intervertebral discs, flexion between two adjacent vertebrae does not take place, as under normal conditions, round a frontal axis through the nucleus pulposus of the intervening intervertebral disc, but round a frontal axis through the intervertebral joints of the two vertebrae; the movement there will then be one of »separation«. Such an inflexion movement between two vertebral remnants may thus be regarded as a forward bending movement round a frontal axis through the intervertebral joints,—which in the follow-

ing, we will term the »inflexion axis«. On inflexion the anterior portions of the vertebral remnants approach one another, the spinous processes spreading out in a fan-like manner. In the case of widespread destruction of vertebral bodies in the dorsal region, arches that have separated may become dislocated backwards through pressure from surrounding vertebrae.

Owing to anatomical conditions the tendency to inflexion is more apparent in the dorsal than in the lumbar region. In the dorsal region, extension beyond full straightening of the spine is prevented by the form and position of the vertebral arches, and by the tile-shaped arrangement of the spinous processes. Displacement in an axial direction between two dorsal vertebrae is prevented by the obliquely placed, dorsally and cranially convergent intervertebral joint surfaces, and by the spinous processes placed closely one over the other. It will therefore be clear that even a slight destruction of vertebral bodies in this region will give rise to inflexion which cannot be compensated by extension. In the lumbar region, the tendency to inflexion may be compensated by extension and lordosation, the weight being simultaneously transferred to the usually better maintained dorsal parts of the vertebral bodies. Even under normal conditions, the vertical position of the intervertebral joints and the shape of the arches and spinous processes permit a certain amount of shortening of the lumbar region during extension movements. In lesions of vertebral bodies and intervertebral discs the shape and position of the intervertebral joints often permit still further compression of the damaged part, in an axial direction; whereby the destruction becomes partly compensated without inflexion. In the case of more widespread destruction, inflexion occurs also in the lumbar region, and a typical inflexion gibbus may also form here (see Cases 18, 27, 35).

An Albee graft-inlay united in the lumbar spinous processes prevents axial compression of the damaged vertebrae, and also lordosation of the fixed area. A vertebral destruction in the lumbar region continuing after the Albee operation can therefore not be compensated by axial compression and lordosation of the damaged vertebrae (see Case 34).

Because of the possibility of compression in axial direction and of lordosation in the lumbar region the position of the inflexion axis cannot be determined as exactly there as in the dorsal region where such possibilities are excluded.

When the spine of a patient with an Albee operation is subjected to the weight of an erect posture about 2 months after operation, there will at once be a tendency to inflexion. The Albee graft fixed into the spinous processes will then be subjected to powerful bending and traction. In the cases where the vertebral destruction involves the opposing parts of two adjacent vertebrae, the inflexion axis passes frontally through the intervertebral joints of the two affected vertebrae. In the cases where the destruction involves parts of several vertebral bodies it is often impossible to determine the position of the inflexion axis; inflexion may sometimes take place round several frontal axes. In cases with extensive lesions, where the intervertebral joints have been destroyed or dislocated, the inflexion movement takes an irregular course. Displacements in the sagittal and frontal planes help to create the faulty position, and the axes cannot be exactly determined.

In those cases where reduction of the gibbus obtained by correction is only apparent, and where such reduction has been attained by extension and lordosation of parts of the back located immediately above and below the affected part, the graft-inlay is intended not only to secure the individual damaged vertebrae to one another, but also to maintain the corrected shape of the back. As already stated, the bone-graft is inserted into the spinous processes of one or two sound vertebrae above and below the tuberculous vertebrae. On weight-bearing in erect position the static conditions of the back are altered, the movements of the vertebral column become greater than in the supine position. The undamaged vertebrae fixed to the end parts of the graft are connected with the partly destroyed vertebrae nearer the centre of the spondylitic area by undamaged discs and intervertebral joints, which permit normal movements between the vertebrae concerned. At a level with these normal intervertebral connections the Albee graft constitutes the only means of fixa-

tion. Under weight-bearing in a vertical position, and under the increased activity of the patient connected therewith, forces of various kinds come into play, which, at a level with the intact intervertebral connections, exert local stresses on the bone-graft. These forces cannot be analysed in detail. *Hoffmann* refers to them under the summary term of »arthrogenous stress«. In some of the cases the paragibbous lordosis previously observed, in conjunction with a graft defect, arisen at the level of an intact intervertebral connection, has become less noticeable. Such a levelling of the paragibbous lordosis, like the inflexion movement, signifies flexion of the spine.

All spondylitic patients operated on at the C. S. A. were for a longer or shorter period before the operation corrected in plaster bed by *v. Finck's* method. Under this treatment, the gibbus in most cases diminished in size, and in many cases entirely disappeared. In some cases this reduction of the gibbus was due to atrophy from the pressure exerted, with absorption and alteration in the shape of the spinous processes and arches involved in the gibbus. In other cases the reduction was due to the change taking place in the relative position of the vertebrae. In such cases where mobility existed between individual vertebral remnants, the correction pressure produced diminution of the inflexion and thereby direct reduction of the size of the gibbus. In such cases, on the other hand, where the vertebral remnants are mutually fixed the correction pressure is unable to alter the existing inflexion position. The reduction of the gibbus produced by the correction has in that case only been apparent, its less marked prominence being explained by extension and lordosis of the parts of the back immediately above and below the affected area. The Albee graft inserted into the spinous processes is intended to secure the corrected shape of the spine. By this fixation continued »ulceration compressive« is to be prevented and at the same time it shall further repair of the tuberculous focus.

In by far the greatest number of Albee patients at the C. S. A. the graft inlay tolerated the increased stress in erect position without its shape being altered, and without its continuity being

interrupted. In many of these cases a defect in the column of vertebral bodies was gradually filled up with bony substance, and the stability of the column more or less completely reestablished.

In other cases the graft was unable to withstand the increased strain in erect position. The damaged part of the spine collapsed under inflexion and the graft was bent in a dorso-convex arch over the gibbus. This development was often observed in children, whose tibial grafts are thinner and softer, and possess greater elasticity than those of adults.

In other cases again, defects arose in the graft in connection with increased weight-bearing. Such defects generally arose at an early stage, during the first six months after the Albee operation whilst the graft was still in its »atrophic stage«. Even much later, while the graft was in the stage of reconstruction, recent defects were observed in it.

With reference to the mechanical conditions for the production and localisation of graft defects the author has classified his whole clinical material, 37 cases (15 children under the age of 14 and 22 adults), as based on X-ray appearances, according to the following scheme:

A. Graft defects arisen in conjunction with increase of inflexion after the operation, »inflexion defects«, 25 cases (6 children, 19 adults).

I. During the whole period of treatment the spondylitis involves portions of two vertebral bodies: 13 cases, all adults. Cases 2, 6, 7, 8, 9, 15, 16, 20, 22, 23, 24, 34, 37.

a. The graft defect is localised at a level with the inflexion axis: Cases 2, 6, 7, 8, 9, 16, 20, 22, 23, 37.

b. The graft defect is located above or below the inflexion axis: Cases 15, 24, 34.

II. The spondylitis involves portions of more than two vertebrae:

1. At the time of the Albee operation the spondylitis involves portions of two vertebral bodies, later it attacks several vertebrae: 4 cases (2 children, 2 adults).

- a. Graft defect level with inflexion axis: Cases 5, 17 (II).
 - b. Graft defect above or below inflexion axis: Cases 3, 31.
2. At the time of the Albee operation the spondylitis involves portions of three or more vertebral bodies: 8 cases (4 children, 4 adults).



Fig. 9
(Case 16, 28. VIII. 28).
Before correction.

- a. Graft defect level with inflexion axis: Cases 10, 11, 12; 13, 35 (I), 36 (I).
 - b. Graft defect below inflexion axis: Cases 1, 4.
- B. Graft defects in the peripheral part of the bone-graft, in

conjunction with change of relative position of the tuberculous vertebrae situated farthest toward the periphery. No inflexion within the centre of the spondylitis: 3 cases (children), 18, 26, 27.

C. No increase of inflexion after operation. Graft defects level with intact intervertebral connections: 13 cases (9 children,

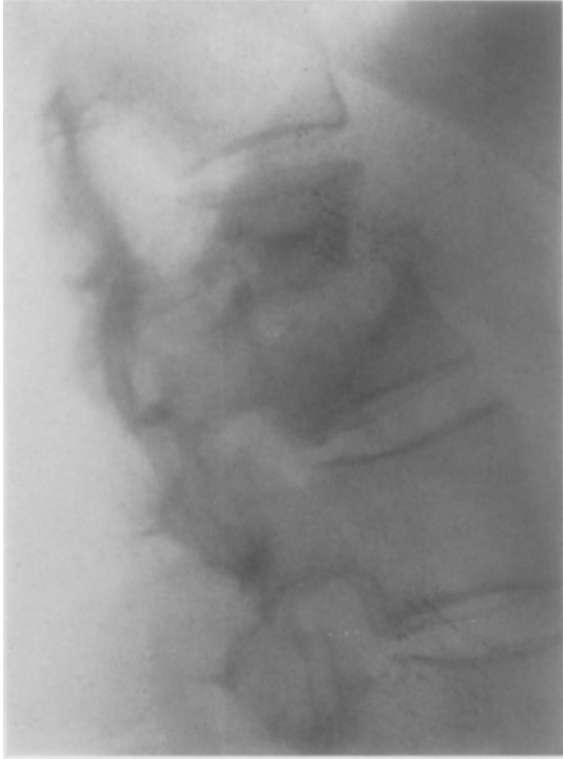


Fig. 10
(Case 16, 16. V. 29).
After correction.

4 adults), Cases 14, 17 (I), 19, 21, 25, 27 (I), 28, 29, 30, 32, 33, 35 (II), 36 (II).

A:

I. In Cases 2, 6, 7, 8, 9, 15, 16, 20, 22, 23, 24, 34, 37 the destruction involved the opposing parts of two adjacent vertebral

bodies during the whole observed period of disease. (Apart from superficial caries of the anterior surface of the vertebral bodies within the area of an abscess, and apart from simultaneous spondylitic foci within other parts of the vertebral column). In Cases 2, 6, 7, 8, 15, 16, 23, 24, 34 an inflexion position discovered before commencement of treatment was corrected, en-

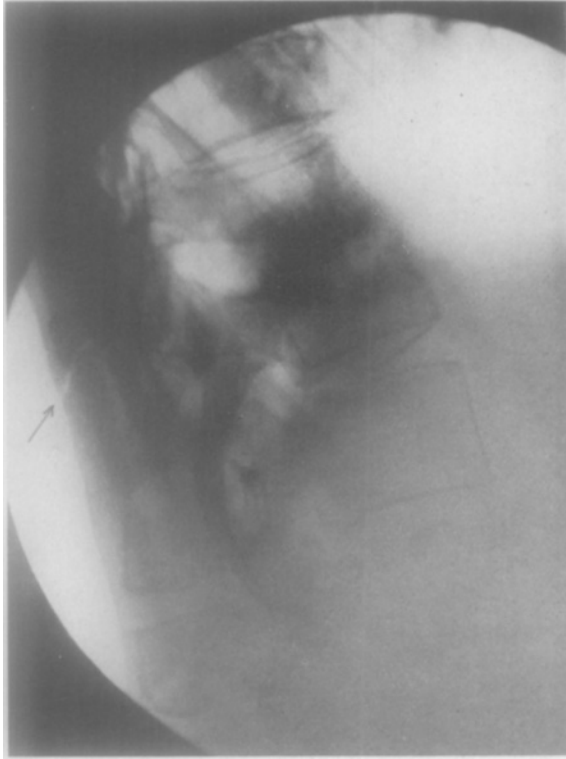


Fig. 11
(Case 8, 18. IV. 33).

tirely or in part, through redressment. On comparing the skia-grams before and after the correction it will be seen that the remnants of the damaged vertebral bodies have been forced apart so that a bone defect appears in the vertebral column at the seat of the tuberculous lesion. Fig. 9, 10. In several cases (e. g. cases 9, 20) a diminution of the original inflexion is likely to have taken place but has not been verified. In numerous cases

the position of the damaged vertebrae as observed at the time of operation has altered a longer or shorter time after the operation under weight-bearing in vertical position, the remnants of the vertebral bodies have collapsed under increase of the inflexion. This was the case in Cases 2, 6, 7, 8, 9, 15, 16, 20, 22, 23, 24, 34. Concurrently with this increase in the inflexion, the inlaid bone graft has been subjected to a break in its continuity, earliest 7 weeks, latest about 2 years after the Albee operation.

a. This graft defect is located on a level with the intervertebral joints of the two damaged vertebrae in Cases 2, 6, 8, 9, 16, 20, 23. Fig. 11. (In Case 7 the defect is located immediately distally of, and in Case 22 immediately proximally of the intervertebral articular connection of the two damaged vertebrae). In Cases 2, 6, 9, 22, 37 the defect is located on the proximal side of the spinous process of the uppermost of the damaged vertebrae, in the rest between the spinous processes of the damaged vertebrae. In all the cases the fragments of the graft formed a more or less marked angle open ventrally.—In Case 23, in which the vertebral destruction is asymmetrical, the vertebral remnants formed at the commencement of treatment an angle open laterally. This angle was corrected by redressment. Two years, at least, after the operation the patient again had trouble with his back. On examination 3½ years after the Albee operation the original malposition of the vertebrae had returned, and the bone graft was the seat of a defect, the fragments of which formed an angle open ventrally as well as laterally. In Case 37 the lesion involved the opposing parts of the bodies of L V and S I, there was no definite increase in inflexion after the operation. Ten months after the Albee operation a defect was observed in the graft, on a level with the intervertebral joints L V-S I, between the spinous processes of L IV—V.

b. In Case 24 a graft defect arose twelve months after the operation, in connection with strong flexion of the back. The skiagram shows a slight increase in inflexion between the bodies of the affected vertebrae L II and L III; the graft defect is located at a level with the undamaged intervertebral junction L I—II, above the spinous process of L II; the graft fragments

form a slight angle open ventrally.—In Case 15 the destruction involved the opposing parts of the bodies of D XII and L I. In the bone-graft fixed in the spinous processes of D X—L II a vertical fissure was observed, 15 months after the Albee operation, between the spinous process of L I and the bone graft.



Fig. 12
(Case 34, 12. IX. 29).

After 18 months the vertebral remnants of D XII and L I had approached one another and occupied the same position as at the commencement of treatment. Between the spinous processes of L I and L II there was now seen a broad defect in the bone graft, the fragments of which formed a ventrally open angle. The relative position of L I and L II was unaltered. The above-men-

tioned fissure seems to have enabled a displacement of L I to take place in relation both to the bone-graft and to D XII. The inflexion movement resulting from the displacement of L I has caused a defect of the bone graft, located below the inflexion axis and immediately below the undamaged intervertebral junc-

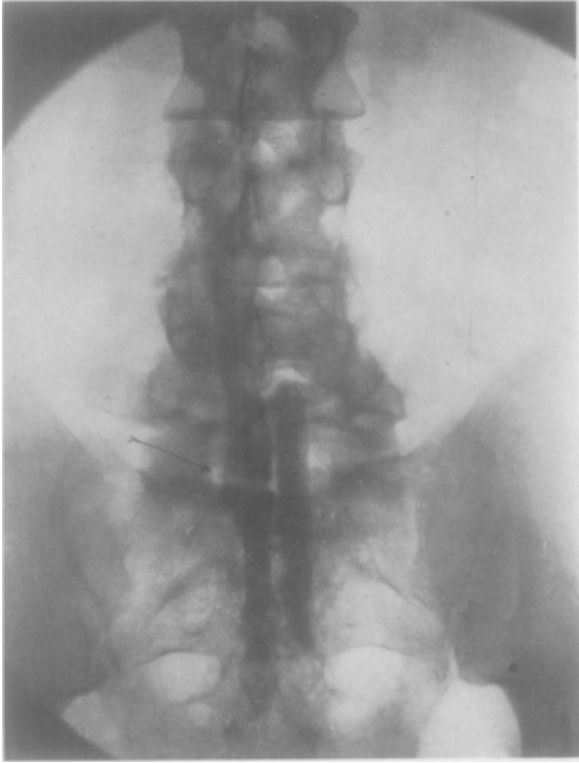


Fig. 13
(Case 34, 5. X. 33).

tion L I—II.—In Case 34 the tuberculous lesion in the bodies of L IV and L V continued also after the Albee operation. The position of L IV in relation to L III and to the bone graft was unaltered. Nor did the spinous process of L V show any altered position in relation to the graft. The remnant of the body of L V progressively diminished during the period of observation and

gradually approached that of L IV so that the two remnants 3 years after the operation formed a wedge. For this displacement of the vertebral remnant of L V to take place in relation to L IV and the bone graft, the arch of L V must have altered in shape

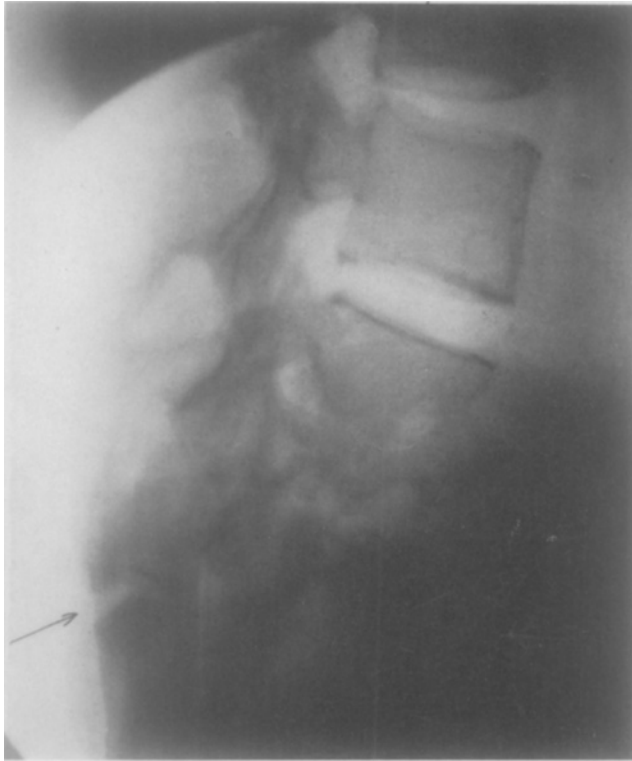


Fig. 14
(Case 34, 5. X. 33).

or have been the seat of a defect between the spinous process and the remnant of the vertebral body. As no details of this area are apparent on any skiagram, it is impossible to localise exactly the seat of the displacement. Through the displacement of the vertebral remnant of L V the intervertebral space L V—S I becomes higher. At the level of the intervertebral disc and the interver-

tebral joints L V—S I a graft defect appeared 14 months after the Albee operation. Fig. 12, 13, 14.

II. 1. In Cases 3, 5, 17, 31 the destruction involved at the commencement of treatment portions of two vertebral bodies. During the subsequent course of the disease one or more additional vertebrae were also attacked. In Cases 3, 5, 31 the correction did not alter the original inflexion position, in Case 17 inflexion increased, in spite of correction, in conjunction with progressive destruction of the vertebral bodies.

a. In Case 5 the lesion originally involved the distal portion of the body of D X and the proximal portion of that of D XI. The shape and position of these vertebral remnants have not altered since the Albee operation. On the other hand, the distal portion of the body of D IX has been destroyed and absorbed, and its remnant fallen down against the body of D X, thereby giving rise to a new inflexion. At the level of the axis of the new inflexion between the remnants of D IX and D X a defect appeared in the graft 2 years after the Albee operation.—In Case 17 the skiagram shows how 2 years 1 month after the operation the originally affected bodies of D XII and L I have been almost entirely absorbed and the bodies of D XI and L II been attacked. At the level of the intervertebral joints D XII—L I a graft defect is now apparent, the fragments of the graft form an angle open ventrally.

b. In Case 3 the lesion involved at the time of operation the distal portion of the body of D IX and the proximal portion of that of D X. Eighteen months after the operation the remnants of the bodies of D IX and D X had undergone still further absorption. The anterior distal half of the body of D VIII was absorbed, the rest had fallen down upon the remnant of D IX. The graft showed a defect at the level of the intervertebral joints D X—XI, within the spinous process of D X. The graft fragments formed a sharp angle, open ventrally. The inflexion movement seems to have taken place partly between D VIII and D IX, and partly between D IX and D X. The distance between the spinous processes of D IX and D X has increased. The graft defect is located distally of the inflexion axes, at the level of

the undamaged intervertebral junction D X—XI.—In Case 31 the destruction originally involved the opposing parts of the bodies of L III and L IV. After the operation, absorption of the remnants of these bodies continued, the remnants falling together still further. The apparently undamaged body of L II



Fig. 15
(Case 31, 15. IV. 29).

fell down upon the slight remnants of L III—IV. At the level of the intervertebral joints L II—III a graft defect was observed 6½ months after the Albee operation, the fragments forming a well-marked angle, open ventrally. Fig. 15. Three years after the Albee operation, almost 2 years after renewed bone grafting, widespread recent destructions were discovered in the dorsal

parts of the bodies of L I and L II. In the spinous processes of D XII—L IV there was a broad coherent bone bridge with a dorsally convex curve.

2. In Cases 1, 4, 10, 11, 12, 13, 35, 36 the lesion involved, already at the commencement of treatment, portions of ~~three~~ or more vertebral bodies. In several of these cases (e. g. cases 11, 12, 35, 36) the remnants of the damaged vertebral bodies had through correction been forced apart before the operation, causing the inflexion to become less. In Cases 4 and 13 inflexion remained the same despite correction; in case 10 it increased during correction. After the patients had been in the erect position for some time after the operation inflexion again increased. (Cases 1, 4, 10, 11, 12, 13, 35. In Cases 1 and 4 increased inflexion could only be observed some time after the appearance of the graft defect).

a. In Case 10, where the destruction at the time of operation involved the anterior lower border of the body of D X and most of those of D XI and D XII, absorption and inflexion have steadily increased. Two years after the Albee operation the destruction involved the anterior $\frac{2}{3}$ of the body of D X, nearly all of the bodies of D XI and XII, and the proximal $\frac{3}{4}$ of that of L I. The vertebral remnants were entirely collapsed, and the graft was lying as an arch over the well marked gibbus. It is impossible to determine the position of the inflexion axis. Between the spinous processes of D X—XI, opposite the lesion, there was a broad defect in the graft.—In Case 11 the destruction involved the anterior lower border of the body of D XI, besides most of the bodies of D XII and L I. Five months after the operation the vertebral remnants had collapsed under the weight imposed by the erect posture. The inflexion seems to have taken place between the remnants of D XII and L I. At the level of the inflexion axis in the intervertebral joints D XII—L I a defect appeared in the graft, the fragments of which formed an angle, open ventrally.—In Case 12 the destruction involved the lower part of the body of D XI and most of those of D XII and L I. Six months after the operation the weight imposed by the erect position had caused an inflexion movement to take place

between the remnants of D XI and D XII as well as between D XII and L I. At the level of the intervertebral joints D XI—XII a broad graft defect is observed, with a considerable angle, open ventrally, between the fragments. Fig. 16.—In Case 13 the destruction involved at the time of operation the distal portion



Fig. 16
(Case 12, 20, II. 34).

of the body of D XI and considerable parts of those of D XII and L I. After the operation destruction was going on, and the inflexion was steadily increasing. Eighteen months after the Albee operation the destruction involved the distal part of the body of D X, most of those of D XI, D XII and L I, and the proximal half of the body of L II. The graft showed a defect just on the

distal side of the intervertebral joints D XII—L I.—In Case 35 the destruction involved the distal surface of the body of L III, the whole of the body of L IV, and the proximal half of that of L V. Five months after the operation inflexion had increased so that the anterior part of the vertebral remnant of L III was



Fig. 17
(Case 35, 15. IV. 29).

in contact with that of L V. Level with the intervertebral joints L III—IV the graft shows a defect, the fragments of which form a slight angle open ventrally. Fig. 17. Four and a half years after the operation this defect had become consolidated in an unaltered position; between the vertebral remnants of L III and L V a commencing osseous fusion was observed. At the level of

the intervertebral junction L II—III the graft presented a fresh 5 mm, broad defect with regular contours and without deposits in the surroundings; there was relative mobility between the spinous processes of L II and L III.—In Case 36 the lesion involved the distal part of the body of L IV and the proximal

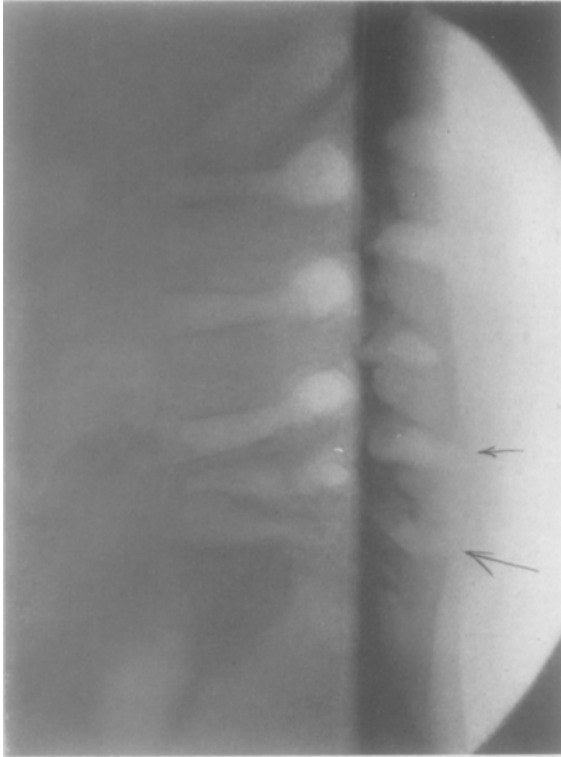


Fig. 18
(Case 36; 6. IV: 32).

part of that of L V, besides the anterior upper boarder of S I. On correction before the Albee operation the remaining parts of L IV and L V were forced apart. When the spine had to carry the weight of the body after the operation, no definite change was observed in the destruction or the position of the vertebral bodies. Five months after the operation a graft defect appeared

on each side of the spinous process of L IV, the upper one located just below the intervertebral joints L III—IV, the lower one just below the intervertebral joints L IV—V. After the operation a moderate gibbus formed, with its maximum point over the spinous process of L IV, indicating a certain tendency to in-

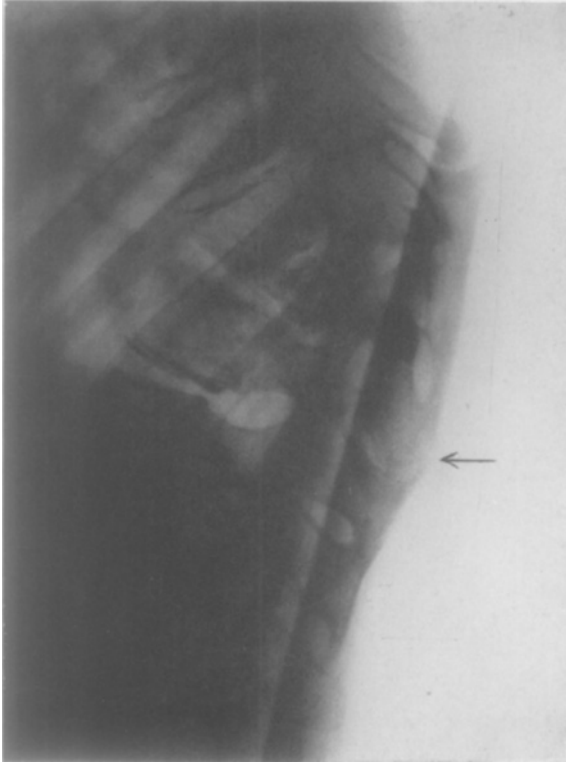


Fig. 19
(Case 4, 28. IX. 32).

flexion. No graft remnant can be seen in the spinous process of L IV. Fig. 18. (A graft defect may thus be present within the spinous process of L IV with a broad gap between the fragments).

b. In Case 1 the destruction involved considerable portions of the bodies of D VII—IX. The inflexion position which was

considerable on admission to the C. S. A. was not appreciably influenced by the correction. Five months after the Albee operation a defect in the graft was found at the level of the intervertebral junction D X—XI on the distal side of the destruction and between the spinous processes of D VIII—IX. At this time no increase in inflexion could be discovered. Seventeen months after the operation the defect was filled up with bone, and within the destruction inflexion had definitely increased.—In Case 4 the destruction involved large portions of the bodies of D VIII—X; inflexion was well marked at the commencement of treatment and was not influenced by the correction. Four months after the Albee operation, under weight-bearing in the erect position, a graft defect was found at the level of the intervertebral junction D XI—XII, between the spinous processes of D X—XI and on the distal side of the vertebral destruction. The graft fragments formed an angle open ventrally. The inflexion had not appreciably altered since the operation. During continued treatment inflexion was definitely increased, and a considerable amount of callus formed around the defect. Fig. 19.

In Cases 1, 3, 4, the graft defect is located at the level of an uninjured intervertebral junction on the distal side of the destruction and the inflexion axes. In Cases 1 and 3 the graft defect is located within or between spinous processes belonging to damaged vertebrae, in Case 4 immediately on the distal side of the spinous process belonging to the lowermost of the damaged vertebrae. In these cases the defect seems to have arisen in conjunction with increase in the inflexion, even if this increase was discovered in Cases 1 and 4 only after the defect had arisen. The stress exerted in these cases would seem to have been transferred by the powerful oblique spinous processes to a more distal part of the bone-graft.

B.

In Cases 18, 26, 27 there was widespread destruction of vertebral bodies in the lumbar region. In the central part of the spondylitic area the bodies were largely absorbed. Nearer the periphery vertebral bodies originally affected by tuberculosis were

better maintained. In the process of correction these slightly destroyed vertebrae took part in the formation of para-gibbous lordoses.—In Case 18 the lesion involved large portions of the bodies of D XII—L III; the bodies of D XI and L IV showed altered structure and irregular outlines. By the application of energetic correction 9 years after the onset of disease the gibbus was almost completely eradicated, chiefly by straightening and

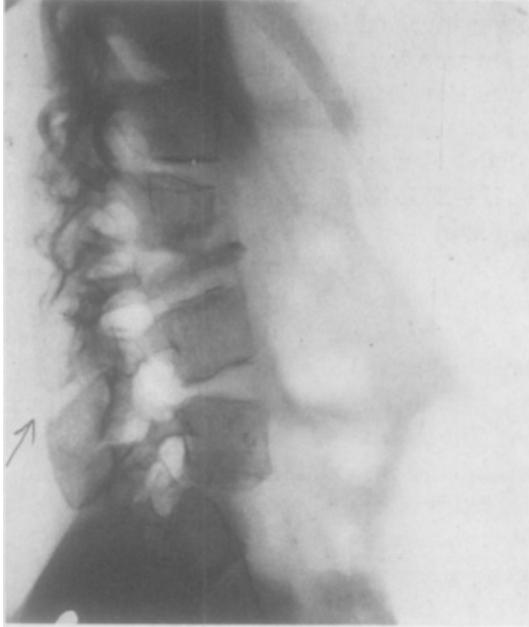


Fig. 20
(Case 21, 22. IX. 32).

lordosation of the areas covered by D IX—X—XI and L IV—V—S I. A bone-graft was inserted into the spinous processes of D X—L III. Five months after the operation a flat gibbus formation again appeared. The graft had lost its attachment to the X. spinous process. On a level with the intervertebral joints D XI—XII a defect appeared in the bone graft. Four years 5 months after the operation the vertebral bodies of D XII—L III had formed into one block. The graft defect was 1 cm. broad,

and there was relative mobility between the fragments. Between the spinous processes of L III and L IV, previously free, there was now a broad osseous union.—In Case 26 the lesion involved the distal portion of the body of L I, nearly the whole of those of L II and L III and the proximal surface of the body of

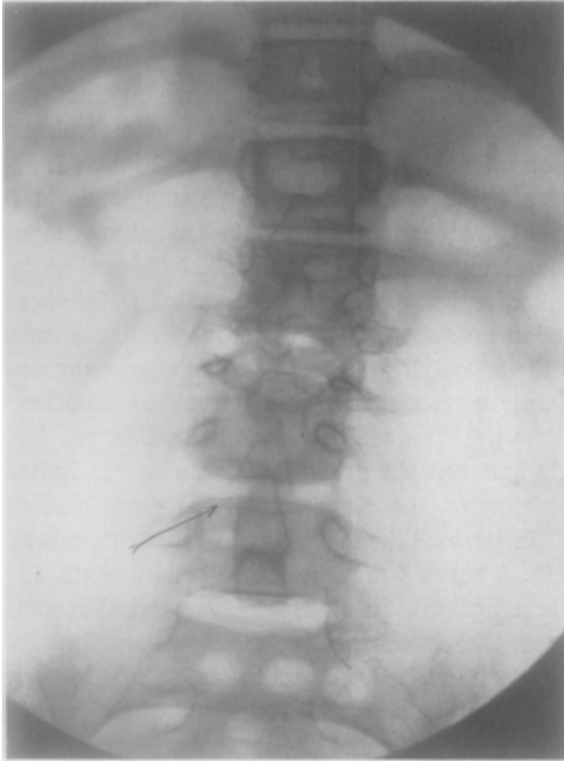


Fig. 21
(Case 26, 24. I. 33).

L IV. Ten months after the operation the position had not appreciably altered under weight-bearing. Immediately on the distal side of the intervertebral joints of L III—IV the graft was found the seat of a defect, the fragments formed a slight angle, open ventrally. Seventeen months after the operation the previously irregular proximal contour of the body of

L IV became smoother, and a normal epiphysis appeared on it.— In Case 27 the bodies of L III—V were entirely absorbed, their arches and peduncles fused by bony union. After correction a bone-graft was inserted into the spinous processes of L I—S I. Five months after the operation the position within the area of operation remained unaltered. On a level with the intervertebral joints of L I—II a defect appeared in the graft. Eighteen months after the operation this defect was filled up with bone. The body of L II had now fallen down against the minimal remnants of the bodies of L III—IV, and a fresh graft defect appeared on a level with the intervertebral joints L II—III.

In these three cases the para-gibbous lordosis is formed, in part, of vertebrae whose bodies show signs of old spondylitic changes. In Cases 18 and 27 these slightly damaged vertebral bodies have under the stress of weight-bearing after the operation approached the vertebral remnants located in the centre of the spondylitic area. A graft defect appears on a level with the axis of movement. In Case 26 no positive change is found in the position of the vertebral bodies, yet the ventrally open angle between the graft fragments rather indicates a displacement between the vertebrae, of the same kind as in Cases 18 and 27. In Case 18 the mobility of the intervertebral junctions D XI—XII, 4 years 5 months after the operation, is somewhat greater than normal. In Case 27 the graft defect has become consolidated. The vertebral displacement described in Cases 18, 26 and 27 may be regarded as an inflexion within the peripheral part of the spondylitis, or as a reduction of the para-gibbous extension, with diminution of the lordosis.

C.

In Cases 14, 17, 21, 25, 28 and 33, all children, the parts of the spine immediately above and below the spondylitis were lordosed at the correction, the gibbus thereby becoming less prominent. Inflexion was not influenced by the correction. A fairly short time after the operation, between $3\frac{1}{2}$ and 6 months, one or several defects were discovered in the peripheral part of the graft. These defects were situated on a level with an

undamaged intervertebral junction. In one or two cases it may be said that the lordosis above or below the gibbus was reduced under weight-bearing after the operation. In other cases the skiagrams show no definite change in the relative position of the vertebrae. These defects have early been surrounded by periosteal deposits, and show a satisfactory tendency to repair.

In Case 14 the destruction involved parts of the bodies of

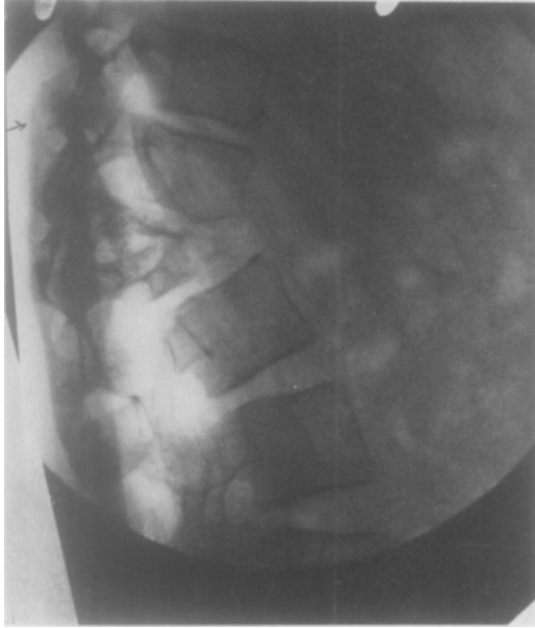


Fig. 22
(Case 21, 22. IX. 32).

D XI—L I. At the time of operation there was marked lordosis of the lumbar region. Six months after, this lordosis had become definitely smaller, the graft showed a defect immediately on the distal side of the intervertebral joints L I—II.—In Case 17 the destruction, already at the beginning of treatment, involved most of the bodies of D XII and L I, and increased during correction; the inflexion increased slightly. By lordosation above and below the gibbus this became less prominent. The graft was

fixed into the spinous processes under tension. Three and a half months after the operation the position of the vertebrae had undergone no apparent change. In the distal part of the graft, on a level with the intervertebral joints L I—II, there was a graft defect with blurred outlines. This defect appeared while the

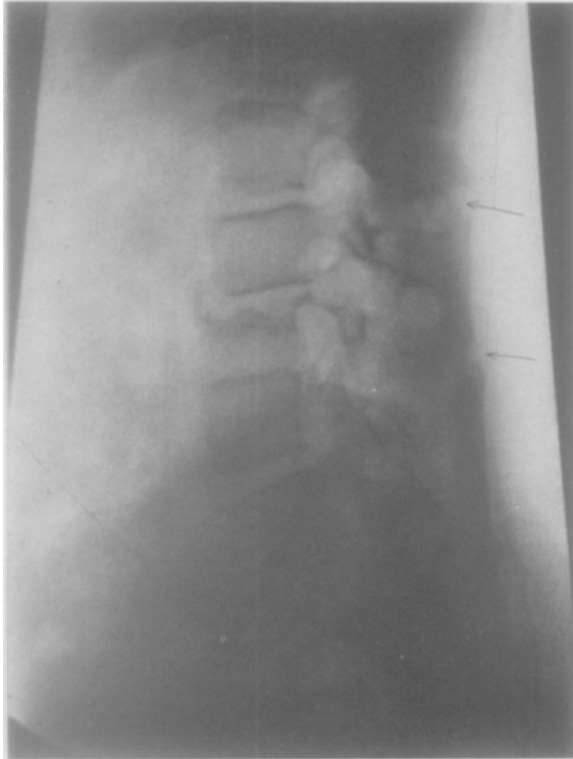


Fig. 23
(Case 32, 3. XII. 30).

patient was still in plaster bed, before the spine had borne any weight in the erect position. During subsequent treatment absorption from the remnants of D XII—L I increased, and also the inflexion increased still further. 2 years 1 month after the operation a fresh defect with a ventrally open angle between the fragments was discovered on the arc-shaped bone graft just

on the distal side of the intervertebral joints D XII—L I. The defect at the level of the intervertebral junction L I—II was consolidated.—In Case 21 the destruction involved most of the bodies of L I and L II; the distal outline of D XII was blurred. Correction had no effect on the inflexion, but the parts im-

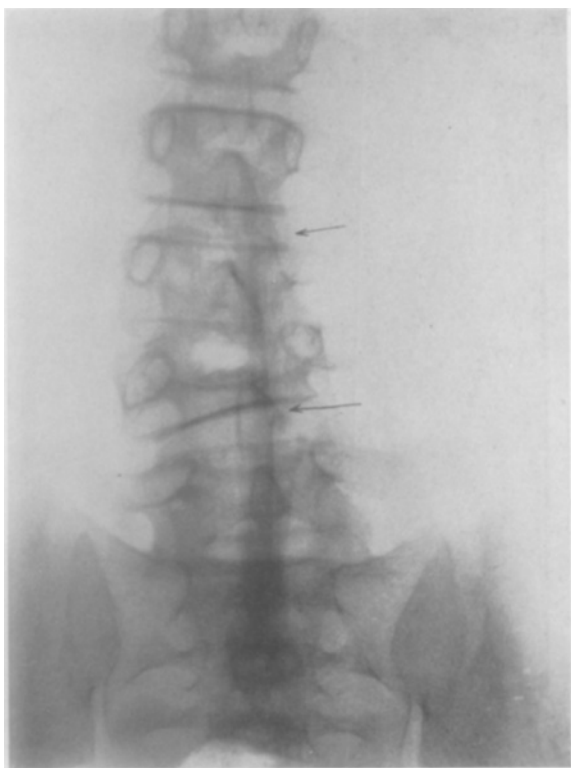


Fig. 24
(Case 32, 3. XII. 30).

mediately above and below the gibbus became lordosed. The graft was fixed into the spinous processes under tension. There was no visible change in the position of the vertebrae after the operation. In the proximal part of the graft, at the level of the intervertebral joints D XI—XII, a sharply defined graft defect was discovered 4 months after the operation. At the same time

the distal tip of the graft had become detached from the spinous process of L III. The inflexion remained unchanged in spite of increased destruction of D XII. Fifteen months after the operation the defect had consolidated, and the distal apex of the graft had united firmly into the spinous process of L III. The originally straight graft formed a dorso-convex arc over the gibbus.—In Case 25 the lesion involved parts of the bodies of

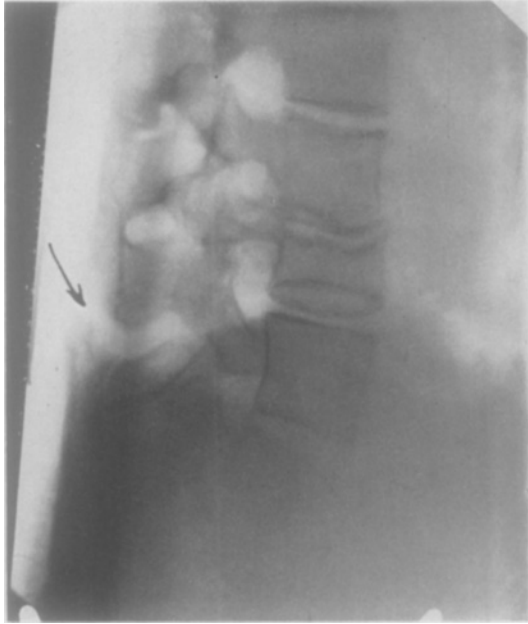


Fig. 25
(Case 32, 27. II. 32).
Maximal flexion of spine.

L II and L III. Correction had no effect on the inflexion, but the parts immediately above and below the gibbus became lordosed. Six months after the operation there was no change in the destruction, and the distal lordosis was slightly reduced. The graft showed a defect, proximally, on a level with the intervertebral joints L I—II, another, distally, on a level with the intervertebral joints L IV—V. Four years after

the operation the proximal defect had consolidated, the distal one remained; there was mobility between the graft fragments. As the body of L I shows signs of old lesions, Case 25 may also be referred to »B«.—The proximal graft defect in Case 27, already described, was located on a level with the undamaged intervertebral junction L I—II. One year 5 months after the operation this defect had consolidated.—In Case 28 the destruction involved the distal portion of the body of L II and most of those of L III and L IV. The soft gibbus was easily corrected, under formation of lordosis on the proximal and distal side of the spondylitis. Five months after the operation the position was apparently unchanged. A narrow defect with sharp outlines was discovered on a level with the intervertebral joints L I—II. The distal end of the graft had detached itself from its anchorage in the spinous process of L V. Two years four months after the operation the defect was 1 cm. broad, and the graft fragments were mobile. There was no contact between the distal end of the graft and the fifth spinous process.—In Case 32 the lesion involved a considerable portion of the upper left part of the body of L IV. The intervertebral space L III—IV was obliterated, the body of L III had fallen down into the defect, causing an angle open to the left. The position was not appreciably influenced by the correction. Five months after the operation there was no change in the position of the vertebrae; on a level with the intervertebral joints L II—III a defect was discovered in the graft, and another was found on a level with the intervertebral joints L IV—V. Two years ten months after the operation the proximal defect had consolidated. The distal defect remained, and there was relative mobility between the graft fragments. On after-examination there was ankylosis of the area L II—IV; mobility existed between L V and L IV and probably also between the former and the sacrum, since the spinous process of L V lacks attachment to the graft.—In Case 33 the lesion involved parts of the bodies of L III and L IV, the remnants have collapsed. The destruction and position did not change after the operation. Five months after the operation a defect was discovered in the distal part of the graft, on a level with

the intervertebral joints L IV—V. The defect is still present three years after operation and the graft fragments are mobile.

In Cases 19 and 29, both adults, the graft showed, at the level of an intact invertebral junction, a defect arisen as late as respectively 19 and 23 months after the operation. In the

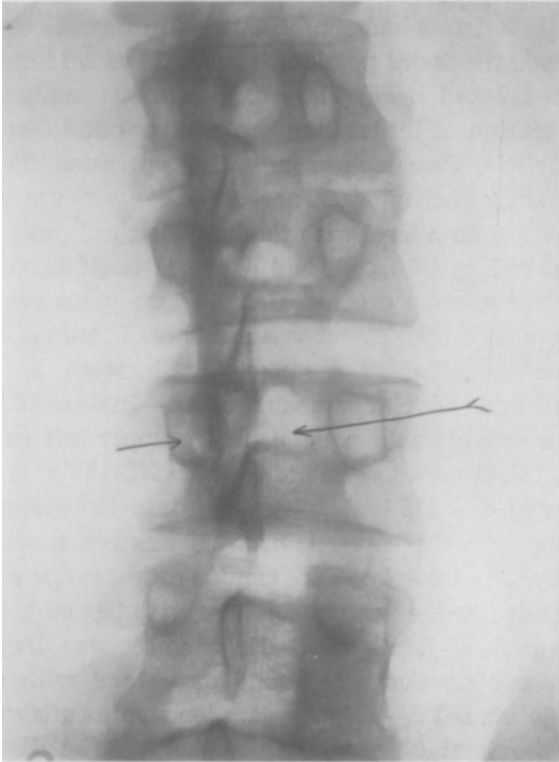


Fig. 26
(Case 19, 29. XII. 31).

former case the defect was discovered shortly after the back had been subjected to a heavy strain (lifting), in the latter there was no known trauma. In both cases the X-ray appearance of the graft shows a fairly advanced reconstruction, of its original form and bone structure there are no signs. In Case 19 a narrow pseudarthrotic slit is formed at the seat of the defect, in Case 29

the defect, after twelve months, has a breadth of 1 cm. In both cases there was relative mobility between the graft fragments.—In Case 30 the destruction involved portions of the bodies of L III and L IV. During weight-bearing after the operation no change took place in the lesion and the position. Seventeen



Fig. 27
(Case 29, 6. VIII. 32).

months after the operation, a graft defect without surrounding deposits was discovered on a level with the undamaged intervertebral joints L II—III. The series of skiagrams being incomplete, no particulars can be given of the case.—The upper graft defect in Case 35, previously described, and the defect in Case 30, seem to be of the same nature as the defects in Cases

19 and 29; the exact time of origin of the former is however unknown.

In all these cases there seems to be a firm union between the damaged vertebral bodies. The movable graft defects can best be likened to Nussbaum's »Aufhellungszonen« as observed in a dog, on which an operation had been done by Henle's method, at the level of undamaged intervertebral junctions; these zones being, on autopsy, found to consist of a fibrocartilaginoid tissue which permitted a certain amount of displacement between the respective vertebrae.

Of *Waldenström's* cases of tuberculous spondylitis operated on according to Albee's method, 30 eventually showed defects in the graft. Of these patients thus concerned, 8 were adults, 22 children under the age of fourteen years. In 13 of the cases inflexion had increased under stress after the operation. In 9 cases the graft defect was at the level of the lesion (in several cases exactly on a level with the inflexion axis); in four cases immediately above or below the destruction. In numerous cases there was an angle, open ventrally, between the fragments.—In 17 cases the defect was located peripherally from the spondylitis, on a level with an undamaged intervertebral junction. In two of the cases two spondylitic foci with two intervening intact vertebrae had been fixed by means of a long bone graft. In both these cases a defect arose between the foci, on a level with an undamaged intervertebral junction; the fragments of the graft formed an angle open ventrally.

In patients operated on according to Albee's method, and in whom the distribution of the lesion and the position of the spine permit an inflexion movement to take place, the tendency to such inflexion is apparent during gravitation in erect posture. The tibial graft fixed in the spinous processes is then exposed to flexion- and traction stress. Graft defects arisen in connection with an inflexion movement (»inflexion defects«), have in most cases been situated on a level with the vertebral lesion, in many cases at the exact level of the inflexion axis. In all the cases the graft fragments have formed an angle, open ventrally. In these

cases the defect in the bone graft would seem to have been caused by the flexion- and traction stress occasioned by the tendency to inflexion to which it has been exposed. In some cases the graft defect seems to have been produced as a result of a momentarily increased strain on the spine, in other cases without any known external cause.

In other cases where there has been no increase of the inflexion, the graft defect is located beyond the spondylitic area, on a level with an undamaged intervertebral junction, where normal relative mobility of the vertebrae is only checked by the graft fixed in the spinous processes. In some cases such graft defects have occurred when a para-gibbous lordosis produced by correction is getting straightened out as the result of weight being put on the spine after the operation. An inflexion movement, as well as straightening of a lordosis, signifies flexion of the spine. In the former case the flexion takes place round frontal axes through the intervertebral joints, in the latter round frontal axes through the nuclei pulposi of the intervertebral discs. On the boundary line between the spondylitic area and the adjacent, intact parts of the spine, these two kinds of displacement pass over into one another. In certain cases of superficial vertebral lesions and only slightly damaged intervertebral discs it is impossible to be certain of the character of the flexion (see Cases 18, 26, 27).

In many cases no change is to be observed in the position of the vertebrae united by the graft. When the contracted back muscles relax after the operation, the peripheral, intact vertebrae, fixed by the graft and connected with other adjacent healthy vertebrae through intact discs and intervertebral joints, strive to regain their normal mobility. The only thing to prevent this is the Albee graft fixed in the spinous processes. At the level of an intact intervertebral junction, the graft is in such cases subjected to continuous stress of various kinds; flexion, extension and lateral movements, besides lateral displacement on rotatory movements of the vertebrae. The continuous stress to which the bone-graft is exposed at the level of an undamaged intervertebral junction may be compared to W. Müller's »mechan-

ical irritation» and to *Hoffmann's* »arthrogenous stress«. In cases of that nature such persistent stress at one single point of the graft is probably the cause of the graft defects.

Graft defects in connection with increase of the inflexion have occurred more frequently in the thoracic and thoracolumbar regions than in the lumbar region proper. Defects at the level of an undamaged intervertebral junction have occurred more frequently in the lumbar than in the thoracic region, a fact explained by the differences in anatomical construction and mobility of the two regions, as has already been pointed out.

The graft defects arising in connection with increased weight-bearing of the operated area of the spine, their localisation on a level either with a vertebral lesion or with an undamaged intervertebral junction, and the angulation frequently existing between the graft fragments,—all these factors support the view that graft defects are caused by mechanical strain on the bone graft fixed in the spinous processes. The strength of the bone graft is materially reduced at least during the first 8—10 months after an Albee operation. One would seem justified in using the term »acute«, or »insidious«, fracture in speaking of a graft defect produced by mechanical strain on the tibial graft united in the spinous processes, largely necrotic and impaired by absorption of lime salts.

Chapter VIII.

THE CLINICAL PICTURE OF THE GRAFT DEFECT

Defects in an Albee graft have sometimes been found immediately after a momentary increase of strain on the patient's back, or in immediate connection with some trauma. In Case 2 the patient, was motoring home from the hospital, 2½ months after the operation, when she felt a sudden pain in her back, in the middle of the field of operation, as the car once gave a sharp bump on the road. The pain persisted, and a month later a graft defect was found at the place where the pain was felt. (On X-ray examination shortly before she went home the graft had been found to be intact).—In Case 16 the patient felt a sudden pain

in the middle of the operative area while attempting to stand upright with her plaster bed on, 7 weeks after the operation. Immediately after, a tender mass was found over the centre of the graft, at the seat of the pain; a graft defect was diagnosed, and was verified by X-ray examination 10 days later. Skiagrams showed the defect to have sharp outlines.—In Case 19 the patient, 19 months after the operation, subjected his back to the heavy strain of lifting a petrol barrel, when he felt a sudden pain in the lower part of the field of operation. Shortly afterwards, a graft defect was diagnosed in the same place; the skiagrams showing sharp irregular contours.—In Case 22 the patient fell backwards hitting his back on the stairs 18 months after the operation. Soon afterwards a broad defect was found in the graft, at the seat of the injury.—In Case 24, the patient, while stooping down to pick berries, 12 months after the operation, felt a «click» in the back, and pains in the field of operation. Shortly afterwards a sharply defined defect was found in the Albee graft at the seat of the pains.—In Case 37 the patient slipped on a stone 10 months after the operation and strained his back. He felt a local pain in the field of operation, and at the seat of the pain a sharply defined defect of the graft was immediately discovered.—S. T. I., who had had an Albee operation barely 2 years earlier, and who 15 months earlier had been operated on for a defect in the Albee graft, was riding in a bus, when he suddenly felt a local pain in the upper end of the operative field, as the vehicle gave a bump over some depression in the road. Immediately after, a graft defect was immediately found at the seat of the pain, showing sharp outlines on the skiagram. (On X-ray examination six weeks earlier the graft had been intact).

In most of the cases the patients have been unable to state definitely when the symptoms commenced, or to give any hint as to any external cause of the defect. Symptoms have appeared gradually. Patients have been complaining of weakness, fatigue and indefinite pains in the back and flanks. The back, which after the operation felt firm and steady, has again shown signs of impairment. Pains have appeared when they were standing up, and have disappeared again when they lay down. Swelling

and tenderness; at times crepitation, have been observed over the defect. In some cases, mobility between the graft fragments was observed at the operation; for instance, in the case of S. T. I., 14 days after the defect occurred; and 7 months afterwards in Case 36. The gibbus, obliterated or strongly reduced by the correction, has in many cases reappeared or become much increased on the occurrence of the graft defect.

In numerous cases, clinical symptoms have been lacking entirely, the defect being discovered on examination in connection with change of corset or before the patient returned home.

In many of those cases where the defect was produced in connection with increase of the inflexion, pains have been considerable and have persisted for a long time. Defects arisen on a level with an intact intervertebral junction have often taken their course without symptoms, in other cases of that character the symptoms have disappeared in a short time.

Osteitis of the bone-graft was present in Cases 1, 5, 12, 20 and 27, and sequestra were cast off. In Case 20 the osteitis was of tuberculous nature, in others a septic cause was considered likely. Osteitis of the bone graft occurred a couple of months after the operation, except in Case 20, where signs of osteitis did not appear until after twelve months. In the cases mentioned, the osteitis probably impaired the graft, and in Cases 1, 12, 20 and 27 contributed to the production of the defect. The above mentioned cases have been included in the author's material as they do not differ, clinically or roentgenologically, from other uncomplicated cases.

On skiagrams in frontal and sagittal projections the graft defect appears as a thorough rarefaction of varying breadth. On diagnosis of the defect, the contours of the graft fragments have in many cases been sharply defined and irregular. After some time this irregular sharp outline has become more even and blurred. Around the defect, on its dorsal, ventral and lateral sides, thin periosteal deposits gradually arise which by and by become denser and more widespread. The fragments of the Albee graft form, particularly in »inflexion defects«, an angle open ventrally; at times a laterally open angle may also appear.

Only in one case (Case 17) was the defect discovered while the patient was still reclining in the plaster bed. (In this case the graft had at the operation been fixed under tension). In all other cases the graft defect was not observed until some time after the operation, when the spine was subjected to weight-bearing in the erect position.

In one of the cases from the C. S. A. (Case 16) a graft defect was discovered already 7 weeks after the Albee operation. Most defects appeared between 4 and 7 months after the operation. Several recent defects were discovered between one and two years after the operation, in Cases 5 and 29 after about 2 years. In *Waldenström's* clinical material the earliest time at which a graft defect was found was 3 months after the Albee operation. Most of the defects appeared 5—7 months after operation. In 4 cases graft defects were discovered more than 2 years after the operation.

Chapter IX.

REPAIR OF GRAFT DEFECTS

In those cases where the Albee graft has been purposely fractured at the operation in order better to fit the shape of the vertebral column, periosteal formation of new bone has been very lively; these fractures have united under formation of a great deal of periosteal callus and have become rapidly consolidated.

In nearly all patients in whom a defect had occurred in the Albee graft after the operation, it became surrounded some time later by periosteal deposits on its dorsal, lateral and ventral aspects. The intensity of this periosteal formation of new bone has varied in different cases. In those cases where the defect arose a short time after the operation the formation of new bone was generally abundant, in children as well as in adults. In cases, on the other hand, where the defect had occurred a long time after the operation, periosteal formation of new bone was less marked. In Case 29, where the defect arose nearly two years after the operation, it was slight, likewise in Case 35 as regards

the upper defect. Periosteal formation of new bone is particularly lively in children, where large coherent deposits often form around the defect, especially on the lateral aspects of the bone graft. Such extensive deposits may be observed as early as 3—4 months after the defect has occurred, forming a coherent periosteal mass of callus around it. In Case 31, a patient aged 5 years, where the defect was discovered 7 months after the operation,

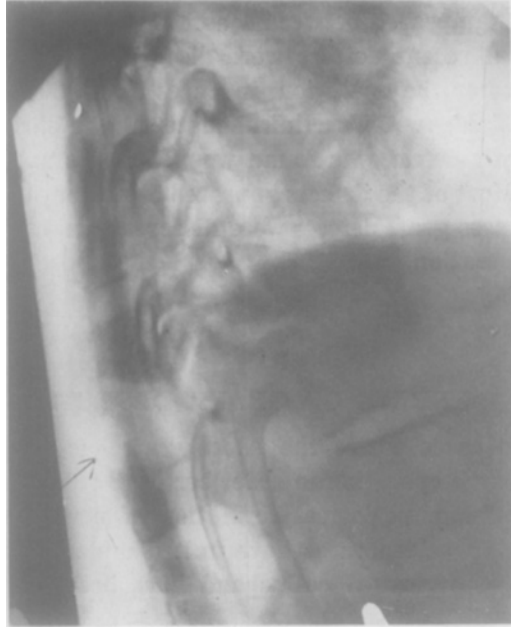


Fig. 28
(Case 7, 2. I. 31).

the tendency to periosteal formation of new bone was fairly slight. In adult patients the periosteal callus formation around the defect is less and appears later than in children. In many cases, however, it attains considerable dimensions, even in adults. Thus in a patient aged 57 years the periosteal deposits were quite apparent 6 months after of the defect had occurred (Case 16).—In cases where the bone-graft has been the seat of osteitis, periosteal formation of new bone has been remarkably

lively. In many cases it is possible to observe and follow on the skiagrams how the deposits grow larger, until they finally cover the defect all round. The diastasis in the bone itself is gradually filled up with a dense shadow. In many cases a defect in the Albee graft has thus united and become consolidated under conservative treatment in supine position and with wear of a corset (for instance Case 7). In cases 5, 23 and 36, microscopically

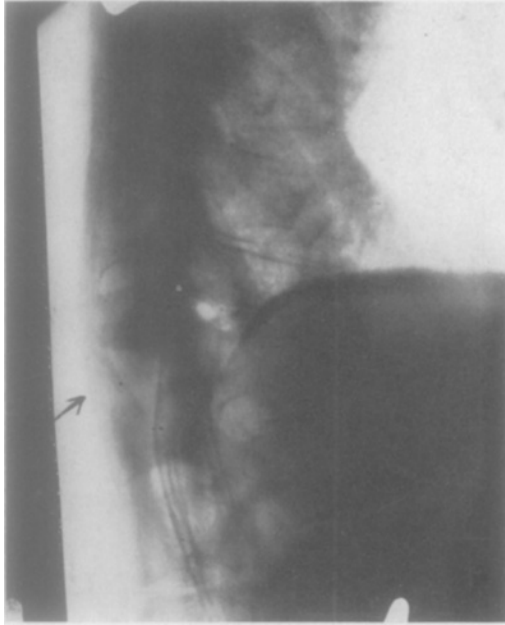


Fig. 29
(Case 7, 28. V. 32).

examined, the defect between the graft fragments was filled up with cartilage and cartilaginous tissue enclosing small cavities. On the boundary between the cartilaginous tissue filling up the defect, and the spongiosa of the graft fragments, endosteal formation of new bone can be observed.

In the cases where the graft defect was caused by increasing inflexion after the operation, the tendency to bony union has been considerable. In Cases 1, 3, 6, 7, 9, 11, 16, 27 and 35, the

graft defect filled up, under conservative treatment, with bone of a longitudinal spongy design, which continued without break at the site of the defect. The latter has become »consolidated«. In Cases 4, 8 and 20, the defect is largely filled up with bone, and is entirely surrounded by deposits; in the centre there are

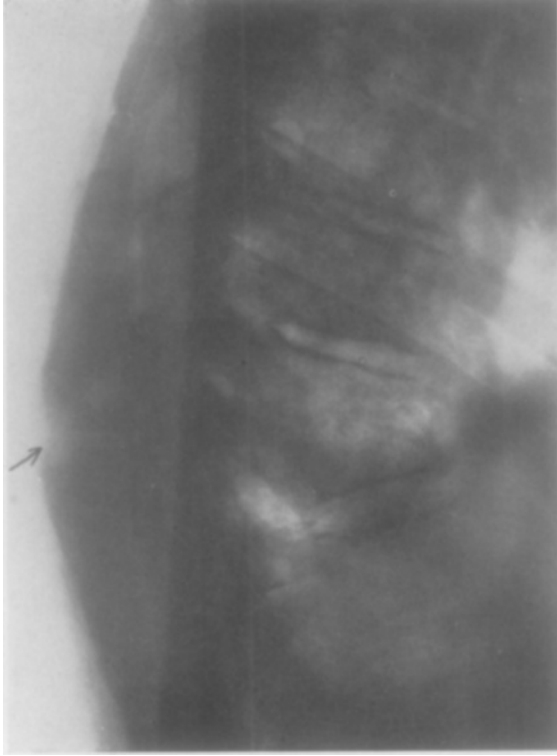


Fig. 30
(Case 2, 30. IV. 30).

still slight rarefactions in the bone. In Case 1, the graft defect consolidated in 12 months, in Case 7 in 17 months, in Case 9 in a little more than 14 months. In several cases the period of observation is too short to permit of any estimate with regard to the ultimate fate of the defect. In Cases 10, 12, 13 and 17, the inflexion increased during the whole period of observation, and in spite of periosteal formation of new bone the defect

remains more or less the same. In Case 37 the defect is located on a level with the inflexion axis above the spinous process of the upper diseased vertebra. In spite of considerable periosteal callus formation it still exists, 4 years 6 months after the operation. The tendency to repair has been more pronounced in the



Fig. 31
(Case 2, 28. IX. 33).

cases where the defect was located within a split spinous process (Cases 3, 11, 16, 20) than in those where it was located between two spinous processes.—In Cases 2, 5, 15, 22, 23, 31, 34 and 36, a reoperation was carried out. One or several new grafts were inserted parallel with the old one, covering the dorsal or lateral side of the graft defect. In Cases 2, 15, 22, 23, 31, 34 and 36, the

new grafts united and fused with the old graft without complications. In Case 5 the new graft underwent partial sequestration; in spite of this the defect was entirely filled up with bone ten months after the second operation. In Case 2 the new grafts were applied after recorection whereby the gap in the column of

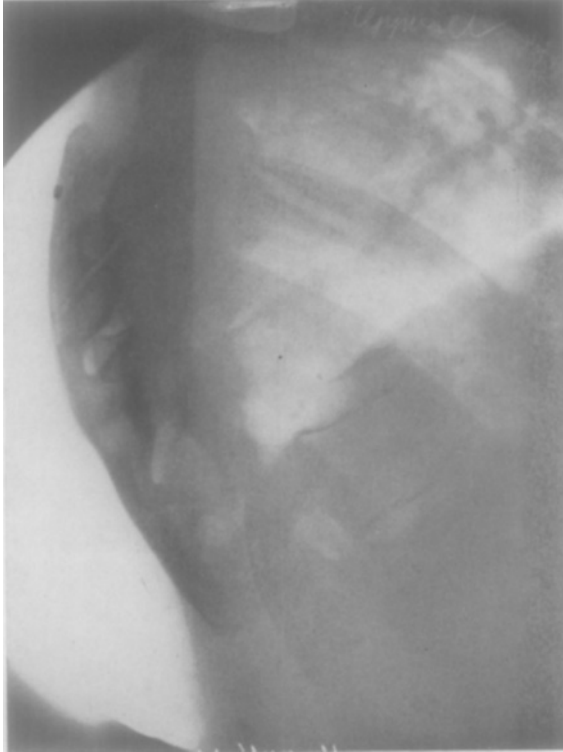


Fig. 32
(Case 3, 31. X. 33).

vertebral bodies again increased. A little more than 18 months after the second operation, inflexion increased under weight-bearing in erect position, the defect in the vertebral column diminishing in the meanwhile. Also the new graft showed a line of rarefaction, on a level with the old defect. Judging by skiagrams there is bony union between the old and the new

graft, as well as between these and the spinous processes. In spite of this, the new graft had been unable to withstand the tendency to inflexion. Three years after the last operation there still remained a defect through the fused bone grafts, on a level with the inflexion axis, and there was a certain degree of mobility between the graft fragments on movements of the spine. In Case 36 there was a defect on each side of the spinous process of L IV (? ? defect within the spinous process of L IV with a broad diastasis between the graft fragments). At the reoperation a bone graft was inserted in the spinous processes of L III—S I, parallel with the old graft. The defect at the level of the intervertebral joints L IV—V became consolidated, the defect at the level of the intervertebral joints L III—IV persisted in spite of the operation. On back movements there was some mobility between the graft fragments. In Case 31 the new graft united, and the defect became consolidated. After the second operation the tuberculous process progressed, and encroached upon new, previously sound, vertebrae. The entire broad and powerful bone graft had bent into a dorsal convex arc, but showed no defects.

In the cases where inflexion did not alter after the operation, and where the graft defect was located on a level with an undamaged intervertebral junction above or below the spondylitic area, the tendency to repair has been more variable. In Cases 17, 25, 27 and 32, such a defect ensued eventually became completely consolidated under conservative treatment. In Cases 14 and 21 the defect was filled up with bone without any clear spongy structure, in Case 26 a thin line of rarefaction still remains at the seat of the defect; the graft fragments show no relative mobility on back movements. In Cases 18, 19, 24, 28, 30 and 33 the defect still persists, its outlines are fairly regular, and surrounding deposits are but of slight extent. On movements of the back the graft fragments move on one another. In such cases the defect can be regarded as a pseudarthrosis permitting movements between the parts of the vertebral column fixed by the graft fragments. In Cases 25 and 32, where two graft defects were present, the defect above the spondylitic area was consolidated, while the one below that area developed into a pseudarthrosis. In Case 35

a graft defect occurred, long time after the operation, above the spondylitic area, between the spinous processes of L II and L III; 4 years 8 months after the operation it measured 5 mm. in breadth. In Case 29 the defect had a breadth of 1 cm. twelve months after it occurred. In Case 35 there were no signs of periosteal formation of new bone; Case 29 showed slight deposits around the defect.

Waldenström's operated cases show similar conditions of repair. Eleven of the 13 graft defects arisen in conjunction with increase of the inflexion consolidated; 5 cases under conservative treatment, 6 cases after reoperation. Of the 17 cases without increase of inflexion, with graft defects on a level with an undamaged intervertebral junction, 7 consolidated under conservative treatment, and 2 after reoperation; in 8 cases a pseudarthrosis persisted during the period of observation. Most of *Waldenström's* cases have been under observation for a very long time, and during that time numerous pseudarthroses in the graft have been repaired, even in a late stage. Thus, consolidation of one pseudarthrosis has been observed between 5 and 8 years after the defect had occurred.

Judging by the material here presented, the repair and consolidation of a graft defect are largely determined by the degree of fixation afforded the fragments of the bone graft. The »inflexion defects«—those on a level with the vertebral lesion no less than those located above or below it—have usually given rise to troubles in the form of pains and weakness in the back, and the hump has shown a tendency to become bigger. At the C. S. A. these patients have therefore, after the defect had been discovered, been extended again in plaster bed for a longer or shorter time, after which they have for a long time been wearing a supporting corset. These measures, as well as the renewed contracture of the back muscles, induced by the returning pains, seem to have afforded the graft fragments a fixation in many cases good enough to allow callus to form unchecked. In several of the cases where the graft defect had arisen in conjunction with increase of inflexion, reoperation, with insertion of a fresh bone-graft over the defect, was deemed indicated, with a view to

preventing progression of the vertebral lesion through friction and »ulceration compressive«.—In Cases 2 and 37 a graft defect nevertheless persisted for a long time. In Case 2 the bone-graft applied at the reoperation also showed a defect; 4 years after the Albee operation, the latter still permitted a change of position between the parts of the spine fixed by the graft fragments and the damaged vertebrae. In Case 37 a steady fixation seemed to exist between the damaged L V and S I, the graft defect was located on the proximal side of the spinous process of L V, and permitted of displacements between L IV and LV.

In the cases where the defect is located on a level with an undamaged intervertebral junction above or below the vertebral lesion, the clinical symptoms are slight. The relative fixation of the damaged vertebrae is unimpaired, the movements possible after the defect has occurred concern the undamaged parts of the spine. It is therefore only immediately after the defect has originated that movements in it give rise to pains. Contractures of the back muscles are insignificant, and rapidly pass. In such cases prolonged fixation has not been considered as indicated. Those graft defects therefore become incompletely fixed, and in many cases a typical mobile pseudarthrosis develops at the seat of the defect, in spite of abundant periosteal callus formation, (Cases 18, 19, 28, 29, 30, 32, 33, 34, 35, 36).

In cases with specific or non-specific osteitis of the graft, with sinus formation and partial sequestration of the bone-graft, the tendency to periosteal formation of new bone has been greater than in uncomplicated cases. In Cases 1, 5, 20 and 27 the defect was rapidly filled up with bone. In Case 12 the inflexion steadily increased, and in spite of lively new bone formation the defect still remains, 2 years 6 months after the operation.

In conservative treatment of the graft defect, the capacity of the latter for repair seems to be greater in children than in adults, and greater in the case of defects arisen shortly after the Albee operation than in the case of those occurring a long time afterwards. It would seem that pseudarthrosis arises especially in cases where the defect is located on a level with an undamaged intervertebral junction which permits movements

between adjacent vertebrae. There is only slight chance of a fully developed pseudarthrosis in an Albee graft healing, at least without operative intervention.—At the C. S. A., operative treatment of graft defects has only been employed in cases where the defects have arisen in conjunction with increase of inflexion. After operation with application of a new graft, the latter has rapidly entered into bony union with the old one, and the defects have usually become rapidly consolidated. In two cases, however, a defect arose also in the new graft, and a movable pseudarthrosis is occupying its place.

Chapter X.

THE SIGNIFICANCE OF GRAFT DEFECTS FOR THE PROGNOSIS OF THE OPERATED SPONDYLITIC PROCESS

As stated before, the object aimed at with an Albee operation is to secure vertebrae attacked by tuberculosis to each other and to immediately adjacent healthy vertebrae by means of a bone-graft inserted into the spinous processes. By the resulting fixation one hopes to create better conditions for localisation and repair of the tuberculous process, and at the same time to maintain the altered shape of the vertebral column obtained by correction.

At the C. S. A. the Albee operation has not been considered as indicated, until all clinical signs of the general or local activity of the tuberculous process have disappeared, or until the X-ray examination proves a destruction which has been steady for a long time with sharp outlines and a clear bone structure in the remnants of the damaged vertebrae, and until the gibbus has been corrected as far as possible.

Correction of a tuberculous spondylitis with extensive destruction of vertebral bodies often results in a gap arising in the vertebral column, at the site of the destruction. The shape of the vertebral column obtained by the correction is made secure by insertion of a tibial bone-graft into the spinous processes of the diseased vertebrae and the sound ones immediately above

and below. Now, if there is a defect in the vertebral column, the graft at the level of this defect will be the only support that holds the spine together. Under gravitation, when the patient operated on is in the erect posture, the whole stress in the plane of the vertebral defect will then be received by the bone graft inserted in the spinous processes. Under the influence of the re-appearing tendency to inflexion in the erect position the graft will be subjected to flexion—and traction—stress. In many cases a defect then arises in the graft, usually on a level with the axis of inflexion. If no attempt is made to correct the gibbus occasioned by the spondylitis, the only thing gained by the operation will be fixation of the gibbus in an unaltered position. In that case, the gravitation strain on the graft after the operation will be much less. In such cases the graft must be cut to the profile shape of the gibbus; if the latter is very prominent the graft must be fractured or bent, so as to allow of its adaptation to the form of the gibbus. If the graft is fractured at the operation, fixation of the affected part of the column will only be obtained on consolidation of the artificial fracture.

In the cases where inflexion within the affected part of the spine has been corrected, and where a defect has arisen in the Albee graft owing to increase of inflexion after the operation, such a defect will permit of still further inflexion, with the resulting possibility of compression of the remnants of the vertebral bodies, and of friction between the compressed remnants on minor movements of the spinal column. This would seem to be the case especially when the graft defect is located on a level with the axis of inflexion. The fixation established by operation will in this case be impaired at an important point, and the aim of the operation be missed.

In cases where the tuberculous process has been quiescent or subsided altogether, consolidation of the graft defect has been obtained by conservative treatment, and fixation of the diseased part in good position obtained. In Cases 1, 7, 9, 16 and 35, the graft defect consolidated under conservative treatment, the destruction of the vertebral bodies did not increase after the operation, and the deformity of the back was slight.

All these patients are free from symptoms and able to work. In Case 16 the damaged vertebral bodies fused into one osseous block. In Cases 4, 6 and 20 the malposition is extremely slight; the bone destruction was at last examination well localised, and has not increased appreciably after the operation; in Case 6 the graft defect is consolidated, in Cases 4 and 20 it is in a far advanced stage of callous union.

In Case 37 the lesion involved parts of the bodies of L V and S I. The graft defect is located on a level with the inflexion axis between L V and S I, between the spinous processes of L IV and L V. The powerful spinous processes of L V and S I are united by a coarse bony bridge, which absolutely prevents any movement between these vertebrae. On examination 4½ years after the operation, the vertebral lesion is well localised, the graft defect still exists, and there is a certain degree of mobility between the graft fragments. The patient is free from symptoms and able to work.—In Case 24 there was an unmistakable increase of inflexion between the damaged L II and L III after the operation. One year 4 months after the defect occurred, the vertebral lesion is well localised, and the patient free from symptoms and able to work. The graft defect measures several millimetres in breadth, and gives evidence of slight periosteal callus formation.

In Cases 3, 10, 11, 12, 13, 17 (and 34) the tuberculous lesion in the vertebral bodies has increased materially after the operation. As a result of the progressive vertebral destruction and consequent increased tendency to inflexion, the bone graft, united within the spinous processes, has after the operation been subjected to powerful flexion stress; as a result of this a graft defect has arisen. In Cases 3 and 11 the vertebral process has not with certainty become localised; in spite of this, consolidation of the defect has taken place.—In Case 10 the vertebral lesion is still going on 2 years 2 months after the operation; on a level with the centre of the lesion a broad defect without visible callus remains in the bone graft.—In Case 12 a well-marked gap in the column of vertebral bodies was revealed at the correction. After the defect of the graft had arisen, the ori-

ginal inflexion again appeared, and after further absorption from the remnants of the vertebral bodies it increased still further. Two years 6 months after the operation the vertebral lesion is not yet localised; the patient shows signs of compression of the spinal cord, and in spite of lively formation the graft defect has not consolidated.—In Cases 13 and 17 the diseased process has increased during the whole period of observation, the graft defect still persist.

In Cases 2, 5, 15, 22, 23, 31, 34 and 36 an »inflexion defect« in the graft has been reoperated on, with insertion of a new graft parallel with the old one, covering the defect. In Cases 15 and 34 the inflexion defect was located below the lesion. In Cases 5, 15, 22, 23 and 36 the inflexion defect has consolidated after reoperation, the spondylitic lesion has not been further increased. Cases 5, 22, 23 and 36 have been free from symptoms for a long time; in Case 15 the spondylitic process seems to be localised, but the patient shows symptoms of insufficiency of her back.—In Case 36, in which the lesion involves most of the vertebral bodies of L IV and L V as well as the anterior upper border of S I, there are two defects in the graft, one above and one below the spinous process of L IV. The lower defect, at the level of the intervertebral joints L IV—V, must be regarded as an »inflexion defect«. The upper defect is located on a level with the intervertebral joints L III—L V. The intervertebral space L III—IV is lower than normal, the caudal vertebral contour of L III and the cranial ditto of L IV are irregular. This fact goes to show that the bony parts mentioned have originally been affected by a destructive process. During the further course of the disease the outlines of L III and L IV have become more regular, the intervertebral joints L III—IV show broad spaces with intact outlines (see Cases 18, 26, 27). Already at the second operation, movements were found to take place between the spinous processes of L III and L IV. The bone graft inserted at the second operation united, the inflexion defect between the spinous processes of L IV and L V consolidated, and between the spinous processes of L III and L IV a typical mobile pseudarthrosis developed in

the graft. On examination $2\frac{1}{2}$ years after the Albee operation, the remnants of L IV and L V show commencing osseous union. The intervertebral space L III—IV shows sharp outlines, the mobility between these vertebrae is normal. The patient is in good health and free from symptoms.—In Case 34 the lesion involved parts of the bodies of L IV and L V (Fig. 12). A bone graft was inserted in the spinous processes of L III—S II. The destructive process increased after the operation, chiefly within the upper part of L V; probably a defect had arisen in the arch of L V, between the spinous process and the remnant of the vertebral body. The graft defect appearing on a level with the intervertebral junction L V—S I would in ordinary cases be rather insignificant. In this case, where the vertebral remnant of L V had been displaced in relation to the arch, and the spinous process fixed to the graft, there has been the possibility of progressive compression of the vertebral remnants of L IV and L V. The bone graft united with the spinous processes has prevented compression in a vertical direction with parallel gliding in the intervertebral joints, whereby part of the defect in the vertebral bodies might have been compensated. The vertebral body of L V has rotated round a mainly frontal axis, its anterior border has approached the remnants of L IV, its sagittal axis has formed with that of L IV an angle open backwards (Fig. 14). In erect posture the body weight will force the remnant of the body of L V against the sacrum. In order to compensate the considerable angulation between the vertebral remnants of L IV and L V, and to keep the body erect, the patient must form a maximal lordosis above the fixed area in the upper lumbar and dorsal region. On flexion and extension of the back, displacement between the graft fragments can be observed. This mobility of the graft pseudarthrosis has made it possible for displacement to take place between the bodies of L V. and S. I, and has forced the patient to hold his back muscles in a continuous tension in order to prevent the spine from collapsing forwards. The back musculature showed definite signs of insufficiency. It is impossible as yet to form any opinion of the result of the second operation, which was performed in August, 1933.

In Case 31 the graft defect had consolidated, the bone graft was broad and powerful. Four years and a half after the onset of the disease, and 3 years after the Albee operation, fresh tuberculous lesions were found in previously sound vertebral bodies, immediately above those attacked before. The whole lumbar spine collapsed, the bone bridge formed a dorso-convex arc over the collapsed remnants of the vertebral bodies. On examination four and a half years after the Albee operation the vertebral foci showed signs of beginning localisation, but the prognosis of the disease is still doubtful.—In Case 2 a defect was discovered in the column of vertebral bodies after the first correction. After the graft defect occurred, the original inflexion position appeared again, under formation of a moderate angular gibbus. By renewed correction, the gibbus and inflexion were again reduced, causing the bone defect in the vertebral column to appear again. At the reoperation, a tuberculous abscess forced its way between the spinous processes of the diseased vertebrae; this may possibly have helped to weaken the inserted graft. The spine was once more fixed in the same corrected position as at the Albee operation. After the second operation, the graft became subjected to the same stress from gravitation as before, and at the same point. Eighteen months after the second operation, the new graft, located at the side of the defect, and in bony union with the old graft and with the spinous processes, showed a defect on a level with the old one. Inflexion and gibbus developed again; there was little change in the lesion of the vertebral bodies. Three years after the second operation, the vertebral lesion was fairly well localised. The relative position of the diseased vertebrae could be readily altered, as a pseudarthrosis had developed at the seat of the graft defect. The patient was out of bed and almost free from pains in the back.

In *Waldenström's* cases with »inflexion defects« in the Albee graft the development was similar to that in my own. In five cases the defect was operated on and consolidated, and the vertebral lesion did not grow materially worse. In the case of S. T. I. a new vertebral lesion with inflexion arose, 17 months after the second operation, above the original destruction, with-

in the fixed area. On a level with the new inflexion axis, a few centimetres above the former defect, previously operated on and now consolidated, a new graft defect had arisen.—In 6 cases the »inflexion defect« had consolidated under conservative treatment; in two cases no consolidation of the defect has been observed.

It is thus evident that graft defects arising in conjunction with an increase of inflexion constitute a serious complication to the operated spondylitis. Under conservative treatment, consisting in a long period of fixation, first in plaster bed and subsequently in a well-fitting corset, these defects show, however, a great tendency to repair. In the cases where the tuberculous process has been quiescent, such defects have often consolidated, so that the desired fixation of the damaged part of the vertebral column has been attained without further surgical intervention. By reoperation, with application of a new bone graft parallel with the old, consolidation of the defect is often more rapidly attained. In several cases (Cases 3, 10, 11, 12, 13 and 17), where the tuberculous process had not been arrested at the time of operation, and where destruction of the vertebral body had continued after the operation, the graft fixation has not given the desired result. The operation has not prevented further tuberculous destruction of the vertebral body, nor could it be expected that it would do so. Neither has, in these cases, the bone graft united in the spinous processes been able to prevent further inflexion in connection with the progressive vertebral lesion. In such cases the graft fixation is therefore of no essential value as regards the subsequent course of the disease; operation does not produce the result desired. In connection with the secondary increase of inflexion, the bone graft has bent in a dorso-convex arc, and graft defects of inflexion type have arisen. As the graft fixation in such progressive cases of spondylitis does not affect the course of the disease to any great extent, such late »inflexion defects« of the bone graft are of slight importance when compared with the progressive vertebral destruction. (At the time of the Albee operation the tuberculous process in these cases was considered to be localised, and operation thus indica-

ted). In the cases where the activity of the vertebral process has subsequently diminished, and the inflexion been arrested, the graft defect has consolidated (Cases 3, 11). In these cases the bone graft probably affords some support to the damaged vertebral area after consolidation of the defect, in cases contributing to the final repair of the spondylitis.—The less successful therapeutic result in Case 2 may perhaps have been due, in part, to the slight post-operative increase of the vertebral destruction. It may be questioned whether, in this case, the powerful correction, after an inflexion defect had arisen in the graft, was well advised. Such powerful correction in order to obliterate a new-formed gibbus after the occurrence of an »inflexion defect« in the graft does not always, however, constitute a hindrance to the final consolidation of the graft defect and to the repair of the spondylitis without deformity. (See Waldenström's case: Gösta Bohlin, *Acta Chir.* Vol. LVI).

Defects in the Albee graft above or below the tuberculous vertebral lesion, unconnected with any increase in inflexion and located on a level with an undamaged intervertebral junction, have been of frequent occurrence in the lumbar, less often in the thoracic region. If the tuberculous process is quiescent, and the damaged vertebrae firmly united with one another, such a defect does not seem to be of any great importance as regards either the prognosis of the spondylitis or the stability of the back. In many cases such defects have consolidated in such a manner that one or several undamaged vertebrae have entered into bony union with the damaged vertebrae (Cases 17, 21, 25, 27). In other cases a mobile pseudarthrosis has developed at the seat of the graft defect. Such a pseudarthrosis at the level of an undamaged mobile intervertebral junction does not seem to affect the spondylitis, provided the diseased vertebrae are firmly united without the chance of moving on one another. Cases 19, 28, 29, 33 and 35 among others, illustrate how a typical pseudarthrosis of this nature has developed without causing any inconvenience to the patient. In Case 32, in which there were destructions of L III and L IV, there were originally two defects, the upper of which, above the spondylitic area, was con-

solidated, the lower, immediately below that area, was transformed into a mobile pseudarthrosis. The originally ankylosed area, L II-sacrum, can, as a result of this pseudarthrosis, obtain a movement between, on the one side, the block made up of L II—IV, on the other side, L V and the sacrum. Since the spinous process of L V has not been fixed to the Albee graft, L V and the sacrum can move on one another.—In Case 18 a mobile pseudarthrosis developed at the seat of a graft defect on a level with the intervertebral joints between the originally affected D XI and D XII. The intervertebral space D XI—XII is high, the intervertebral joints show no signs of destruction. Four years five months after the operation the remnants of D XII—L IV form a block. The possibility of movement of the lumbar region is thus confined to the junction L IV—V. In this case the mobility between D XI and D XII is rather greater than normal, and is made use of by the patient, who is in good health and able to work. (*W. Müller* points out that in cases where part of the vertebral column has been ankylosed with an Albee graft, the mobility between the peripheral vertebrae of the fixed part and the adjacent free vertebrae is often increased beyond the normal).—In Case 35 a beginning of osseous fusion between the remnants of the damaged vertebral bodies can be observed four years six months after the Albee operation; the inflexion defect has become consolidated. At the level of the undamaged intervertebral junction L II—III a mobile graft pseudarthrosis has developed. The patient is free from symptoms and able to work.

In the authors and Waldenström's material nearly all the graft defects that had their seat on a level with an undamaged intervertebral junction in the dorsal region have consolidated. In the lumbar region a mobile pseudarthrosis has often formed at the seat of the defect. Pseudarthroses at the level of an undamaged intervertebral junction have not caused any persistent troubles. It would thus seem that an extensive graft fixation is unnecessary when the lesion only involves portions of one or two vertebrae, and when the process can be regarded as definitely localised. This is the case particularly in the lumbar region,

whose mobility should be maintained as far as possible. The normal mobility of the parts immediately above and below the spondylitis, inhibited at the operation, are partly re-established on formation of the graft pseudarthrosis. The greater mobility can be utilised only in cases where the remnants of the damaged vertebral bodies are firmly united with one another, and only after there is no further reaction from the spondylitis, and the contracture of the back muscles has subsided.

An »inflexion defect« of the bone graft united with the spinous processes jeopardises the operative result. When the tuberculous lesion has become localised and quiescent, such a defect, however, has a great tendency to undergo repair, both by conservative and operative treatment. Cases of progressive spondylitis in which widespread vertebral destruction continues after the operation have a doubtful prognosis. In such cases a tibial graft united in the spinous processes will not arrest the progress of the disease to any appreciable extent. In a late stage of such cases, »inflexion defects« of the Albee graft have arisen in conjunction with the proceeding vertebral destruction and the increase of inflexion dependent thereon. In comparison with the progressive vertebral destruction such defects have but little influence on the prognosis of the disease.

A graft defect above or below the spondylitic area on a level with an undamaged intervertebral junction and unconnected with any increase in inflexion is of little importance as regards the prognosis of the spondylitis. Such graft defects sometimes become consolidated under conservative treatment. Particularly in the lumbar region, such defects often develop into mobile pseudarthroses. As a rule, these pseudarthroses do not give rise to any symptoms; in some cases the patients derive a certain benefit from the increased mobility created by the pseudarthrosis.

Chapter XI.

SUMMARY AND CONCLUSIONS

Under what Conditions do Graft Defects arise, and what are the immediate Causes of their Production?

All authors seem to agree that defects in the continuity of a bone graft are produced by mechanical factors, *Bier* also considers that hormonal factors play a certain rôle. Most graft defects arise during the first five months after the transplantation, during the »atrophic stage« of the transplant. In this stage a well-marked absorption of lime salts and »Kittsubstanz« is going on in the mainly necrotic graft, strength and elasticity are much below normal (*Lewer*). Graft defects may be produced either by increased stress acting in a certain direction, or by steadily recurrent, minor strains of various kinds setting in at one point. (»Arthrogenous stress«, *Hoffmann*).

In most of the author's cases, the Albee graft fixed into the spinous processes became subjected to increased stress when gravitation began to exert itself in the erect position, 2—3 months after the operation. The strength of the bone graft is at that time considerably reduced.

Graft defects often arise in connection with increased inflexion. On inflexion the bone graft is subjected to flexion and traction stress. In the majority of such cases the graft defect is located on a level with the inflexion axis. Sometimes, graft defects arisen in connection with increase of the inflexion have been located above or below the inflexion axis, occasionally beyond the vertebral lesion. In some cases attention has been drawn to factors which have contributed to such a localisation (for instance in Cases 15 and 34). In the case of »inflexion defect«, the fragments of the bone-graft have formed a more or less marked angle, open ventrally.— At the level of a mobile defect in the vertebral column the Albee graft is subjected to continuous minor strains as a result of mainly bending, possibly also rotatory forces. At the level of intact intervertebral junctions, on the peripheral aspect of the spondylitic process, the graft is subjected to similar minor strains, mainly as a result

of bending forces. (»Arthrogenous stress«, *Hoffmann*; »mechanical irritation«, *W. Müller*).

Several authors have likened defects in the bone graft to *Looser's* »Umbauzonen«. *W. Müller* and others maintain that these graft defects are produced through increased local bone absorption with diminished formation of new bone in parts exposed to »mechanical irritation«. Numerous authors regard the graft defects as »graft fractures«.

Looser maintains that the »Umbauzonen« (*U. Z.*) described by him as occurring in the long bones in rachitis and osteomalacia are produced by recurrent traumatism with crack formation in the corticalis. The fibrous bone marrow, growing into the cracks, absorbs the surrounding lamellar bone, and is in its turn replaced by osteoid tissue. He regards the process as an insidious callus formation. On repair of the original disease the osteoid tissue is calcified, the rarefied band visible on the skiagram disappears, and the irregular bony tissue is rebuilt into lamellar bone. Clinical symptoms are usually lacking; malposition rarely occurs. Even should certain analogies exist, *Looser's* *U. Z.*, arising as they do in living bone with disturbed calcium metabolism, cannot be compared to defects in the continuity of a largely necrotic bone graft.

A corticalis graft from the tibia is for a long time after the transplantation largely necrotic;—judging by *Lewer's* and the author's investigations, for more than two years. The living tissue is confined to the bone canals and their neighbourhood, and to the surface of the graft. The strength of the necrotic bony parts is reduced as a result of absorption of lime salts and »Kittsubstanz«. There seems little likelihood of primary absorption, localised to a single plane, taking place, of the undoubtedly more or less decalcified, but nevertheless massive necrotic graft. It is more probable that the continuity of the graft becomes primarily impaired by »mechanical irritation«, under loosening of the Haversian systems and crack formation. The minor defects thus created are invaded by fibrous bone marrow and blood vessels, which absorb the surrounding necrotic bone. Under mechanical strains new cracks form in the graft already

impaired by crack formation and local absorption, until finally a complete defect in the continuity arises. («Schleichende Fraktur», *Lexer*).

In Cases 2, 16, 19, 22, 24 and 37, and in the case of S. T. I., the patients complained of local pain in the operative field, in close relation to a definite trauma or strain in the back, at the very point where a graft defect was found shortly after. In these, as well as in numerous other cases, the roentgenological appearance is one of sharp irregular contours indicating a sudden interruption in the continuity of the bone graft (Cases 8, 34, 35, and others). In the majority of cases the fragments of the defect form an angle.

A histological section from the dorsal portion of the graft defect in the case of S. T. I. shows the following picture: Transversely through the graft there is a defect partly filled up with a haematoma; the graft fragments show torn irregular outlines with superficial bone necrosis; the bone marrow shows lively reaction, with bone absorption and early formation of new bone. —The histological picture shows a fairly recent fracture through the graft.

Histological examination of the graft defect in Cases 2, 5, 23 and 36 shows more or less cartilaginous callus. In these cases the examination supplies no information as to the manner in which the defect originated. Judging by the clinical and X-ray appearance a fracture of the graft was present in Cases 2, 16, 19, 22, 24 and 37. In many other cases the sharp, irregular contour of the graft defect is indicative of a sudden break in the continuity of the bone graft. In other cases the graft defect never during the period of observation presented any sharp fracture-like outlines. It would appear likely that in the latter cases an »insidious fracture« had produced the defect in the graft.

In the author's opinion, the defects arising in the continuity of the Albee bone-graft after operation must be regarded as »acute« or »insidious« fractures arisen as a result of stress on the graft beyond its strength, whether momentary, prolonged or steadily repeated; the graft being during the first two years

after transplantation largely necrotic. Fractures of that nature cannot be likened either to *Looser's* »Umbauzonen« occurring in rachitis and osteomalacia, to acute reconstruction zones in healthy bone tissue, or to fractures arising in living intact bone substance.

What are the Symptoms produced by the Graft Defect, and how does it affect the Function of the vertebral Column?

The symptoms of the graft defect have been local pain in the operative field and indefinite pains in the back and flanks. Patients have complained of increasing weakness of the back. Swelling, tenderness and crepitation have been found over the defect and after some time there has been bony enlargement.—In cases of »inflexion defects« such symptoms have persisted for a long time. The spine, formerly fairly stable, has again become weak and impaired; in most cases the gibbus formation has increased during the period immediately following the occurrence of the defect.—In cases of a graft defect at the level of a mobile intervertebral junction, and with the inflexion position unchanged, clinical symptoms have often been absent. In other cases the patients have complained for a week or two of local pains in the operative field. Tenderness, swelling and crepitation have been observed over the defect.

On the skiagram, the graft defect appears as a rarefied band through the graft. In many cases the defect shows sharp irregular outlines from the start. Gradually these become blurred, and minor irregularities are levelled out; as time goes on the defect becomes surrounded by thin deposits. In other cases the contours of the defect are blurred already from the beginning.

What are the Possibilities for Repair of a Graft Defect?

The graft defects arisen after an Albee operation generally show considerable tendency to repair under formation of periosteal callus. This periosteal callus formation is particularly lively and abundant in children. A graft defect arisen a short time after the operation usually gives evidence of more abundant

callus formation than a defect produced at a later stage. In the case of osteitis of the graft, periosteal callus formation has been particularly abundant.—»Inflexion defects« with slight mobility between the graft fragments have shown a fairly good tendency to repair under conservative treatment. In a great many cases a defect of that nature has been consolidated, in others a far advanced callus union has been found. In other cases of progressive destruction of the vertebral body, and increasing inflexion with a gradual increase of angulation between the graft fragments, the tendency to repair has been slight. »Inflexion defects« have in many cases been treated operatively, with insertion of new grafts on the lateral and dorsal sides of the defect. A more rapid consolidation of the defect has been obtained by regrafting than by conservative treatment. In two cases, however, (Cases 2 and 36) a defect arose also in the new graft.

In cases where the position of the damaged vertebrae remained the same after the operation, graft defects have occurred on a level with an entirely intact or slightly altered and normally functioning intervertebral junction. Especially in children, such defects often show an abundant amount of periosteal callus. In the dorsal and upper lumbar regions such defects have in many cases consolidated. In numerous other cases a movable pseudarthrosis has developed at the seat of the defect, in spite of a frequently abundant amount of periosteal callus. In *Walldenström's* material some pseudarthroses of that nature consolidated after a long time; in one case consolidation was observed more than five years after the graft defect occurred.

What is the Significance of Graft Defects for the Prognosis of the spondylitic Process?

A graft defect in conjunction with increase of inflexion within the damaged part of the spine jeopardises the object of the operation, which is to stabilise the affected part of the vertebral column in the most favourable position possible. Especially in the cases where the defect is located on a level with the inflexion axis it seems to make it possible for displacements to take place between the remnants of the damaged vertebrae, thereby causing

still further compression of these, with still further increase of inflexion. When displacement is possible between the vertebral remnants there is also a risk of friction between the vertebral fragments during the continuous minor movements to which the spine is subjected. In the cases where the vertebral lesion is localised at the time of operation, the graft defect shows a fairly good tendency to repair by conservative as well as by operative treatment, also when the defect is situated on a level with the inflexion axis. In many cases such a graft defect has become consolidated in good position, the spondylitic process has shown signs of complete localisation, and in several cases block formation has been observed between the remnants of the damaged vertebrae. The patients in these cases have been free from symptoms, and more or less capable of work. Other cases show a far advanced, but still incomplete, callus union of the graft defect; in one or two of these cases the localisation of the vertebral lesions is not quite reliable. In some cases a pseudarthrosis remains at the seat of the graft defect (Cases 2, 24 and 37).

In the cases where a progressive, more marked vertebral destruction has developed, with considerable increase of inflexion, the fixation of the graft has little influence on the progress of the spondylitis. As compared with the progressive tuberculous lesion in the vertebral bodies, a late »inflexion defect« of the bone bridge, arisen as a result of flexion stress on inflexion, is of little importance. When, in such cases, the tuberculous process has subsequently become less intense, the graft defect has become consolidated (Cases 3 and 11). The unbroken bone bridge in the spinous processes would in these cases seem to serve as a *relative* support for the damaged part of the spine, thereby contributing to the final localisation and repair of the bone lesion. In some cases (Cases 10, 12; 13 and 17) the vertebral lesion and inflexion movement seem to go steadily on. The gradually increasing diastasis and angulation between the graft fragments seem to prevent consolidation of the graft defect. In such cases the final therapeutic result depends upon the further course of the lesion in the vertebral bodies; as compared with the activity of the tuberculous process itself the graft defect is of slight significance.

When there is good fixation between the damaged vertebrae, a graft defect on the peripheral aspect of the spondylitic area, at the level of an undamaged intervertebral junction is of little importance. Such defects have sometimes become consolidated, at other times a mobile pseudarthrosis has developed at the seat of the defect. A pseudarthrosis of that nature usually causes no inconvenience. In certain cases, where greater portions of the spine have been fixed by operation, such graft defects are rather an advantage, and are utilised in active movements of the back.

How to prevent Graft Defects from arising?

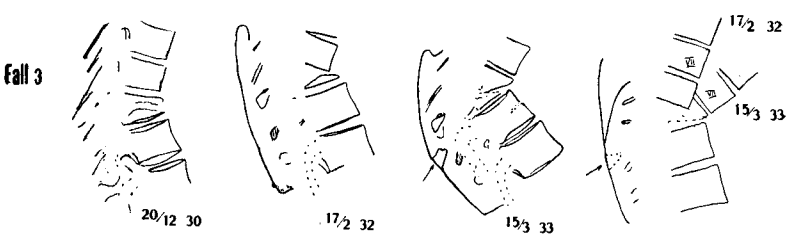
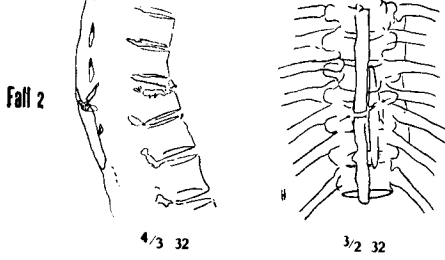
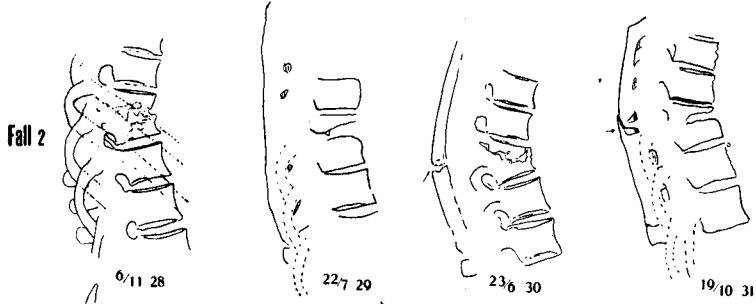
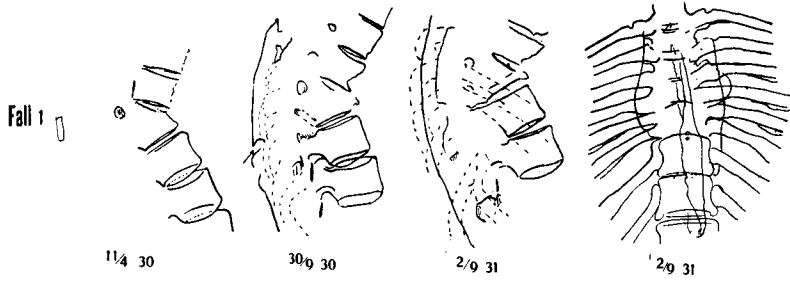
Several authors have laid stress on the importance of the post-operative treatment when it is a question of preventing graft defects from arising. *Albee* keeps his adult patients in bed for six weeks after the operation, after which time they are allowed to get up without any corset. Children are kept in bed for 5—6 weeks, and are then allowed to get up wearing a »Taylor brace« which is worn for 4—6 months. *Waldenström* recommends supine position in an extending plaster bed for from 7 weeks to 3 months after the operation; the patients are then allowed to get up wearing a supporting corset which is kept on for at least twelve months and worn day and night. *Sorell* keeps his adult patients in bed for 6 months after the operation in order to avoid fracture of the graft. The patients are then allowed to get up fitted with a corset which is worn for twelve months. Other authors recommend other forms of after-treatment.

For the development and functional adaptation of the new-formed bone within and around the necrotic bone graft, relatively early weight-bearing is probably of the greatest importance. By keeping the patient for a long time in supine position, and thus exposing the bone graft to a minimum amount of stress, there is a risk of absorption of the necrotic bone with insufficient formation of new bone, and with the development of a narrow atrophic bone bridge at the seat of the graft. In the author's opinion the after-treatment of the Albee-operated spondylitic patient should be individualised; patients should

not be kept in bed for an unnecessarily long time after the operation. The method usually practised in uncomplicated cases at the C.S.A., viz. keeping the patients extended in plaster bed for 7—8 weeks after the operation, followed by the wear of a corset for 12—18 months, has on the whole given good results, but has not always prevented graft defects from arising during the »atrophic« or »rebuilding« stage of the bone graft. Under suitable treatment the chance of repair of such defects, arisen during the »atrophic« or »rebuilding« stage of the graft, would seem to be fairly good. It is probably a complication of far less importance than extensive absorption of the bone-graft, whereby the fixation aimed at by the operation will be entirely nullified.

	Age at Albee-op.	Localisation of spondylitis	Duration of disease before Albee-op.	Defect diagn. (time after Albee-op.)
Case 1	F 29 yrs	D VII—IX	3 yrs	5 mths
" 2	F 30 "	D VIII—IX	2 yrs	1) 4 mths 2) 2 yrs
" 3	M 20 "	D VII—X	18 mths	17 mths
" 4	F 8 "	D VII—X	2 yrs 6 mths	4 mths
" 5	M 21 "	D IX—XI	18 mths	2 yrs
" 6	M 30 "	D XI—XII	21 mths	7 mths
" 7	M 49 "	D XI—XII	13 mths	5 mths
" 8	M 31 "	D XI—XII	2 yrs 10 mths	4 mths
" 9	M 25 "	D XI—XII	17 mths	21 mths
" 10	F 9 "	D X—L.I	2 yrs 2 mths	22 mths
" 11	F 25 "	D XI—L.I	ab. 4 yrs	5 mths
" 12	M 44 "	D XI—L.I	ab. 3 yrs	6 mths
" 13	M 11 "	D X—L.II	22 mths	15 mths
" 14	M 9 "	D XI—L.I	2 yrs 2 mths	4 mths
" 15	F 33 "	D XII—L.I	ab. 3 yrs	18 mths
" 16	F 57 "	D XII—L.I	ab. 2 yrs	7 weeks
" 17	M 7 "	D XII—L.I	23 mths	1) 3 $\frac{1}{2}$ mths 2) 2 yrs
" 18	F 12 "	D XII—L.III	ab. 9 yrs	5 mths
" 19	M 23 "	L I—II	ab. 1 yr	19 mths
" 20	M 36 "	L I—II	ab. 4 yrs	16 mths
" 21	F 11 "	D XII—L.II	ab. 3 yrs	4 mths
" 22	F 33 "	L II—III	22 mths	20 mths
" 23	M 32 "	L II—III	15 mths	3 yrs 5 mths
" 24	F 22 "	L II—III	2 yrs 5 mths	1 yr
" 25	M 5 "	L II—III	ab. 4 yrs	6 mths
" 26	F 8 "	L II—IV	3 yrs 6 mths	10 mths
" 27	F 8 "	L II—V	ab. 4 yrs	1) 5 mths 2) 18 mths
" 28	M 9 "	L II—V	7 yrs	5 mths
" 29	F 25 "	L III—IV	ab. 2 yrs	23 mths
" 30	M 26 "	L III—IV	2 yrs	17 mths
" 31	F 5 "	L I—IV	17 mths	7 mths
" 32	F 13 "	L III—IV	14 mths	5 mths
" 33	M 7 "	L III—IV	17 mths	5 mths
" 34	M 23 "	L IV—V	ab. 1 yr	14 mths
" 35	F 17 "	L III—V	ab 3 yrs	1) 5 mths 2) 4 yrs 6 m
" 36	M 7 "	L IV—V	2 yrs	5 mths
" 37	M 32 "	L V—SI	ab. 2 yrs	10 mths

Localisation of defect in rel. to intervertebr. artic.	Reoperation (Time after Albee-op.)	Consolidation (Time after Albee-op.)	Time of obs.	
I. a. D X—XI	—	1 year	3 yrs 2 mths	Case 1
" D VIII—IX	15 mths	—	4 yrs 4 mths	" 2
" D X—XI	—	2 yrs 1 mth	2 yrs 1 mths	" 3
" D XI—XII	—	—	18 mths	" 4
" D IX—X	2 yrs 5 mths	3 yrs 4 mth	3 yrs 4 mths	" 5
" D XI—XII	—	5 yrs 1 mth	5 yrs 1 mths	" 6
" D XI—XII	—	2 yrs	2 yrs	" 7
" D XI—XII	—	—	10 mths	" 8
" D XI—XII	—	2 yrs 10 mth	2 yrs 10 mths	" 9
" D X—XI	—	—	2 yrs 2 mths	" 10
" D XII—L I	—	14 mths	14 mths	" 11
" D XI—XII	—	—	2 yrs 6 mths	" 12
" D XII—L I	—	—	2 yrs 2 mths	" 13
" L I—II	—	—	9 mths	" 14
" L I—II	21 mths	3 yrs 3 mths	4 yrs 4 mths	" 15
" D XII—L I	—	3 yrs 5 mths	3 yrs 5 mths	" 16
" L I—II	—	13 mths	2 yrs	" 17
" D XII—L I	—	—	—	" 18
" D XI—XII	—	—	4 yrs 5 mths	" 19
" L II—III	—	—	2 yrs 6 mths	" 20
" L I—II	—	—	22 mths	" 21
" D XI—XII	—	15 mths	15 mths	" 22
" L II—III	22 mths	2 yrs 4 mths	3 yrs 10 mths	" 23
" L II—III	3 yrs 6 mths	4 yrs 2 mths	4 yrs 2 mths	" 24
" L I—II	—	—	2 yrs 2 mths	" 25
1) " L I—II	—	1) 19 mths	3 yrs 10 mths	" 26
2) " L IV—V	—	2) —	2 yrs 9 mths	" 27
" L III—IV	—	—	4 yrs 7 mths	" 28
1) " L I—II	—	1) 18 mths	2 yrs 4 mths	" 29
2) " L II—III	—	2) 4 yrs 7 m.	3 yrs 1 mth	" 30
" L I—II	—	—	17 mths	" 31
" L II—III	11 mths	16 mths	4 yrs 7 mths	" 32
1) " L II—III	—	2 yrs 7 mths	2 yrs 7 mths	" 33
2) " L IV—V	—	—	3 yrs 11 mths	" 34
" L IV—V	—	—	3 yrs 8 mths	" 35
" L V—S I	3 yrs 6 mths	—	4 yrs 6 mths	" 36
1) " L III—IV	—	4 yrs 6 mths	—	" 37
2) " L II—III	—	—	—	" 38
1) " L III—IV	1 yr	—	2 yrs 5 mths	" 39
2) " L IV—V	1 yr	16 mths	3 yrs 8 mths	" 40
" L V—S I	—	—	—	" 41



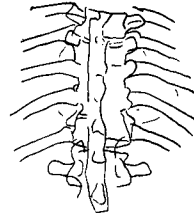
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3/9 32



3/9 32

Fall 6



27/12 28



17/9 29



7/11 32

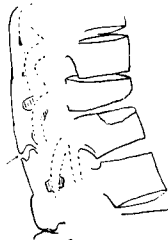
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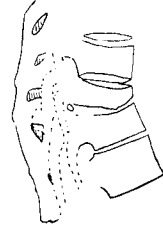
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23/5 30



2/1 31



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Fall 8

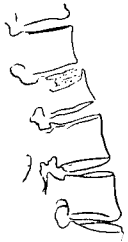


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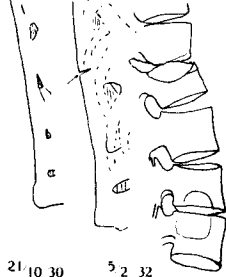


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Fall 10



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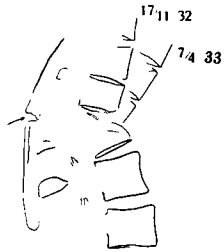
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Fall 13



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Fall 14



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20/4 33



21/6 33

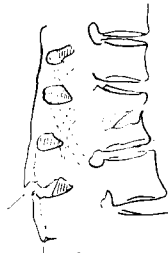
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Fall 16



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Fall 17



24 11 31



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12/12 33

Fall 18



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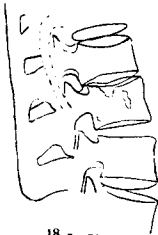


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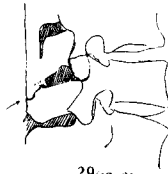


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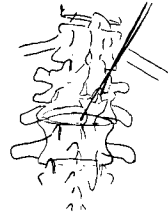
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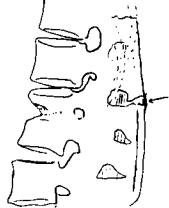


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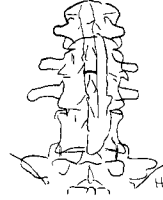
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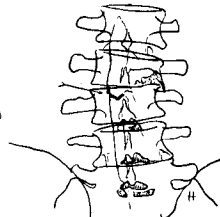
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Fall 24



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Fall 27



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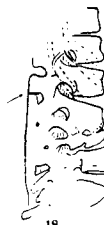
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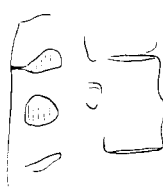


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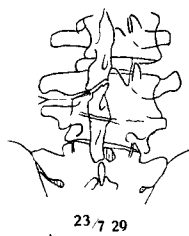


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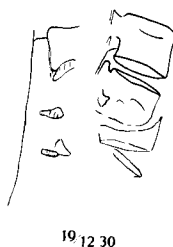
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Fall 35



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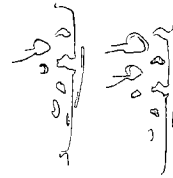
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Fall 37



20/2 30



16/9 30



13/3 31



20/9 32

CASE HISTORIES

CASE 1. R. F., female, born 1901. Treated in 1921 for tuberculosis (tbc) of the calcaneus, in 1922 for left-sided renal tbc. Developed symptoms of thoracic spondylitis in June, 1927; was treated in plaster bed. Admitted to C. S. A. (Coast Sanatorium, Apelviken) July 5th 1929.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—In the lower dorsal region a spinous process can be felt, projecting about 1 cm., and somewhat tender to pressure. The region above this forms a small fixed kyphosis. No signs of abscess. Knee jerks exaggerated. *Rtg. ex. July 11th, 1929.*—Lateral view: extensive destructions within the bodies of 7th—9th dorsal vertebrae, the remains of which have partly collapsed. Anterior contour of the bodies of 5th—6th dorsal vertebrae blurred and torn. Antero-posterior view: in the region D VI—D X there are no intervertebral spaces, D VII—D IX collapsed, paravertebral abscess shadow, 10 cm. broad, D IV—D X.

Correction was carried out in plaster bed, during which the gibbus showed scarcely any signs of reduction. In November, 1929, patient was allowed to try to get up with a plaster corset. As girdle sensations and pains appeared, she was again put in a plaster bed. Skiagrams now showed increased absorption; what was left of D VII—D IX showed still further collapse. *April 11th, 1930.*—Albee's op. (RH): a bent tibial graft was inserted edgewise into the spinous processes of D V—D XI (?XII). The operation incision suppurated for a long time, and a few minor sequestra detached themselves. In the middle of June, 1930, the patient was gradually allowed up in a plaster corset. *Rtg. ex. Sept. 30th, 1930.*—Lateral view: destruction and position unaltered since Dec. 1929. in the spinous processes of D V—XI there is a broad bone graft, in which a defect, 1 cm. broad, is seen at the level of the intervertebral joints D X—XI, between the spinous processes of D VIII—IX. No deposits. Antero-posterior view: position and destruction unaltered, abscess shadow smaller. The graft in the spinous processes of D V—XI and to the left of the spinous proc. of D XII is surrounded by deposits. On a level with the intervertebral space of D X—XI there is a broad irregular defect in the graft, surrounded at the sides by deposits (callus 20 mm. in breadth). Patient suffered no symptoms, the operation field

was firm, not tender, with one or two small sinuses. Was discharged with a leather corset on Sept. 30th, 1930. Shortly after she arrived home a sequestrum was cast off, and the last sinus healed up.

On after-examination Sept. 1st, 1931, the back felt firm and was not tender; no sinuses. No abscess, no spasticity. *Rtg. ex.*—Lateral view: The remains of the bodies of D VII—IX still further collapsed. In the spinous process of D V—VI a broad uninterrupted bony bridge. Antero-posterior view: at the seat of the defect there is a bony mass, 2 cm. broad, with a slight central rarefaction. Condition otherwise unaltered.

According to later information patient has kept well, and been able to work. *Rtg. ex.* Nov. 18th, 1933, showed unaltered position and a well defined destruction. In the spinous processes of D V—XII there is a bulky, well united, confluent graft.

Commentary.—At the time of operation the destruction involved large parts of the bodies of D VII—IX. A tibial graft was incerted in the spinous processes of D V—XI (?XII). Immediately after the operation no increase of inflexion could be observed. The graft became the seat of osteitis and sequestra detached themselves. Five months after the operation a broad defect was discovered in the graft, at the distal side of the vertebral destruction, on a level with the intervertebral junction D X—XI, and on the proximal side of the spinous process of D IX. Later, a definite increase of inflexion was observed, with compression of the remains of D VII—IX. Twelve months after the defect in the graft had been diagnosed it was well united, and largely rebuilt despite the increased inflexion.

CASE 2. E. W., female, born 1899. Patient was under treatment in 1916 for pulmonary tbc. Since then she has had symptoms from the lungs off and on. In June, 1927, she developed pains in the thoracic part of the back; and in Oct., 1928, a tuberculous spondylitis was diagnosed. Admitted to C. S. A. on Nov. 5th, 1928.

Condition on adm.—General condition good. Abnormal physical signs over upper parts of both lungs (dullness, altered breath-sounds, râles). Solitary tbc bacilli in the sputum. *Rtg. ex.* of lungs shows diffuse density, with shrinkage of the entire right lung, fibrosis at the apex, mottling above clavicle in I 1—2, and small areas of rarefaction. Mottling over the left upper lobe. Otherwise nothing of note from internal organs. *Spine.*—Fairly small, flat, non-tender gibbus in the lower thoracic region. Pains on movements, no signs of abscess formation; reflexes normal. *Rtg. ex. Nov. 6th, 1928.*—Lateral view: distal 2/3 of body of D VIII and proximal 1/3 of that of D IX absorbed, destruction not localised; remains of vertebral bodies collapsed with a gibbus formation of 145°. The anterior contour of bodies of D VII, D X and D XI blurred and torn. Antero-posterior view: Destruction of opposing parts of D VIII

and D IX, remaining parts collapsed. Paravertebral abscess shadow at D VI—XI.

Correction was made in plaster bed, the gibbus disappearing almost completely. Skiagrams show increased absorption of the remnants of D VIII—D IX, which show simultaneous separation, so that on May 17th, 1929, there is a defect, 1 cm. in breadth, in the column of vertebral bodies, at the seat of the destruction. *May 22nd, 1929. Albee's op. (RH).*—A slightly bent tibial graft was inserted edgewise into the spinous processes of D V—X. Healing by first intention.—After about 2 months the patient was allowed to get up gradually, with a plaster corset padded over the operation field. On Aug. 10th, 1929, she went home by motor car. At a sudden jolt of the car she felt a distinct pain right in the operation field, which soon abated, however. (Skiagram July 22nd shows an uninterrupted graft in the spinous processes of D V—X; position unaltered since May 17th).—In the middle of September pains recurred at the same place, in the middle of the operation field. On rtg. ex. Sept. 29th, 1929, a defect, 5 mm. broad, was found right through the graft, on a level with the destruction and the intervertebral joints of D VIII—IX, just on the proximal aspect of the 8th spinous process. The remains of the bodies of D VIII and D IX had again collapsed in the same position as prior to the correction, the gibbus was again apparent, and the fragments of the graft formed an angle, open ventrally. Patient was again put in a plaster bed; in Nov. 1929, thin periosteal deposits were seen dorsally and laterally of the defect.—During the next few months the patient was up from bed in a corset, but time after time she was back in a plaster bed. Skiagrams show slightly increased destruction within the recollapsed remains of D VIII—IX. The defect in the graft increased to about 1 cm., more deposits are formed around it, particularly at the sides. In May, 1930, patient again felt pains and tenderness in her back, and she was again corrected in a plaster bed. The vertebral remains separated again, bringing in evidence the gap in the column of vertebral bodies, and making the graft defect narrower (rtg. July 30th, 1930).—Aug. 21st, 1930, *Operation (RH).*—>Incision over the graft. Thin layer of bone on the dorsal aspect of the graft fracture, underneath a yellow-white fibrous mass which was chiselled away. A gutter was made in the bone on the left side of the old graft. This caused a moderate amount of typical tbc-pus to exude in the wound; the pus was wiped up. In the gutter to the left a new graft, 9.5 cm. in length, was inserted, a small splinter of bone was placed in the defect, and a thin fragment of periosteum applied, covering the defect dorsally. Healing by first intention.

Histological examination of portion excised from the graft: »Specimen from Albee-graft. The bits of specimen, submitted admixed in a pot, consist partly of spongy bone with periosteal parts attached and

showing signs of lacunar bone absorption, partly of such bits of bone, but with new-formation of cartilage and chondrogenous ossification. The process thus shows distintegration and reconstruction of bone such as is generally found in callus formation (Gellerstedt)«.

At the end of October, 1930, the patient was allowed to get up gradually in a plaster corset. During the next few months she remained free from symptoms: skiagrams show the position to be unaltered. The new graft to the left of the old is intact, the small graft on the dorsal aspect of the defect is uniting firmly to the distal fragment of the old one.—In the spring of 1931, the patient had pleurisy. In October, 1931, she felt indefinite pains in her back: skiagrams show the grafts to be intact, position unaltered, absorption from the vertebral remnants slightly increased. In February, 1932, lumbar spondylitis was diagnosed. In April, 1932, new skiagrams show how the remaining parts of D VIII and D IX have again collapsed under formation of a gibbus, with angular position between the fragments of the old graft. 3 mm. above the old graft defect there is a narrow transverse defect also through the new graft.—The patient was now put in a plaster bed and gradually got rid of her symptoms.—In the operation area there was a rounded fixed non-tender kyphosis.

Rtg. ex. Jan. 24th 1933: Lateral view: The remains of the bodies of D VIII—IX are more sharply defined, the gibbus has diminished somewhat since April 1932. Farthest ventrally between the fragments there is a thin shadow in the defect of the graft, otherwise no signs of consolidation. The anterior contour of the bodies of D VII, D X and D XI is sharply defined. Antero-posterior view: destruction and position unaltered, abscess shadow much diminished. The lumbar spondylitis shows the destroyed area to be unaltered and well localised. Patient is allowed to get up with a corset.—On after-examination April 1934 she is out of bed and going out. No corset, no pains.—*Rtg. ex.*—Lesions as before, and well localised. Remnants of D VIII and D IX from Jan. 24th, 1933, are compressed, the graft defects shows no signs of consolidation.

Commentary.—At the Albee operation the lesions involved the opposing anterior parts of the bodies of D VIII—IX. The original inflexion was corrected, causing a gap, 1 cm. broad, in the column of vertebral bodies to appear at the site of the lesion. At the Albee operation a tibial graft was inserted in the spinous processes of D V—X. Two months after the operation the patient, in connection with a momentary stress, experienced a local pain in the middle of the operation area. One month later a gap was discovered in the graft at the very same place. The damaged vertebral bodies again collapsed. The defect in the graft is situated at the level of the inflexion axis, the fragments forming an angle, open ventrally. The spine was again corrected in blaster bed. New bone grafts

were again applied parallel with the old ones, 15 months after Albee operation. At this further operation a tbc abscess pointed between the spinous processes. Primary union of the new grafts took place, and for more than twelve months the patient was free from symptoms. Subsequently also the new graft became the seat of a defect, the remnants of D VIII and D IX again collapsed. Five years after the first operation a pseudarthrosis still persisted at the site of the graft lesions. The relative position of D VIII and D IX can readily be modified by altering the stress of the spinal column.

CASE 3. H. K. U., male, born 1911.—Pains in the back since Feb. 1930, in July 1930 a gibbus was observed. Admitted to C. S. A. on Dec. 17, 1930.

Condition on adm.—General condition good. Lungs (rtg.).—Extensive fine mottling over most of the right lung. No clinical pulmonary symptoms. Internal organs otherwise normal. *Spine*: In the distal part of the thoracic region there is a moderate non-tender gibbus, slightly yielding to pressure, the apex of which corresponds to the spinous process of D X. No palpable abscess. Tendon jerks brisk, Babinsky negative. No ankle clonus.—*Rtg. ex. Dec. 20th 1930*: Lateral view: Of the body of D IX only the proximal end plate remains, of the body of D X barely more than the distal end plate, between these there is a small space. The anterior proximal border of D XI and the anterior contour of D VIII are not quite sharply defined. The lesions are ill-defined.—Antero-posterior view: Thin collapsed remains of D IX—X. Around the area of D VI—XI there is a bottle-shaped paravertebral abscess shadow, 16 cm. broad.—Correction was carried out in plaster bed, during which the gibbus somewhat diminished. Skiagrams show unaltered destruction and position, the abscess shadow somewhat smaller.—*Sept. 11th 1931 Albee's op. (RH)*: A slightly bent bone graft was inserted in the spinous processes of D VII—XII. Healing by first intention. After two months, the patient was allowed gradually to get up in a plaster corset.—Skiagrams in Feb. 1932 show increased absorption of the remains of D IX—X, which now appear in lateral pictures as a thin wedge. The contour of D VIII is intact. Powerful unbroken bone graft in the spinous processes of D VII—XII.—*March 8th, 1932*: General condition good. Operation area firm, non-tender, with good mobility above and below. Discharged to go home with leather corset.

In May, 1932, patient felt slight discomfort in his back and was under the impression that his hump was getting rather bigger. Has had no symptoms since then, and the hump has not grown. In March, 1933, it was discovered that the hump had increased since March 8th, 1932. *Rtg. ex. March 15th 1933*: Lateral view: the anterior distal border of the body of D VII shows a blurred contour and ir-

regular rarefactions. Of the body of D VIII the proximal dorsal half remains, the remains of D IX and D X have been still further absorbed and collapsed. The anterior proximal border of D XI shows a blurred contour. What is left of D VIII has dropped down against the small remnants of D IX—X. United with the spinous processes of D VII—XII there is a broad, powerful bony bridge. Level with the intervertebral joints D X—XI and within the spinous process of D X a gap, dorsally 13 mm. broad, is seen to run through the bony bridge; it is partly filled out by a thin bone shadow of spongy structure, and dorsally covered by a deposit. The distance between the spinous process of D IX and that of D X has clearly increased since Feb. 1932. The graft fragments form a considerable angle, open ventrally. Antero-posterior view: the remains of D VIII—X are collapsed. In the midline there is a broad bony bridge united within the spinous processes of D VII—XII. No defect is apparent at the level of the spinous process of D X, but large deposits are seen here on the bone bridge. The abscess is much diminished.—The patient was treated in plaster bed during the period May 20th—Sept. 1st, 1933. During this time there was little change in his condition. Skiagrams show unaltered destruction and position. The defect in the bone graft is gradually rebuilt, and on Oct. 31st, 1933, it is entirely reshaped: position unaltered. Destruction has not increased, is now more clearly defined. The abscess shadow is considerably reduced.—The patient's general condition is satisfactory; no discomfort in the back. Discharged to go home. Leather support.

Commentary.—At the time of operation the lesion involved large parts of the bodies of D IX—X. Destruction of vertebral bodies continued after the operation, involving, eighteen months later, the anterior distal corner of the body of D VII, the anterior distal half of the body of D VIII, and most of the bodies of D IX and D X. The distal end plate of D X and the intervertebral space D X—XI show sharp contours and normal shape. A proximal block involving D VII, the rest of D VIII and the arch and spinous process of D IX together with the graft enclosed therein, and possibly also the remaining part of the body of D IX, has been displaced in relation to a distal block involving the distal end plate and spinous process of D X and D XI and D XII. The displacement has the character of an inflexion movement, the axis of which is located between D VIII and D X but which cannot be more definitely localised. The distance between the spinous processes of D IX and D X is clearly increased. In connection with the inflexion movement a defect arose in the bone graft, on a level with the intervertebral joints D X—XI, and within the spinous process of D X. The fragments of the graft form quite a large angle, open ventrally. The defect is located at the distal aspect of the inflexion axis.

Two years and one month after the operation, 7 months after the diagnosis, the defect is found to be completely consolidated and rebuilt.

CASE 4. I. L. M., female, born 1923.—In the spring of 1929 the patient developed a hump in the thoracic region; treated with plaster jacket. Admitted to C. S. A. on March 7th, 1930.

Condition on adm.—General condition good. Lungs: Dullness, altered breath-sounds and râles over right upper lobe. *Rtg. ex.*: Considerable infiltration in the upper part of the right pulmonary field. Otherwise nothing of note from internal organs. *Spine*: In the distal third of the thoracic region there is a moderate hump involving three spinous processes. The gibbus is somewhat tender, and not quite unyielding to pressure. No signs of abscess. Reflexes normal.—*Rtg. ex. March 12th, 1930*: Lateral view: destructions distally and ventrally in the body of D VIII; of the bodies of D IX and D X there remain small collapsed fragments. Anterior contours of D VII and D XI blurred. Gibbus about 140°.—Antero-posterior view: the VII—XI intervertebral spaces obliterated, the remnants of D IX—X collapsed. Abscess shadow, 6 cm. broad, along D VI—XI.—The patient was first treated with a plaster corset with padding over the gibbus (*Calot*). Signs of spasticity appearing in June 1930, correction was carried out in plaster bed. During subsequent treatment the spasticity disappeared, and the hump slowly became less marked. Skiagrams show continuous absorption from the remains of the affected vertebral bodies, and slight reduction of the gibbus.—*Rtg. ex. July 27th, 1931*: Lateral view: the remains of D VIII—X are more sharply defined, collapsed into a wedge. The contours of D VII and D XI are sharply defined. Gibbus is clearly reduced, partly due to the altered shape of the previously prominent spinous processes of D IX—X. Inflexion very nearly as before.—*Oct. 16th, 1931, Albee's op. (RH)*.—A straight tibial graft was laid edgewise into the spinous processes of D VI—XII. Healing by first intention. About two months after the operation the patient was allowed gradually to get up in a plaster corset.—*Rtg. ex. Feb. 9th, 1932*.—Lateral view: destruction and position not materially altered since July 27th. A bone graft is seen in the spinous processes of D VII—XII, separated by a rarefaction from the spinous process of D VI. On a level with the intervertebral joints D XI—XII and on the proximal side of the spinous process of D XI there is a defect, 5 mm. broad, right through the graft, whose fragments form an angle, open ventrally. Gibbus about 140°. Antero-posterior view: a narrow graft surrounded by deposits is seen in the spinous processes of D VII—XII. On the distal aspect of the spinous process of D X there is an irregular rarefaction passing right through the graft.—Patient was put in plaster bed for 2½ months and then allowed to get up wearing a plaster corset.—Skiagrams show the bone graft to be surrounded by periosteal deposits both dorsally, ventrally and laterally, and that the space between the fragments is gradually filled up by dense bone. At the same time the rebuilding of the graft is proceeding. On a skiagram of Aug. 25th, 1932, there is seen an in-

crease of destruction and inflexion within the area of D VIII—X.—*Oct. 1st, 1932.*—General condition good. Gibbus fairly small, rounded and not tender. At the seat of the graft defect a non-tender enlargement of bone can be felt; there is no movement between the graft fragments. Skiagrams show the defect to be entirely filled up with bone ventrally, while dorsally an irregular rarefaction still remains. The defect is not apparent in the antero-posterior view. Patient was discharged with a leather jacket.

On after-examination at the Östersund Hospital on April 20th, 1933, the patient's general condition was found to be good, there were no symptoms; the kyphosis was unaltered and not tender.—Skiagrams show no change in the spondylitis since Aug. 25th, 1932. Graft defect unaltered since Oct. 1st, 1932.

Commentary.—At the time of operation the lesion involved large parts of the bodies of D VIII—X, the remnants of which had collapsed. A tibial graft was inserted into the spinous processes of D VI—XII. Four months after the operation there was no definite increase of vertebral destruction and inflexion, as evident on skiagrams. Level with the intervertebral joints of D XI—XII and on the proximal side of the spinous process of D XI the bone graft showed a defect with an angle, open ventrally, between the fragments. As treatment went on, inflexion definitely increased, concurrently with increased absorption from the remnants of the vertebral bodies; the axis of inflexion was located within the area of D VIII—X. The defect was located on the distal side of the axis of inflexion on a level with the undamaged intervertebral junction D XI—XII, between the spinous processes of D X and D XI. The defect has shown a great tendency to unification, but has not as yet consolidated, 18 months after the Albee operation.

CASE 5. E. G. J., male, born 1908. In the autumn of 1927 he sustained an injury to his back, and began to suffer pains in that region. In the spring of 1928 he was under treatment for pleurisy. From Aug. 1928 to Feb. 1930 he was under treatment for thoracic spondylitis at the Linköping Hospital. During his stay there, an Albee operation was done on his back, in the spring of 1929. At the time of operation the vertebral lesions involved the opposing parts of the bodies of D X—XI. An inlay bone-graft was applied in the spinous processes of D VII—L I. After the operation the wound suppurated, and sequestra are said to have detached themselves. From then on he wore a leather corset, but in the summer of 1930 he was again troubled with his back. On rtg. ex. further destruction was found in the distal part of the body of D IX; in the summer of 1930 the graft was intact; in May 1931 a faint line of rarefaction was seen through it, on a level with the intervertebral joints of D IX—X. The patient was seen and examined at the out-

patient department of C. S. A. on June 11th, 1931, and was admitted on July 17th of the same year.

Condition on adm.—General condition good. Dullness over the base of the right lung. Internal organs otherwise normal.

Spine.—Patient is unable to stand or sit without support. Over the lower thoracic region there is a radiant scar over a moderate arc-shaped gibbus, which is not tender, unyielding. Pain on axial compression of the spine. No signs of abscess. Knee jerks brisk, indication of ankle clonus on the left side.

Rtg. ex. June 11th, 1931: Lateral view: disintegration and absorption of the anterior distal part of the body of D IX, extensive destruction and absorption of the parts of the bodies of D X and D XI opposite to one another, the remains of which have collapsed into a wedge. Bone bridge united in the spinous processes of D VIII—L I. On a level with the intervertebral joints of D IX—X, immediately on the proximal aspect of the spinous process of D IX, there is a defect, 1 cm. broad, passing right through the bone bridge. (Position of vertebral bodies unaltered since rtg. ex. in Linköping on May 16th, 1931). Antero-posterior view: D IX—XI collapsed. In the spinous processes of D VIII—L I there is an irregular bone bridge. Immediately on the distal side of the 8th spinous process there is seen a defect, 1 cm. broad, through the bone bridge. Paravertebral abscess shadow along D VIII—XI.

Correction of the back was carried out in plaster bed, the back getting a little straighter. Skiagrams from the beginning of Nov. 1931 show that the defect has become narrower and is partly covered by deposits.—*Nov. 4th, 1931, operation (RH).*—The left border of the bone bridge was cut through with chisel and mallet, and a thin bony layer bent laterally. At the seat of the defect the cut section shows a white fibrous band firmly fixing the fragments of the bone graft. No respiratory displacement between them can be observed. In the gutter made, a tibial graft as long as the old one was inserted edgewise.

Histological ex. of the portion excised from the area of the defect gave the following result: »In the intervening substance there is a hard connective tissue with a well-marked tendency to cartilage formation. True bone tissue, on the other hand, has not been found. C. O. F-s.«

After the operation suppuration ensued, and sequestration of a large jagged piece of bone. Healing took place in the middle of March 1932.—*March 31th, 1932:* Patient free from symptoms. Gibbus fixed, slight mobility on the proximal and distal sides of the operation area. Patient can stoop forwards without any trouble. Discharged with leather corset.

After-examination Sept. 3rd, 1932.—In good health since discharge; has been working with the corset on. The back is healed, and not tender to direct or indirect pressure. Patient can move about without discomfort, and can stoop forward and downwards without difficulty.—

Rtg. ex.—Lateral view: Destruction and position unaltered. At the seat of the defect a powerful bone bridge is now observed. Antero-posterior view: Position unaltered, abscess shadow diminished. Bone bridge without interruption.

Commentary.—At the time of the Albee operation the lesion involved parts of the bodies of D X and D XI. A bone-graft was inserted into the spinous processes of D VII—L I. Twelve months after the operation symptoms again arose, and further destruction was in evidence distally in the body of D IX. At least two years after the Albee operation the remaining part of D IX had dropped down against the remains of D X. On a level with the intervertebral joints of D IX—X a defect was discovered in the graft. This defect was level with the axis of the new inflexion between D IX and D X. The relative position of D X and D XI had not changed since the Albee operation. 2½ years after the Albee operation a new graft was applied parallel with the old one, after which the defect within ten months had consolidated in spite of suppuration of the operation wound and separation of a large sequestrum.

CASE 6. A. G. A., male, born 1899.—In 1922 patient had had the peritonitis and pleurisy, in 1924 the of abdominal lymphatic glands. In May 1927, back symptoms arose, in Dec. 1927, gibbus and weakness in the legs. Was admitted to C. S. A. on April 13th, 1928.

Condition on adm.—General condition good. Dullness over the whole of the right lung, internal organs otherwise normal. *Spine:* Small hump with maximum prominence at D X, tender to percussion and axial compression. The whole lower thoracic and upper lumbar part of the back are kept rigid. No signs of abscess. Reflexes normal.—*Rtg. ex. April 18th, 1928.*—Lateral view: Extensive destructions with absorption from the bodies of D XI—XII, remaining parts collapsed. Antero-posterior view: Angulation, open to the left. Paravertebral abscess shadow along D VIII—L I.—Correction was carried out in plaster bed, the gibbus diminishing somewhat during the treatment. Skiagrams show increased absorption from the vertebral remains. Between the remains of D XI and D XII a slight gap is to be seen.—*Feb. 6th, 1929, Albee's operation (RH).*—A bent tibial graft was inserted edgewise in the spinous processes of D VIII—L I. Healing by first intention. After about two months patient was allowed gradually to get up and about in a plaster corset.—June 1929, left-side pleurisy.

Rtg. ex. Sept. 17th, 1929.—Lateral view: The absorption of the remnants of D XI—XII has increased, and between the remnants there is a small space. In the spinous processes of D VIII—L I there is a powerful, slightly bent bone-graft. On a level with the intervertebral joints D XI—XII, immediately on the proximal side of the 11th spinous process, there is a broad defect through the graft: its fragments form

an angle, open ventrally. Antero-posterior view: At the level of the lesion there is an irregular rarefaction running across the graft, surrounded by moderate deposits. Abscess shadow diminished.—General condition good. Discharged home with leather corset, free from symptoms.

On after-examination Jan. 10th, 1931, the gibbus had somewhat increased, was fixed and not tender. Skiagrams show increased absorption, and the remnants of D XI—XII to be still further collapsed. The ventrally open angle between the fragments of the graft had increased. The deposits on the ventral and lateral aspect of the defect were much larger.

On after-examination Nov. 7th, 1932 (Vitus) patient felt quite well and was able to do light work. Gibbus was fairly large, rounded, fixed and not tender. There was no tenderness over the graft, and no mobility within the operation area.—*Rtg. ex.*—Lateral view: Lesion scarcely altered since Jan. 1931. The bone bridge in the spinous processes is much more bent. At the seat of the defect there is a mass of callus, 2 cm. thick, with thin lines of rarefaction; it is uncertain whether these are passing right through. On bending and stretching of the back there is no displacement between the fragments of the graft. Antero-posterior view: at the seat of the defect there is a massive callus, over 2 cm. broad.

March 26th, 1934.—Condition unchanged since Nov. 1932; patient cannot get along without corset. Skiagram shows unaltered position and destruction, bone graft consolidated.

Commentary.—At the time of operation the lesion involved the distal half of the body of D XI and the proximal half of the body of D XII. In the process of correction the remaining parts of the vertebrae were forced apart, causing considerable separation between them. After the operation absorption continued from the remains of the vertebral bodies which fell together still further under increased inflexion. In the graft a defect was found to have arisen on a level with the inflexion axis in the intervertebral joints D XI—XII.—

Five years 1 month after the operation the defect is consolidated; the vertebral lesion has not altered during the last twelve months.

CASE 7. J. A. J., male, born 1881.—Pleurisy in 1928, and in April 1929 trouble with his back. January 1930, spondylitis was diagnosed. Admitted to C. S. A. on March 7th, 1930.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—Patient has difficulty in standing upright and is unable to stoop forwards without support. The dorsal and upper lumbar parts of the back are kept rigid. In the region of D XI—XII a spinous process is more prominent than the others. Tender on percussion. No signs of abs-

cess. Knee jerks brisk.—*Rtg. ex. March 21st, 1930.*—Lateral view: Distal third of the body of D XI and the proximal fourth of the body of D XII are absorbed, the outline of the lesion is ragged and blurred, and the remaining parts of the bodies collapsed. Gibbus about 155°. Antero-posterior view: D XI—XII collapsed, paravertebral abscess shadow along D XI—L I.

On correction in plaster bed the gibbus clearly diminished. Skiagrams show that the remnants of the D XI—XII have been forced apart causing a gap between them; the outlines of the lesions more clearly defined.—*May 23rd, 1930:* Albee's op. (Og-Jn.).—A slightly bent tibial graft was inserted edgewise into the spinous processes of D VIII—L I. Healing by first intention.

About two months after the operation the patient was allowed gradually to go about with a plaster corset; he was quite free from symptoms. In October he again began to complain, off and on, of tenderness and weakness in the back. On examination the gibbus was found to have grown bigger, and there was a small enlargement, tender to pressure, over the middle of the graft.—*Rtg. ex. Oct. 21st, 1930.*—Lateral view: the remaining parts of the XI—XII vertebral bodies have again met. The graft is seen lying in the spinous processes of D VIII—L I. Close to the distal side of the intervertebral joints D XI—XII and immediately on the proximal aspect of the spinous process of D XII, a defect, fully 1 cm. broad, is seen extending through the graft, the fragments of which form an angle, open ventrally. Antero-posterior view: in the spinous processes of D VIII—L I, just to the right of the midline is a narrow graft surrounded by deposits. Proximally from the XII spinous process a rarefaction with blurred out-lines is seen extending through the graft.

The patient was again put in plaster bed, which caused some reduction of the gibbus. Skiagrams show diminishing angulation between the fragments of the graft, and periosteal callus formation on the dorsal, ventral and lateral aspects of the defect. After March 17th, 1931, he was allowed to be up and about wearing a corset, and on April 17th, 1931, he was discharged, free from symptoms.

The patient subsequently remained free from symptoms; skiagrams show increase of periosteal callus. On after-examination May 28th, 1932, the back was found to be firm and not tender; no subjective symptoms. Skiagrams show unaltered position and destruction in the spondylitic area, which is clearly demarcated. The graft defect is now completely filled out and rebuilt: its site is marked by an enlargement on the graft. Jacket left off.

Commentary.—At the time of operation the lesion involved the distal part of the body of D XI and the proximal part of the body of D XII. The remaining parts of the vertebral bodies were forced apart, correc-

tion having caused their separation. Five months after the operation the vertebral remnants had again come in contact with one another; the bone graft shows a broad defect just distally from the inflexion axis in the intervertebral joints D XI—XII; the fragments form an angle, open ventrally. Two years after operation the bone destruction is well defined, its extent is unaltered. The position has not altered appreciably. The graft defect has consolidated; its site is marked by a ridge on the graft.

CASE 8. S. A. Q., male, born 1901.—Since the age of 14 years, the patient has had a hump, and has been suffering from aching pains between the shoulder blades and in the small of his back. In Feb. 1930, the spondylitis was diagnosed; he was treated in plaster bed and with corset, and was admitted to C. S. A. in April 17 1932.

Condition on admission.—General condition good., body well covered; patient nervous. Internal organs normal. *Spine.*—Well-marked kyphosis of the lower thoracic region, lumbar lordosis exaggerated. Tenderness on pressure and percussion over the fixed kyphosis and in the lumbar region. No signs of abscess. Reflexes normal.—*Rtg. ex. May 5th, 1932:* Lateral view: The bodies of D VIII—X are wedge-shaped, with irregular, sharp outlines facing the discs, and osteophytic nodules on the anterior corners. In the body of D X a central rarefaction the size of a cherry. The parts of the bodies of D XI and D XII opposite to one another show extensive irregular destruction, the remnants of the bodies are collapsed. In the region of L III—IV there are rather extensive destructions, fairly sharply defined; the vertebral remains are collapsed, and on their anterior surface osteophytes are present. Antero-posterior view: Opposing parts of D XI—XII are absorbed, their rests collapsed. No displacement laterally. Narrow, spindle-shaped paravertebral, abscess shadow proximally to D XII. The remaining parts of L III—IV collapsed; both psoas outlines slightly bulging.

The patient was put in plaster bed without any forcible correction being attempted. Skiagrams show no increase of the bone destruction in D XI—XII. A narrow gap gradually arises between their remaining parts; the bone structure becomes somewhat clearer. No changes in the lumbar spondylitis.—*Dec. 2nd, 1932: Albee's operation (RH).*—In the spinous processes of D IX—L II an almost straight tibial graft was inserted edgewise, with the periosteum to the left. Soft parts were sutured without tension. Healing by first intention.

In the beginning of Feb. 1933, patient began to get up, wearing a plaster corset. During the whole hospital period he had complained of all kinds of strange symptoms in different parts of the body; for instance, in the spine.—*Rtg. ex. April 18 1933.*—Lateral view: The lesions in the vertebral bodies of D XI—XII show no definite alteration, the rem-

nants of these vertebrae have slightly approached one another. In the spinous processes of D IX—L II there is a powerful bone-graft situated. At the level of the intervertebral joints D XI—XII, within the distal part of the XI spinous process, there is an irregular defect, about 1 mm. broad, and somewhat broader dorsally than ventrally, sharply outlined and running obliquely through the graft. No deposits.—Antero-posterior view: position and lesions as before. In the spinous processes, to the left of the midline, there is a graft surrounded by insignificant deposits. There is no visible defect, but at the level of the XI spinous process there is a slight angulation in the graft, open to the left. Slight tenderness over the middle of the graft.—*May 18th 1933*: Over the middle of the graft there is a palpable, tender, solid enlargement.—*Sept. 31th 1933*: General condition good. No tenderness on percussion. Slight pains in the lumbar region. *Rtg. ex.*: The defect in the graft shows blurred outlines, its breadth has somewhat increased. Periosteal deposits on the dorsal and lateral side of the defect. Spondylitis areas unchanged.

Commentary.—At the time of operation the lesion involved the distal part of the body of D XI and the proximal part of the body of D XII; through the correction the remaining parts of the vertebral bodies were forced slightly apart. After the operation the vertebral remains fell together. On a level with the inflexion angle in the intervertebral joints D XI—XII, the graft showed a narrow defect, sharply outlined. Five months later, this defect showed blurred outlines and dorsal and lateral deposits.

CASE 9. E. G. H., male, born 1905.—In January, 1929, the patient began to be troubled with backache; in January, 1930, he was treated in hospital for the pleurisy and spondylitis of the thoracic region. Admitted to C. S. A. April 7th, 1930.

Condition on adm.—General condition good. Dullness and diminished breath sounds over the base of the left lung; otherwise nothing of note from internal organs.—*Spine*: »When standing, the patient has a very rigid lumbar lordosis. He can bend forward and downwards without difficulty, but in doing so he keeps the thoracic and lumbar regions rigid. No tenderness on percussion, and no pains elicited on jarring the spine. The spinous processes of D XI—L II seem somewhat prominent; this area is more rigid than others, and the vertebrae there give a dull note on percussion. No signs of abscess. Reflexes normal.«

Rtg. ex. April 9 1930.—Fairly well defined destruction, involving the right proximal third of the body of D XII and a deep part distally-centrally from that of D XI. The intervertebral space D XI—XII sunk. No abscess.

The patient was corrected in plaster bed, the back getting somewhat straighter.—*May 20th, 1930*: Albee's op. (Og-In).—A lightly bent tibial graft was inserted edgewise into the spinous processes of D IX—L II.—

Healing by first intention.—After a little over 8 weeks the patient began to go about, wearing a plaster corset.—By Oct. 21th, 1930, he was free from symptoms, and the operation area looked sound.—*Rtg. ex.*—Lateral view: extent of destructions unchanged, limitations better defined. A powerful graft is visible in the spinous processes of D IX—L II. In the bodies of L II—III there are two well defined rarefactions, the size of hazel nuts; intervertebral space maintained. (This region not previously photographed).—Antero-posterior view: Graft to the right of the midline surrounded by deposits; appearance otherwise unchanged.

The patient was free from symptoms until Aug. 1931, when he again, without any known cause, began to have trouble with his back. Was *readmitted* to C. S. A. on Feb. 1st, 1932. His general condition was then good. *Spine*: Considerable lumbar lordosis. Fixed thoracic kyphosis. Patient has difficulty in bending forward and downwards, all his back muscles are rigid. Definite tenderness on percussion over a point 4 cm. distally from the upper edge of the graft. A tender, crepitant elevation is felt there on the otherwise solid and non-tender graft. Moderate pain on jarring the spine.—*Rtg. ex. Feb. 5th, 1932.*—Lateral view: destruction within D XI—XII slightly increased, vertebral bodies fallen together. L II—III unaltered. On a level with the intervertebral joints D XI—XII and immediately on the proximal side of the XI spinous process there is a defect, 2 mm. broad, running right through the graft. On the dorsal corners of the fragments there are small deposits.—Antero-posterior view: Graft partly rebuilt. On the proximal side of the XI spinous process there is a transverse, irregular rarefaction.

The patient was put in plaster bed. The tenderness rapidly disappeared. Skiagrams show progressive formation of periosteal callus, most marked on the ventral side of the defect. Lesions and position unaltered.

Rtg. ex. Nov. 9th, 1932.—Lateral view: in the dorsal part of the graft a defect is still visible; ventrally there is a solid mass of callus, connecting the fragments of the graft with the XI spinous process.—After the middle of November 1932, the patient was out of bed wearing a corset. When going home, on Dec. 2nd, 1932, he was free from symptoms; the operation area was firm and non-tender, the graft straight. On after-examination on March 23rd, 1933, the skiagram showed that the defect in the graft had been entirely filled out with bone, its place being marked by a slight elevation. The spondylitis was unaltered, and the destruction well delimited.

Commentary.—At the time of operation the destruction involved parts of the bodies of D XI—XII and was fairly well demarcated. A bone graft was inserted into the spinous processes of D IX—L II. Later, a localised spondylitis was found in L II—III. Fifteen months after the operation the patient was again troubled with backache. On examination

21 months after the operation, the destruction in D XI—XII was found to have slightly increased, the remaining parts of the bodies had fallen together still further. On a level with the inflexion axis in the intervertebral joints D XI—XII a defect in the graft was apparent. Two years and ten months after the operation there is no further change in either the destruction or the position of the vertebrae. The graft defect has consolidated, its place is marked by a slight elevation of bone.

CASE 10. E. D. A., female, born 1921.—In September 1928 a tuberculous gibbus was discovered in the thoracic region. Admitted to C. S. A. Jan. 24th, 1929.

Condition on adm.—General condition fairly good. Internal organs normal.—*Spine*: In the lower thoracic region there is a moderate non-tender gibbus yielding to pressure. No signs of abscess. Reflexes normal.

Rtg. ex. March 8th, 1929.—Lateral view: considerable destruction with absorption of large parts of the bodies of D XI—XII; the remnants fallen together, forming a wedge. The anterior distal corner of D X shows blurred bone structure and indefinite outlines.—Antero-posterior view: Remnants of D XI—XII collapsed, paravertebral abscess, 9 cm. broad, along D IX—XII.

Correction was carried out in plaster bed, during which the gibbus diminished considerably. Skiagrams show that the destruction encroaches upon the distal end plate of D X and the proximal part of L I. Inflexion underwent no changes.—*July 7th, 1930*: Albee's op. (RH).—A nearly straight tibial graft was placed, under tension, edgewise into the spinous process of D VIII—L II, the prominent spinous processes being pushed in.—Healing by first intention. Subsequent course uncomplicated, except for a small bed sore over the operation area in Nov. 1930.

Rtg. ex. Nov. 19th, 1930.—Lateral view: Anterior distal part of the body of D X, almost the whole of the bodies of D XI and XII, and the proximal 2/3 of the body of L I, are absorbed. Moderate rounded gibbus. The graft united into the spinous processes of D VIII—L II, bent as an arc over the gibbus.—Antero-posterior view: Bone graft with deposits in the spinous processes of D VIII—L II. Calcified abscesses on both sides of the lesion.—Discharged home with corset.—*After-examination* (Sjögren, Hernösand) Sept. 7th, 1932.—In the lower part of the thoracic region a fairly large non-tender gibbus. Patient feels tired in the back, and again has to wear a corset. (Has been without corset for a year).—*Rtg. ex. lateral view*: Destruction in D X and L I increased, the remaining parts of the vertebral bodies have fallen together still further, so that the rest of D X abuts against the anterior part of L I. The bone bridge in the spinous processes of D VIII—L II forms a regular arc, with a defect almost 1 cm. broad between the spinous processes of D X and XI, on a level with the centre of the destruction.—Antero-posterior view: On the whole unaltered since Nov. 19th, 1930.

Commentary.—At the time of operation the lesions involved most of the bodies of D XI and XII, besides small portions of the bodies of D X and L I. The gibbus was corrected, making it possible for an almost straight bone graft to be inserted into the spinous processes of D VIII—L II. After the operation destruction was progressive, and the inflexion increased. In the meanwhile the graft became bent like an arc over the gibbus, and on a level with the remnants of D X—XI a broad defect appeared in the graft (2 years and 2 months after the operation).

CASE 11. E. K. S., female, born 1907.—The patient has had trouble with her back since 1928. In May 1931 a the spondylitis was diagnosed. Admitted to C. S. A. Jan. 4th, 1932.

Condition on admission.—General condition good. Heart: Systolic murmur, no enlargement. Internal organs otherwise normal. *Spine:* In the lower thoracic region there is a fairly pointed gibbus, unyielding to pressure. Slight swelling in the right iliac fossa, knee jerks brisk, Babinsky negative. *Rtg. ex. Jan. 8th, 1932.*—Lateral view: The anterior distal border of D XI, most of the body of D XII and the anterior proximal two thirds of the body of L I are absorbed, the outlines of the lesions blurred and ragged, the bone structure in the remains of the vertebral bodies blurred. The remnants of the vertebral bodies have fallen together, gibbus 130°. In front of the vertebral remnants there is a calcium-dense shadow, the size of a walnut.—Antero-posterior view: D XI—L I collapsed. Moderate bayonet position. An angle of 170°, open to the right. Along D X—L I there is a paravertebral abscess shadow, 7 cm. broad, continuing to the left, at L II, into a calcified extension.

The patient was corrected in plaster bed, with the result that the gibbus was somewhat diminished. Skiagrams show a slight increase of the defect in the distal part of D XI. The inflexion is clearly diminished, causing the distance between the anterior borders of D X and L I to increase. Furthermore, the lordosis is increased above and below the spondylitis. As the lesions give evidence of a better demarcation it is decided to operate.

Nov. 24th, 1932. Albee's operation (RH).—Into the split spinous processes of D IX—L II a bent tibial graft was inserted edgewise.—Healing by first intention. Out of bed after about 2 months, wearing a plaster corset.—*April 7th, 1933.* General condition good, no symptoms; operation area firm and not tender.—*Rtg. ex. lateral view:* Destruction unaltered. The vertebral remnants have resumed their original position, and the gibbus has again increased. In the spinous processes of D IX—L II there is a coarse, bent bone graft; in the XII spinous process, at the level of the intervertebral joints D XII—L I, this graft presents a dorsally open defect, with blurred outlines and dorsally covered by a thin deposit. Antero-posterior view: Lesion and position unaltered. Abscess diminished, calcium shadows as before. To the left of the midline

in the spinous processes of D IX—L II there is a narrow graft surrounded by moderate deposits, which within the XII spinous process shows a rarefaction clean through, with blurred outlines.—Discharged home with leather corset.

After coming home the patient was well and able to work, and had no trouble with her back. On *after-examination* Jan. 20th, 1934, there was no tenderness in her back, the gibbus was unaltered, and the graft felt intact.—*Rtg. ex.* lateral view: Increased destruction in the caudal part of the body of D XI, destructions fairly well demarcated. No signs of block formation between the vertebral remains of D XI—L I, which have fallen together still further and now form a wedge. The graft has united within the spinous processes of D IX—L II, shows a spongy structure all through at the site of the defect, and forms a regular, dorsally convex arc over the gibbus.

Commentary.—At the time of operation the destruction involved considerable parts of the bodies of D XII and L I, and the anterior lower border of the body of D XI. During correction the vertebral remnants were forced apart. After the operation the vertebral remnants had again fallen together, and 4½ months after the operation a defect in the graft appeared on the level with the intervertebral joints D XII—L I. The fragments of the graft formed an angle, open ventrally. Fourteen months after the operation the defect in the graft was filled out by bone with longitudinal structure. The destruction in the caudal part of D XI is increased; the vertebral remnants have fallen together under increased inflexion, and the graft forms a dorsally convex arc over the gibbus.

CASE 12. J. A. A., male, born 1888.—In 1928, the patient was under treatment for a tuberculous spondylitis. Improvement followed. In 1930 he got sciatica and became weak in his legs. Was admitted to C. S. A. Jan. 26th, 1931.

Condition on admission.—General condition fairly good, but complexion pale. Internal organs normal.—*Spine:* Rounded, non-tender, fixed gibbus corresponding to D XII—L I. Has difficulty in sitting without support. The whole lumbar and the distal part of the thoracic region are carried rigidly. No paresis of bladder or rectum, no gross sensibility disturbances. Paraparesis in lower extremities, Babinsky positive on both sides, tendon reflexes normal.

Rtg. ex. Jan. 28th, 1931. Lateral view: Of the bodies of D XII and L I there remain the proximal part of the former and the distal end plate of the latter, which have fallen together and formed a wedge. The bone structure in the distal part of D XI, its contour and anterior distal border, are blurred. Gibbus about 135°. Antero-posterior view: Destruction in the right distal corner of D XI, the intervertebral spaces of D XI—L I are obliterated; no abscess shadow.

The patient was corrected in plaster bed, with the result that the gibbus was considerably diminished. The pareses disappeared rapidly and almost completely. Skiagrams show inflexion to be reduced; between the remaining parts of D XII and L I there is a wide separation, measuring at least 1 cm.—Wassermann positive, negative after a course of bismuth treatment. *Aug. 28th, 1931. Albee op. (RH).*—A straight tibial graft with the periosteum dorsally was inserted under tension into the spinous processes of D X—L I (?L II).—Seven weeks after the operation a small skin defect arose over the middle of the graft, which was thus laid bare. During January 1932 large sequestra were cast off, whereupon the wound healed.—*Rtg. ex. Feb. 17th, 1932.* Lateral view: The remaining parts of D XII—L I have entirely collapsed, the remnant of D XI has fallen together with that of D XII, causing a gibbus of about 130°. The graft is visible in the spinous processes of D X—L I. Immediately at the distal side of the XI. spinous process, and on a level with the intervertebral joints D XI—XII there is a defect in the graft, 16 mm. broad, without deposits; the fragments of the graft form an angle, open ventrally.—Antero-posterior view: Position and destruction not appreciably altered. To the left of the midline there is a graft surrounded by deposits in the spinous processes of D X—L I. On the distal aspect of the XI. spinous process there is throughout the graft a broad rarefaction with blurred outlines.—The patient again presents a large, non-tender, fixed gibbus, whose vertex corresponds to the graft defect, which can readily be felt. On discharge he was able to bend forwards and backwards without difficulty, though keeping the entire dorsal and lumbar regions rigid.

After-examination. March 30th, 1933.—Gibbus increased, rounded, fixed, not tender. No movement can be elicited in the operation area. No signs of abscess. Free from symptoms and walking without discomfort.

Rtg. ex. Lateral view: Absorption from the vertebral remnants somewhat increased; inflexion definitely larger, with increase of the gibbus as well as of the angular position between the fragments of the graft. The breadth of the graft defect between the dorsal depositions has remained almost unaltered since September 1932; in the ventral part of the defect between the spinous processes there is evidence of new-bone formation.—Antero-posterior view unaltered.

In the autumn of 1933 the patient again became weak in his legs and had difficulty in walking. Was readmitted to C. S. A. on Sept. 1st, 1933: »General condition good. Spine stable, not tender; gibbus unaltered. Spastic paresis of the legs; can neither stand nor walk«. Plaster bed. Paresis rapidly improved; Dec. 1933—Feb. 1934, patient up from bed wearing corset. *Rtg. ex. Feb. 20th, 1934.* shows definite increase of destruction in the basal part of the body of D XI; position very nearly the same. Graft defect persists surrounded by deposits. Angulation be-

tween graft fragments possibly somewhat reduced since March 30th, 1933.

Commentary.—At the time of operation the lesion involved the distal portion of the body of D XI and most of the bodies of D XII and L I. The remnants of the vertebral bodies had been forced apart by the correction; between the remnants of D XII and L I there was a diastasis at least 1 cm. broad. After the operation the wound suppurated, parts of the graft sequestered. The vertebral remnants again fell together, inflexion increased. At the level of the intervertebral joints D XI—XII a graft defect appeared, with a ventrally open angle between the fragments.—Two years and six months after the operation the vertebral lesion had increased still further, also the inflexion was greater. For a long time periosteal new bone formation has been observed around the graft defect; the breadth of the defect remains the same despite increase of the inflexion.

CASE 13. G. R. P., male, born 1920.—Symptoms of tuberculous spondylitis since Dec. 1929; admitted to C. S. A. June 6th, 1930.

Condition on adm. General condition fairly good. Internal organs normal. — In the dorso-lumbar region a flat, fixed gibbus, not tender. The XII. spinous process most prominent. No abscess. Reflexes normal. —*Rtg. ex. July 2nd, 1930.*—Lateral view: anterior distal border of the body of D XI shows a blurred structure and contour, of the body of D XII only the proximal end plate remains; extensive lesion in the proximal part of L I. The outlines of the lesions are blurred and ragged; the vertebral remnants have collapsed into a narrow wedge, between them dense detritus. Antero-posterior view: D XII—L I collapsed, surrounded by structure-less calcium shadows. Abscesses in both psoas muscles.

The patient was corrected in plaster bed, the gibbus diminishing in the meanwhile. Skiagrams show progressive destruction of D XI, the remnant of which is falling down upon D XII.—As the patient's general condition was satisfactory and the gibbus had considerably diminished, and the skiagrams showed the lesion to be better localised, operation was decided upon.—*Oct. 15th, 1931. Albee op. (RH).*—A straight tibial graft was placed edgewise in the spinous processes of D XI—L III.—Healing by first intention. Subsequent course uneventful.—*Rtg. ex. Feb. 5th, 1932.*—Lateral view: since the operation there has been still further absorption from the remnant of D XI, which is now closer to D XII than before. The anterior distal border of D X is absorbed, the contour of the defect blurred. The outline of the anterior proximal border of L II is blurred. In the spinous processes of D XI—L III there is a straight, intact graft. Antero-posterior view: in the spinous processes of D XI—L III a narrow graft with deposits. Appearance otherwise unaltered.—In April, 1932, the patient was discharged free from symptoms, fitted

with a leather corset.—*Re-admitted Jan. 20th, 1933.* While at home he had been in good health and had attended school. General condition impaired. *Spine.*—Gibbus increased, rounded, unyielding, involving six spinous processes; no tenderness. Good mobility above and below the gibbus. (Possibly slight displacement of the vertex of the gibbus on movement of the back; Feb. 6th, 1933).—*Rtg. ex. Jan. 25th, 1933.* Lateral view: since Feb. 5th, 1932, the remnants of the bodies of D XI—L I have collapsed into a wedge. The spongy structure in the whole of D X and most of L II is mottled and blurred, their contours facing the lesion blurred and ragged, the intervertebral space L I—II obliterated. The graft has fused with the spinous processes; immediately on the distal side of the intervertebral joints D XII—L I, distally of the XII spinous process, there is a sharply outlined defect, gaping dorsally, with a ventrally open angle between the graft fragments (155°). Antero-posterior view: since Feb. 5th, 1932, D XI—L III have collapsed still further. Bayonet position between D XII and L I. The graft seems to be partly rebuilt, the defect is not visible.—In Feb. 1933, an abscess in the right psoas was evacuated by puncture.

April 4th, 1933.—Gibbus firm, rounded, not tender, and somewhat smaller than in January. Bone graft firm and regular, on its vertex is felt an irregular, immobile depression.—On Dec. 4th, 1933, the patient's condition is on the whole the same. Skiagrams now show a better localisation of the lesions in D XI—L I. A side view shows in the anterior, central part of D X a rounded, fairly localised defect with sequestra. The bone structure in L II is clearer. Position the same. The dorsal area of the graft defect is partly filled with thin deposits.

Commentary.—At the beginning of treatment, the lesion involved the anterior distal border of D XI, most of the body of D XII, and the proximal part of the body of L I. The destruction increased steadily, and at the time of operation it involved most of the body of D XI.—Fifteen months after the operation the lesion also included the anterior part of the body of D X and the anterior proximal part of the body of L II. The remnants of D XI—L I fell together into a wedge. Simultaneously with increase of inflexion, a graft defect arose, as a result of progressive destruction, at the level of the intervertebral joints D XII—L I. The graft fragments form a ventrally open angle, and the defect is surrounded by deposits.

CASE 14. L. S. J., male, born 1923.—Since the autumn 1930 the patient has had symptoms of tuberculous spondylitis. Admitted to C. S. A. Sept. 18th, 1931.

Condition on adm.—General condition impaired. Internal organs normal. *Spine.*—In the dorso-lumbar part of the back there is a large, fixed, tender hump, including 4—5 spinous processes. No signs of abscess; reflexes normal.

Rtg. ex. Sept. 24th, 1931.—Lateral view: extensive lesions in the bodies of D XII and L I; remnants collapsed into a wedge. Adjacent vertebrae show normal form and contours. Angular gibbus. Antero-posterior view: D XII—L I collapsed, with an angle open toward the left. Abscess in the left psoas.

The patient was corrected in plaster bed. Skiagrams show a slight reduction of the hump, mainly on account of lordosation above and below the lesion. The remnants of D XII—L I are still further absorbed. The bone structure in D XI is getting blurred, but there is no change in the contours. The whole of the vertebral body falls down against the remnant of D XII.

Dec. 16th, 1932. Albec op. (RH).—A slightly bent tibial graft was inserted into the spinous processes of D X—L II, with the periosteum toward the left.—Healing by first intention.—About 2 months after the operation the patient was allowed to get up with a corset, but he had difficulty in walking. *Rtg. ex. April 20th, 1933.*—Lateral view: the distal contour of the body of D XI is now somewhat irregular, the remnant of D XII still further absorbed. No appreciable change in the inflexion. In the spinous processes of D X—L II a slightly bent bone-graft can be seen. Between the spinous processes of L I—II a defect with blurred outlines is seen through the graft, covered on its dorsal aspect by deposits. The lordosis below the spondylitic area has clearly diminished since the *rtg. ex.* prior to the operation.—Antero-posterior view: position and destruction unaltered. To the left of the midline, in the spinous processes of D X—L II, there is a narrow bone-graft. The defect between the spinous processes L I—II is not visible, but the graft in this area is surrounded by large deposits of periosteal bone.—At the seat of the defect a firm, not tender bony enlargement can be felt.

Sept. 21th, 1933.—General condition fairly good. *Rtg. ex.* lateral view: a rarefaction remains ventrally at the seat of the defect. Dorsally and on the left side the defect is covered by a massive deposit, 3 mm. thick. Position and destructive lesion unaltered.

Commentary.—At the commencement of treatment the lesion involved considerable portions of the bodies of D XII and L I. The hump was corrected in plaster bed without visible effect upon the inflexion. On the other hand, lordosis was obtained above and below the gibbus, which thereby became less noticeable. At the operation a bone graft was inserted into the spinous processes of D X—L II. The destruction gradually encroached upon the distal portion of D XI. Inflexion did not change appreciably. Six months after the operation the lordosis visible below the gibbus before the operation had clearly diminished. On the distal side of the intervertebral joints L I—II and the spinous process of L I, a defect with blurred outlines was seen through the graft. Five months later this defect was partly filled up with substance of osseous density,

and was surrounded by large periosteal deposits.—In this case the defect bears no relation to any change in the inflexion, but seems to be associated with reduction of the lordosis produced by the correction on the distal side of the gibbus.

CASE 15. A. A. N., female, born 1896.—The patient has had trouble with her back since 1926; in August 1927, the spondylitis was diagnosed. She was admitted to C. S. A. on Dec. 5th, 1928.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—Moderate-sized gibbus, slightly tender and yielding somewhat to pressure, corresponding to D XII—L I. Patient has difficulty in standing, and is unable to bend forward without support. The whole dorsal and lumbar regions are carried rigidly. Large abscess in the right iliac fossa (940 c. c. drained off). Reflexes normal.—*Rtg. ex. Dec. 6th, 1928.*—Lateral view: the two-thirds of the bodies of D XII and L I facing each other are destroyed and absorbed. The outlines of the lesions are blurred, between the remnants there are calcium-dense, small shadows. Gibbus about 160°. Antero-posterior view: remnants of D XII—L I collapsed; abscess in the right psoas.

The patient was corrected in plaster bed, the gibbus being clearly reduced. Skiagrams show the lesion to be unaltered; there is a considerable gap between the remnants of the bodies of D XII and L I. *Feb. 6th, 1929, Albee op. (RH).*—A straight tibial graft with the periosteum dorsally was inserted into the spinous processes of D X—L II.—Healing by first intention. After the operation the abscess in the right iliac fossa filled up. The patient suffered backache, and was kept in plaster bed, until Jan. 30th, 1930. Skiagrams show position and destruction unaltered. To the left of the midline, in the spinous processes of D X—L II, is seen a straight bone-graft, securely united with the spinous processes D X—L I. In the spring of 1930 the patient tried to stay up from bed wearing a corset, but she had continuous backache.

Rtg. ex. May 24th, 1930.—Lateral view: position and lesion unaltered. The graft has now united also with the spinous process of L II. Between the spinous process of L I and the graft there is a sharply defined, narrow, vertical line of rarefaction.—*Rtg. ex. Aug. 16th, 1930.*—Lateral view: Since May 24th the remnants of D XII—L I have collapsed. On the distal aspect of the intervertebral joints L I—II and immediately below the spinous process of L I there is a defect, about 1 cm. broad, in the graft; it is in close approximation to the distal end of the rarefied line visible on May 24th, and already then intimated as a transverse rarefaction through the graft. The proximal fragment is displaced quite 1 cm. toward the dorsal side of the lower fragment. Thin bone shadows are seen between the fragments, the rarefied line between the spinous process of L I and the bone graft has disappeared.—The patient was put back in

the plaster bed, her symptoms rapidly disappeared.—*Nov. 12th, 1930, Op. (RH).*—The defect was exposed, and a groove was made in the right-hand border of the old graft. An osseous union was then discovered on the ventral aspect of the defect, between the spinous processes of L I and L II. A fresh graft was inserted in the groove.—Obstinate suppuration of the wound followed, yet without any formation of sequestra. Skiagrams show incipient fusion of the vertebral remnants of D XII and L I in an unaltered position. A massive bone bridge is seen between the spinous processes D XI—L II, fortified to the right by the new graft in the spinous processes L I—II.—On the patient's discharge in May, 1932, her general condition was good, and she was relatively free from symptoms. The operative field was healed, firm and not tender.

After-examination, June 1933.—Slight weakness in the back, must wear a corset. Skiagrams show early bony union between the remnants of the bodies of D XII—L I. The bony bridge in the spinous processes D X—L II is continuous and strong.

Commentary.—During the whole period of treatment the lesion involved the distal part of the body of D XII and the proximal part of the body of L I. The remnants of these bodies, originally collapsed, were forced apart by correction, causing a considerable gap to appear at the site of the destruction. The bone graft inserted into the spinous processes D X—L II at the operation immediately united with the spinous processes D X—L I, later also with L II. Fifteen months after operation a vertical fissure appeared between the graft and the spinous process of L I. Eighteen months after the operation the remainder of L I had rotated round a frontal axis, causing re-formation of the original inflexion between D XII and L I. The position of L I in relation to the graft became clearly altered. On the displacement of L I, L II followed. At the same time a defect arose in the bone graft, just on the distal side of the intervertebral joints L I—II, immediately below the spinous process of L I. The proximal graft fragment protrudes dorsally beyond the distal one. At the re-operation 21 months after the Albee operation, bony union was found between the spinous processes of L I and L II on the ventral side of the graft defect. Four years and four months after the Albee operation the bone bridge (including the graft inserted at the second operation) is firm and consolidated. Early bony union is observed between the bodies of D XII and L I.

CASE 16. H. L. E., female, born 1872.—In 1924 the patient had erythema nodosum and phlyctenular conjunctivitis, in the autumn of 1924 she had trouble with her back, and in 1927 a tbc spondylitis was diagnosed. Was admitted to C. S. A. on Aug. 24th, 1928.

Condition on adm.—General condition fairly good. Stout build, musculature ordinary. Internal organs normal. *Spine.*—Small pointed gibbus.

tender to pressure, at the level of D XII. The patient keeps her whole back rigid; she is unable to sit without support for her hands. No abscess; reflexes normal.—*Rtg. ex. Aug. 30th, 1928.*—Lateral view: Considerable destruction in the bodies of D XII—L I, remnants collapsed. Antero-posterior view: No abscess.

Patient was corrected in plaster bed, the gibbus in the meanwhile gradually diminishing. Skiagrams show somewhat increased absorption from the remnants of the vertebral bodies, which have been forced apart with the result that there is a space between them of a little more than 1 cm.

May 17th, 1929. Albee op. (RH).—A straight tibial bone graft with periosteum on the dorsal aspect was inserted into the spinous processes of D X—L III.—Healing by first intention.—When the patient was practising standing upright in the plaster bed seven weeks after the operation, she felt a sudden pain in her back. Soon afterwards (July 17th) a tender swelling was found over the graft, in the centre of the operative field.—Skiagram of July 27th, 1929, shows a sharply outlined defect at the level of the intervertebral joints D XII—L I, within the distal part of the spinous process of D XII. The defect goes right through the graft, whose fragments form a ventrally open angle. The position of the vertebral remnants remains very nearly the same.

The patient was put in plaster bed for another seven weeks, with padding over the graft defect. After this period she was free from symptoms, and was allowed to get up wearing a plaster corset.

Rtg. ex. Nov. 29th, 1929.—Lateral view: The remnants of D XII—L I have clearly fallen together since July 27th. The angulation of the graft is less marked, the contours of the defect are blurred, the defect is partly filled up with shadows of osseous density, and is covered, dorsally, by deposits. Antero-posterior view: To the left of the midline, immediately below the spinous process of D XII, a rarefaction with blurred outlines is seen passing through the graft.—The patient was discharged with leather corset on Dec. 8th, 1929, free from symptoms. The corset was worn until November, 1930. The patient has felt well all the time, and has managed her household duties.

After-examination October 29th 1932 (Vitus).—No gibbus, no mobility within operative area. The spine is kept rigid. *Rtg. ex.* Lateral view: Block formation between bodies of D XII and L I, position unaltered. An intact, massive bone bridge is seen in the spinous processes of D X—L III, its shape has remained unaltered since Nov. 29th, 1929; at the seat of the defect there is a slight bony enlargement.

Commentary.—The destruction involved the distal part of the body of D XII and the proximal part of the body of L I. The vertebral remnants were forced apart by the correction, causing a space between them, 1 cm. broad. After weight-bearing seven weeks after the operation the

bone graft, inserted into the spinous processes of D X—L III, was found to have a defect clean through, at the level of the intervertebral joints D XII—L I. The vertebral bodies fell together under increase of inflexion.—Three years and five months after the operation the remnants of the vertebral bodies have formed into a block, there is a massive bone bridge in the spinous processes of D X—L III; the seat of the defect is marked by a slight bony enlargement.

CASE 17. A. E., male, born 1924.—The patient has had symptoms from his back since Christmas 1929. He was admitted to C. S. A. March 14th, 1930, under the diagnosis of thoracic spondylitis.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—The patient walks with difficulty, leaning the trunk backwards; he is unable to bend over forwards without support for his hands. The whole spine is carried rigidly. In the dorso-lumbar region there is a small, tender gibbus, not quite firm, including three spinous processes. There is no definite malposition sideways. No signs of abscess. Reflexes normal. *Rtg. ex. March 18th, 1930.* Destruction present in juxtaposed parts of D XII—L I; lesions not localised, Bayonet position, with D XII displaced 1 cm. towards the right.

The patient was treated mainly with correction in plaster bed, for shorter periods he was allowed to walk about in a plaster jacket with padding according to *Calot*. The size of the hump definitely diminished. Skiagrams show increase of the lesion in D XII—L I, the remnants of which fell together still further. Small abscess shadows are seen in the psoas.

Nov. 24th, 1931. Albee op. (RH).—A tibial graft was inserted edgewise into the spinous processes of D X—L II. Healing by first intention.—*March 4th, 1932.*—There is tenderness over the centre of the graft, its distal end is slightly mobile in relation to the spinous process. A sequestrum being suspected, an incision was made over the middle of the graft. No sequestra or graft defects were discovered (March 11th).

Rtg. ex. March 4th, 1932.—Lateral view: A graft with a slight dorso-convex curve is located in the spinous processes of D X—L II. Below the intervertebral joints L I—II, between the spinous processes of these vertebrae, the bone structure is blurred and irregular within a transverse band, 5 mm. broad. Antero-posterior view: immediately above the spinous process of L II there is a narrow line of rarefaction passing transversely through the graft and surrounding deposits. (The patient had been in plaster bed since the operation).

In the beginning of April, 1932, patient was allowed to get up, wearing a plaster corset.—Skiagrams show progressive absorption of the remnants of D XII—L I, with increase of inflexion. The defect in the graft is being gradually rebuilt.—*Rtg. ex. Aug. 25th, 1932.*—Lateral view: at

the seat of the defect there is a narrow sharply defined line of rarefaction in the ventral part of the graft, covered dorsally by a massive bone bridge. The whole graft shows a uniform, dorso-convex curve. Antero-posterior view: within the area between the spinous processes L I—L II the bone bridge is powerful, almost sclerotic; the defect does not show.—*Dec. 2nd, 1932.*—Operative field in good condition; patient free from symptoms. Skiagram shows position and lesion to be unchanged. The defect in the graft is non-apparent. Discharged home with leather corset.

Already in March, 1933, the patient's condition grew worse, in May he got paraplegia and was admitted into the Children's Hospital at Solhem, where he has been under treatment ever since. *Rtg. ex.* of Dec. 12th, 1933, shows that the bodies of D XII and L I have been almost completely absorbed. The outlines of the anterior lower border of D XI and the anterior upper border of L II are ragged, and the structure blurred. Inflexion is considerably increased. Immediately below the intervertebral joints D XII—L I the bone-graft shows a defect, partly filled up with thin bone shadows; the graft fragments form a considerable angle, open ventrally. The graft defect between the spinous processes of L I—II is consolidated and rebuilt.

Commentary.—At the commencement of treatment the lesion involved the distal part of the body of D XII and the proximal part of the body of L I. The vertebral remnants were collapsed. For some time afterwards absorption from the surfaces of destruction continued, and inflexion increased in spite of the correction. Lordosation of the spine took place above and below the spondylitic area, causing the gibbus to become less apparent. At the operation a bone graft was inserted into the spinous processes of D X—L II.—Three and a half months after the operation, while the patient was still in plaster bed, a defect was discovered through the graft, just below the intervertebral joints L I—II. Under continued treatment vertebral destruction as well as inflexion were still further aggravated. The bone graft united with the spinous processes became more and more bent, forming a regular dorso-convex arc over the gibbus. Thirteen months after the operation the graft defect had consolidated.—Two years after the operation, both the destructive process and the inflexion had increased still further. At the level of the intervertebral joints D XII—L I the graft showed signs of a fresh defect, the fragments of which formed an angle, open ventrally; the defect was filled up with thin bone shadows.

In this case inflexion increased after the operation. Even before gravitation had had its play a defect appeared in the graft below the spondylitic area, at the level of an intact intervertebral junction. On increase of the inflexion the bone graft bent in the shape of an arc over the gibbus. Two years after the operation still another defect appeared in the graft, this time at the level of the inflexion axis. The

old defect had consolidated 13 months after the operation, the inflexion defect showed slight dense bone shadows between the graft fragments.

CASE 18. E. R. B., female, born 1917.—The patient had been under treatment for the spondylitis since 1920. She was admitted to C. S. A. April 13th, 1928.

Condition on adm.—General condition impaired; patient is thin and pale. Internal organs normal. *Spine.*—Large, rounded gibbus, hard, fixed, but not tender, in the dorso-lumbar region. Otherwise good mobility in the back. No signs of abscess, reflexes normal.

Rtg. ex. April 21st—28th.—Lateral view: extensive destruction in the vertebral bodies of D XII—L III, remnants collapsed. D XI and L IV—V show defective outlines and localised foci, but have retained their shape. Antero-posterior view: D XII—L IV collapsed. Bayonet position, with displacement of D XII to the left. Abscess in right psoas.

The patient was corrected in plaster bed, the condition gradually improved. The hump got smaller, and skiagrams show clearer demarcation of the destroyed areas. The remnants of D XII—L III occupy the same position as before, the intervertebral space D XI—XII is increasing in height. Mild lordoses appear below L III and in the distal part of the thoracic region.

April 5th, 1929. Albee op. (RH).—A straight tibial graft with the periosteum dorsally was inserted into the spinous processes of D X—L III.—After the operation there came necrosis of the soft parts above the graft; no formation of sequestra. Two months after the operation the patient was allowed to get up wearing a plaster jacket.

Sept. 20th, 1929.—General condition satisfactory, patient free from symptoms, operative field firm and not tender. Gibbus slight and fixed. *Rtg. ex.* lateral view: lesion and position unaltered within the area of D XII—L III, lordoses above and below the lesion obliterated. A bone-graft is seen lying in the spinous processes of D XI—L III, it has no attachment to D X. At the level of the intervertebral joints D XI—XII, between the spinous processes D XI—XII, a defect, 7 mm. broad, appears in the graft.

After-examination Sept. 4th, 1933.—Small, rounded, fixed gibbus, not tender, in the dorso-lumbar region; over its vertex is felt a broad plate of bone. Good mobility above and below the operative field. Mobility noticed between the spinous processes D XI—XII. *Rtg. ex.* lateral view: the remnants of the bodies of D XII—L III have fused into a block, the rest of the damaged vertebrae are rebuilt. Considerable growth of vertebrae since 1929. In the spinous processes D XI—L IV there is a broad bone bridge, which between the spinous processes D XI—XII shows a defect whose width varies according to whether the back is flexed or extended (on skiagrams respectively 11 and 8 mm.). There is extensive

bony fusion between the vertebral arches, and also between the spinous processes L III—IV. At the site of the intervertebral joints D XI—XII an intact interarticular space is observed. Antero-posterior view: position and lesion unaltered, vertebrae grown considerably.

Commentary.—For a period of 9 years before the operation the patient had had symptoms of lumbar spondylitis, and had been treated for that disease. At the time of operation the lesions involved the greater part of D XII—L III. The bodies of D XI, L IV and L V had retained their shape, but showed localised lesions. The parts of the back immediately above D XII and below L III became lordosed by the correction in plaster bed. A bone graft was inserted into the spinous processes D X—L III. After the operation the bodies of D XII—L III gradually fused into one block. At the level of the intervertebral joints D XI—L III the graft showed a defect, and the proximal graft fragment lacked attachment in the X spinous process.—On after-examination 4 years 5 months after the operation, a movable pseudarthrosis had developed at the seat of the defect. Extensive synostosis had formed between the spinous processes L III—IV. There is good mobility in the distal part of the dorsal region of the back, and between D XI—XII, L IV—V and L V—S I.

The inflexion position within the area D XII—L III did not change after the operation. At the level of the undamaged intervertebral junction D XI—XII a graft defect arose in conjunction with reduction of the lordosis, the defect being subsequently transformed into a mobile pseudarthrosis. At the same time bony union developed between the spinous processes L II—IV.—As both D XI and XII were originally attacked by spondylitis, flexion between these vertebrae can also be regarded as an inflexion movement.

CASE 19. K. I. V., male, born 1907.—Had erythema nodosum in 1925, and in 1929 developed symptoms of lumbar spondylitis with abscess formation in the lumbar region. Admitted to C. S. A. Aug. 23rd, 1929.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—Lumbar lordosis straightened out, no gibbus, no tenderness. Upper part of the lumbar and lower part of the dorsal region are kept rigid. In the lumbar muscles on the right side there is a fluctuation, the size of a fist. Reflexes normal.

Rtg. ex. Aug. 28th, 1929.—Deep destruction in the upper central part of the body of L II, and a superficial lesion in the lower part of that of L I. Intervertebral space obliterated, outlines of lesions blurred.

Patient was placed in plaster bed, the abscess was opened as it threatened to break through the skin: the sinus soon healed. The correction caused the lumbar lordosis to increase. Skiagrams showed a more sharply defined demarcation of the lesions, the previously obliterated intervertebral space L I—II was broader.

May 7th, 1930. Albee op. (Og-In).—A straight tibial graft was placed edgewise into the spinous processes of D XI—L III.—Healing by first intention. After 2 months the patient was out of bed wearing a plaster corset.—*Oct. 24th, 1930.*—Operative field firm, not tender; patient free from symptoms. Discharged home with leather corset, allowed to start work Dec. 1930.

Rtg. ex.—Position and lesion unaltered since last examination. To the right of the midline there is a straight bone graft surrounded by moderate deposits in the spinous processes of D XI—L III.—On examination May 18th, 1931, the patient was free from symptoms and was allowed to leave off wearing the corset. At the beginning of Dec. 1931, he felt pains and tenderness over the lower part of the operative field; he ascribed these symptoms to his having lifted a barrel of petrol. No clinical signs.

Rtg. ex. Dec. 29th, 1931.—Lateral view: the destructive lesions in L I—II are better localised, position unaltered. On a level with the distal part of the intervertebral joints L II—III, just above the spinous process of L III is seen a line of rarefaction through the graft. Dorsally from this there is a small deposit.—Antero-posterior view: in the distal part of the bone bridge there is a small shut-off remnant of the graft. Proximally to the spinous process of L III there is a narrow sharply defined line of rarefaction passing transversely through deposits as well as the tip of the graft, separating a fragment of this 8 mm. in length.

The patient continued his work, but before long he observed a »ball« in the lower part of the operative field.

On after-examination *Nov. 8th, 1932*, the patient was free from symptoms and able to work. The field of operation was not tender, in its lower part could be felt a bony enlargement. Good mobility above and below the operative field and between the spinous processes of L II and L III.—On skilagrams an irregular defect through the graft appears, varying in size on movements of the back, between the spinous processes of L II—III. A deposit is seen on the dorsal aspect of the proximal fragment of the graft.

Commentary.—At the time of operation the lesion involved the distal part of the body of L I and the proximal part of the body of L II. A bone graft was inserted into the spinous processes of D XI—L III. The position has not changed since the operation. Nineteen months after the operation, after a heavy strain, a sharply defined, narrow graft defect was found on a level with the undamaged intervertebral junction L II—III. Twelve months after the defect occurred, a mobile pseudarthrosis developed at its site.

CASE 20. H. V. T., male, born 1895.—Backache since the autumn of 1927; since April, 1929, treated for lumbar spondylitis (plaster bed). Admitted to C. S. A. Aug. 14th, 1931.

Condition on adm.—General condition good. Lungs: rhonchi over the right upper lobe, otherwise nil. Internal organs otherwise normal. *Spine.*—Lumbar part of the back straight, spinous process of L I somewhat prominent, the whole lumbar part rigid, no tenderness. No abscess, reflexes normal. *Rtg. ex. Aug. 25th, 1931.*—Lateral view: the bodies of L I and L II absorbed except for a thin plate of the proximal part of L I and the distal part of L II. The remnants are in part collapsed; Ventrally the distance between them measures 2 cm. Between the remnants, on the dorsal aspect of the gap, there are dense, irregular shadows. Antero-posterior view: vertebral remnants collapsed without malposition sideways. No abscess.—The patient was also subsequently treated in plaster bed, but the shape of the spine did not alter.

Oct. 8th, 1931. Albee op. (Og-Jn).—When the spinous processes were split open, a small amount of thin, cheesy fluid exuded from between the spinous processes of L I and L II, which was carefully wiped up (abscess at a depth of about 1.5 cm.). The other spinous processes having already been split, a tibial graft was inserted edgewise into the spinous processes of D XI—L III, in spite of the abscess.—Healing by first intention. After 2 months the patient was allowed to get up wearing a plaster corset.—*Feb. 24th, 1932.* Operative field firm and not tender, the graft free from tenderness along its entire length. The whole of the lumbar and lower thoracic region of the back is kept rigid by muscular contracture. Discharged home with leather corset.

Rtg. ex. Feb. 17th, 1932.—Position and lesion unaltered. To the right of the midline there is a powerful tibial graft, convex backwards, in the spinous processes of D XI—L III. The graft is surrounded by deposits.

While at home, the patient was wearing a corset. At Christmas time, 1932, a small sinus developed in the upper part of the operation wound, from which a couple of small sequestra were cast off.

Was *readmitted* to C. S. A. on Feb. 3rd, 1933. General condition then fairly good. Lungs: hypersonorous percussion note. Over the right upper lobe numerous crepitations. X-ray of lungs: widespread nodular and fibrous changes, in the right apex two small liquefied areas.

Spine.—The whole lumbar and the lower part of the dorsal region are entirely rigid. Operative field firm, not tender, no false mobility. In its upper part a small sinus, passing a few centimetres below the centre of the bone-graft.—*Rtg. ex. Feb. 14th, 1933.*—Lateral view: further absorption from the remnants of L I—II slight; remnants now collapsed, so that the diastasis ventrally measures 1.5 cm. Masses of detritus unchanged, reaching dorsally to between the spinous processes of L I—II. The graft is narrower than before. At the level of the intervertebral joints L I—II, in the distal part of the spinous process of L I, there is a defect, 8 mm. broad, clear through the graft; its outlines are blurred, and it is covered dorsally by thin deposits. Immediately on the ventral

aspect there are dense shadows without bone structure. Antero-posterior view: remnants of L I—II still further collapsed. To the right of the midline there is a graft in the spinous processes D XI—L III. Below the spinous process of L I there is an ill-defined defect in the graft, surrounded by deposits; the callus mass measures 20 mm. in breadth.

On incision over the defect there might have been a respiratory movement between the graft fragments. The part of the graft located below the defect was lacking periosteum.—A small sequestrum was extracted from the sinus; on histological examination of granulations from the sinus »masses of typical tubercles« were found.

Aug. 30th, 1933.—General condition good. Freedom from symptoms, sinuses healed. *Rtg. ex.* Lesions and position unaltered. No signs of the defect in either projection.—Discharged home with corset.

Commentary.—At the time of operation the lesion involved the greater parts of the bodies of L I and L II; when the spinous processes were split, a cheesy pus exuded from an abscess, 1.5 cm. deep, below the spinous process of L I. In spite of this the bone graft united with the spinous processes by first intention. Sixteen months after the operation tuberculous osteitis of the graft supervened, with sequestra and sinus formation. The vertebral remnants had fallen together. At the level of the intervertebral joints L I—II and the axis of inflexion, below the spinous process of L I, a graft defect appeared. During the subsequent treatment callus continued to form around the defect, which 22 months after the operation was filled up with a dense bone shadow.

CASE 21. I. M., female, born 1921.—The patient has been under treatment for lumbar spondylitis since the early part of 1929. She was admitted to C. S. A. on March 13th, 1930.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—Pointed, non-tender, fairly fixed gibbus of medium size in the upper lumbar region; the spinous process of L I the most prominent. No abscess, reflexes normal.

Rtg. ex. March 13th, 1930.—Extensive lesions in the bodies of L I—II, the remnants of which have fallen together into a wedge. D XII has fallen down upon L I, its distal contour is not quite sharply defined. Angle open towards the right. Abscess shadows in both psoas muscles.

The patient was first corrected in plaster bed, and afterwards wore a plaster corset with padding according to *Calot*. The gibbus diminished during treatment. Skiagrams show increased absorption from the remnants of L I—II, and a small destructive lesion in the anterior distal corner of D XII, besides an irregular rarefaction in the dorsal part of the body of the latter. The lateral angulation disappeared.

Feb. 26th, 1932. *Albee op. (RH).*—A tibial graft was placed under tension edgewise into the spinous processes of D XI—L III.—Healing

by first intention. After about two months the patient was allowed to get up wearing a plaster corset.—*Rtg. ex. June 28th, 1932.*—Lateral view: position unaltered. The lesion in the base of D XII has increased somewhat, is better localised. The bone graft is united with the spinous processes of D XI—L II; between the graft and the spinous process of L III there is a rarefaction. At the level of the intervertebral joints D XI—XII, below the spinous process of D XI, the graft shows a transverse band with mottled bone structure. Antero-posterior view: narrow graft surrounded by deposits in the spinous processes* of D XI—L III. Immediately below the spinous process of D XI there is a rarefaction passing transversely through the graft and deposits.—*Oct. 1st, 1932.*—Operative field in good condition. Fairly good mobility above and below it. No abscess. *Rtg. ex. lateral view.*—Lesions not increased, localisation better defined. Early osseous fusion between the remnants of L I—II. Position unaltered. The graft forms a regular, dorsally convex arc, in bony union with the spinous process of D XI as well as with that of L III, ventrally in the junction with L III, the bone structure is irregular. Antero-posterior view: spondylitic process unaltered. The defect below the spinous process of D XI is now more sharply defined, and is covered on both sides by thin deposits. Large deposits around the spinous processes of D XI and L III.—Patient returned home free from symptoms, wearing a leather corset.

After-examination (Wahlgren, Skellefteå) May 16th, 1933.—Skiagrams show increased vertebral destruction in the dorsal part of D XII and in the remnants of L I—II. Position unaltered. The graft defect is filled up with bone and consolidated, the distal end of the graft is united with the spinous process of L III.

Commentary.—The patient was under treatment for spondylitis for three years before the operation. At the time of the latter, the lesion involved large parts of the bodies of L I—II, and there was a slight destruction in the distal part of D XII. The position of the vertebral remnants was unaffected by the correction, but above and below the spondylitic area lordoses formed, causing the gibbus to be less prominent. A straight bone graft was fixed under tension into the spinous processes of D XI—L III.—Four months after operation the inflexion was unaltered. The paragibbous lordoses had diminished, causing a slight gibbus to appear. In the bone graft a defect was visible on a level with the intervertebral junction D XI—XII; the attachment of the graft to the spinous process of L III had become loose. The inflexion remained the same 15 months after the operation. The graft formed a dorsally convex arc over the gibbus. The defect was consolidated, and the graft had fused with the spinous process of L III.—In this case, the inflexion had not altered since the operation, a graft defect had arisen on a level with the undamaged intervertebral junction D XI—XII.

CASE 22. E. M. J., female, born 1896.—The patient had had symptoms of tbc spondylitis since April 1927. She was admitted to C. S. A. Nov. 30th, 1928.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—At the level of L I—II there is a small, tender gibbus, not quite firm. The whole dorsal and lumbar regions are kept rigid. No abscess. Reflexes normal. *Rtg. ex. Dec. 7th, 1928.*—Lateral view: The distal two-thirds of the body of L II and the proximal third of the body of L III are absorbed, the outlines of the lesions are ragged and blurred. Diastasis between the vertebral remnants. Antero-posterior view: Remnants of L II—III collapsed. Right psoas shadow broad.

The patient was corrected in plaster bed, during which treatment the gibbus diminished and disappeared.

Feb. 15th, 1929. Albee op. (RH).—A straight tibial graft with periosteum directed dorsally was inserted into the spinous processes of D XII—L IV.—Healing by first intention.—After two months the patient was up and about, wearing a plaster corset. July 19th, 1929.—Patient free from symptoms, operative field in good condition. Skilagrams show unaltered destruction and position. The spinous processes D XII—L IV enclose a straight, intact graft.—Patient discharged with leather corset.

In Oct. 1930, patient fell backwards hitting her back on the staircase, after which she developed pains in the back.—*Readmitted* to C. S. A. Nov. 6th, 1930.

Condition on adm.—General condition good. Small, not tender gibbus including L I—II.—*Rtg. ex. Nov. 4th, 1930.*—Lateral view: The remnants of L II—III have fallen together since last examination. The lesions are well localised. In the spinous processes of D XII—L IV there is a straight bone bridge, the seat of a through and through defect, 8 millimetres broad, located immediately above the intervertebral joints L II—III and just above the spinous process of L II; the fragments of the graft show a ventrally open angle. The defect is surrounded by small deposits. Antero-posterior view: A coarse bone bridge in the spinous processes showing a rarefaction clean through, immediately above the spinous process of L II, laterally surrounded by deposits.

Dec. 12th, 1930, op. (RH).—»Incision in the old scar. Callus at the seat of fracture. The united graft was split lengthwise. At the seat of the fracture a groove was made in the old graft about 3 cm. long, after which a new graft was inserted into the groove, with the periosteum directed dorsally. In the split graft another straight graft was placed edgewise.—Healing by first intention. *Rtg. ex. June 20th, 1931.*—Vertebral destruction unaltered. On the dorsal aspect of the defect there is a new, partly united graft. To the right of the old bone bridge, beyond the still visible defect, there is a new graft with considerable deposits. Patient returned home free from symptoms.

After-examination Dec. 9th, 1932 (Vitus).—General condition good. Back straight and not tender. Mobility above field of operation. Capable of doing light work.—Skiagrams show unaltered destruction and position, possibly early block formation between the vertebral remnants. No sign of the graft defect; the new grafts largely united with the old one. On the dorsal aspect of the original defect there is a vertical line of rarefaction on the boundary between the old and the new graft.

Commentary.—At the time of the Albee operation the lesion involved parts of the bodies of L II and L III; there was a gap between the remnants. In connection with a trauma eighteen months after operation, the bone graft inserted into the spinous processes of D XII—L IV showed a defect immediately above the intervertebral joints L II—III. The vertebral remnants fell together. The graft defect was located just above the inflexion axis. After another bone grafting operation the bone bridge consolidated in the spinous processes.

CASE 23. K. E. E., male, born 1896.—Symptoms of spondylitis since Midsummer 1927; admitted to C. S. A. April 13th, 1928.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—Lumbar region entirely fixed, in its upper part a small tender kyphosis. No pain on jarring the spine. No abscess, reflexes normal.

Rtg. ex. April 18th, 1928.—Lateral view: Extensive destruction in the lower part of the body of L II, the upper outline of L III is blurred. Spicular deposits on the adjacent anterior borders of these vertebrae. Intervertebral space much smaller than normal. Antero-posterior view: Lesion in the right distal corner of L II. Intervertebral space smaller, on the right side entirely obliterated. Angle 170°, open towards the right.

Correction was carried out in plaster bed. After some time the back was straight in both planes. Skiagrams show that L II—III had been forced apart, causing the intervertebral space again to appear in its normal height, and the angulation to disappear in the sagittal as well as in the frontal plane.

Sept. 14th, 1928. Albee op. (Og-Jn).—A straight tibial graft with the periosteum directed dorsally was inserted into the spinous processes of D XII—L V.—Healing by first intention. After two months the patient was up from bed, wearing a plaster corset.—*Feb. 12th, 1929.* Patient free from symptoms, operative field in good condition. *Rtg. ex.*—Position and destruction unaltered since operation. To the left of the midline a powerful graft, united in the spinous processes of D XII—L IV, and separated from L V by a rarefaction. Discharged with leather corset which was worn until the spring of 1930.

At Christmas time, 1930, the patient felt pains in the right side, and had a tender swelling over the operative field.

On examination Feb. 2nd, 1932, the graft showed a hard thick swell-

ling, without crepitation or false mobility, 5 cm. below the upper part of the incision. In prone position and on strong passive lordosation pain was elicited over the swelling. *Rtg. ex. Feb. 5th, 1932.*—Lateral view: Destruction has not increased and is well demarcated. L II—III have fallen together again, especially ventrally. The deposits on the vertebral borders (see above) have grown, and are almost in contact with each other. The spinous processes of D XII—L IV enclose a powerful bone bridge. At the level of the intervertebral joints L II—III, above the spinous process of L III, there is a defect a little over 1 mm. broad, with blurred outlines. The graft fragments form an angle, open ventrally. Ventrally the defect is partly filled up with dense bone shadows; dorsally it is covered by small deposits. Antero-posterior view: L II—III have again collapsed, with an angle open towards the right. On the proximal side of the spinous process of L III the bone bridge shows an irregular transverse defect, the graft fragments form an angle of 160° open towards the right.

March 18th, 1932, op. (Op-Ju).—Incision in the old scar. Between the spinous processes there is a very powerful bone bridge. Between the spinous processes of L II—III there is a small swelling on the dorsal and lateral aspect of the bone bridge. No mobility was noticeable here. From the right side of the bone bridge a portion of bone, about 2 mm. thick, was chiselled off and felled sideways. When this was done, a white line about 1 mm. broad, passing through the entire graft, was observed at the seat of the defect. In the new-formed groove a new tibial graft, measuring 1.5 cm. at its middle, was placed edgewise.

Patho-anat. ex.—»The white line consists mainly of chondroid tissue with transitions into true cartilage, partly along the lateral borders, partly into new-formed bone. C. O. F-s.« Healing by first intention. In June, 1932, the patient returned home, wearing a leather corset.

After-examination Nov. 28th, 1932.—General condition good. Operative field firm, not tender; good mobility above and below it. *Rtg. ex.*—Lateral view: The deposits on the anterior vertebral borders come close to each other. The graft defect is not apparent. Condition otherwise unaltered. Antero-posterior view: The new graft under reconstruction, united with the old one, is located to the right of the still visible defect.

Commentary.—At the time of the Albee operation the lesion involved the right distal third of the body of L II and the upper surface of the body of L III. The previously collapsed intervertebral space L II—III again appeared on correction, and the lateral angulation was corrected. Three years after the operation, the bone graft inserted into D XII—L IV showed a defect at the level of the intervertebral joints L II—III. The remnants of L II—III had fallen together and regained their original position; the graft defect was located on a level with the axis of this inflexion movement. The lateral malposition has returned, and the graft

fragments, too, present an angulation, open towards the right. After new bone grafting the bone bridge in the spinous processes has consolidated.

CASE 24. R. M. J., female, born 1909.—In February, 1928, the patient had erythema nodosum and pleurisy. Since March, 1929, she has had symptoms of spondylitis. She was admitted to C. S. A. on May 21st, 1931.

Condition on adm.—General condition good. Dullness over right pulmonary base, internal organs otherwise normal. *Spine.*—Moderate dorsal scoliosis with convexity to the right. In the proximal part of the lumbar region there is a round, fairly firm gibbus, comprising three spinous processes. Lumbar region muscularly rigid. No signs of abscess. Reflexes normal.

Rtg. ex. May 27th, 1931.—Lateral view: Distal surface of the body of L II destroyed. In the proximal dorsal part of the body of L III there is a large, rounded, destructive lesion with sequestrum. Vertebral remnants collapsed, sclerotic. Antero-posterior view: Destruction in the right parts of L II—III, vertebrae collapsed. Right psoas bulging.

Correction was carried out in plaster bed.—The gibbus disappeared in two months. Skilagrams show a narrow gap between the vertebral remnants of L II and L III.

Aug. 13th, 1931. Albee op. (Og-Jn).—A straight tibial graft was placed edgewise into the spinous processes of D XII—L IV. The bone graft was sutured under slight tension.—Healing by first intention. *Feb. 25th, 1932.* Patient free from symptoms, operative field in good condition. Skilagrams show destruction and position unaltered. To the right of the midline a straight graft, united in the spinous processes of D XII—L III (?IV).—Patient discharged with leather corset.

The patient was free from symptoms until Aug. 1932. Then, one day, while she was bending down to pick berries, she felt something »click« in her back, and since then she had a tender spot in the upper part of the operative field.

Rtg. ex. Aug. 18th, 1932 (Ellwyn).—Lateral view: destruction unaltered. The remnants of L II—III have fallen together again. The intervertebral space L I—II is of the same height. On a level with the distal part of the intervertebral joints L I—II, above the spinous process of L II, a defect, fully 2 mm. broad, appears through the graft, the fragments of which form a slight angle, open ventrally. Antero-posterior view: large deposits around the graft. Above the spinous process of L II there is a defect, 3 mm. broad, transversely through the graft and deposits.—On *after-examination Feb. 1st, 1933 (Ellwyn)* the patient was free from symptoms; over the graft defect there was a small non-tender swelling. Skilagrams show unaltered position; the lesion fairly well

localised. Slight periosteal new-bone formation around the graft defect.—Skiagrams of Oct. 7th, 1933, show no changes in the spondylitic process, no certain bony union between the vertebral remnants. The graft shows a broad defect with slight deposits, its distal part is without contact with the spinous process of L IV.

By April, 1934, the patient was free from clinical symptoms and able to work.

Commentary.—At the commencement of treatment, the lesion involved the distal part of the body of L II and the proximal part of the body of L III; the vertebral remnants were collapsed. At the time of operation the vertebral remnants had been forced apart by the correction. A bone graft was inserted into the spinous processes of D XII—L IV.—Twelve months after the operation the remnants of L II—III had again fallen together. The intervertebral space L I—II was unaltered. A graft defect appeared on a level with the distal part of the intervertebral joints L I—II, with a small angle, ventrally open, between the fragments. The defect had arisen in connection with the new inflexion movement between the remnants of L II—III, and is located above the inflexion axis. The defect shows only slight tendency to repair.

CASE 25. K. E. E. P., male, born 1923.—Has had trouble with his back since August 1924, and has been treated for spondylitis since August 1925. Admitted to C. S. A. on Aug. 3rd, 1926.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—In the dorso-lumbar region there is a moderate, flattened, not tender gibbus. No abscess. *Rtg. ex. Jan. 17th, 1927.*—Extensive destructions in the vertebral bodies of L II—III; the body of L I shows a mottled structure and an excavated anterior contour. L I—III collapsed, gibbus about 150°. Calcified psoas abscesses on both sides.

The patient was treated in supine position on a hard mattress; from the beginning of 1928 with correction in plaster bed. Skiagrams from March, 1928, show reduction of the gibbus and better localisation of the lesions. In Oct., 1928, the gibbus had diminished still further.

Oct. 15th, 1928, Albee op. (Og-Jn).—A straight tibial bone-graft was inserted edgewise into the spinous processes of L I—V. Healing by first intention. After two months the patient was out of bed, wearing a plaster corset.—*Rtg. ex. April 11th, 1929.*—Lateral view: the lesion unaltered; the lordosis below the spondylitic process has diminished. Position otherwise unaltered. Bone graft within the spinous processes of L I—V. At the level of the intervertebral joints L I—II, below the spinous process of L I, there is a defect in the graft, and at the level of the intervertebral joints L IV—V, below the spinous process of L IV, another graft defect. —Antero-posterior view: narrow graft, with large deposits, in the spinous processes L I—V. Immediately below the spinous process of L I there

is an irregular rarefaction right through the graft and deposits, and between the spinous processes of L IV—V a similar rarefaction. Spondylitic process unaltered. Patient was discharged with a corset, free from symptoms.

On after-examination in *May, 1930*, the patient was in good health, mobile in his back above and below the operative field, and was allowed to lay off the corset.—*After-examination Aug. 8th, 1932 (Klason)*: Patient free from symptoms.—*Rtg. ex. lateral view*.—Block formation of remnants of L II—III, which show sharply defined outlines. L I irregular, bone structure clear, contours sharply defined. Powerful bone bridge in the spinous processes L I—IV, the spinous process of L V irregular. Between the spinous processes of L IV—V there is a bone defect 5 mm. broad, the intervertebral joints L IV—V show clear interarticular spaces. Antero-posterior view: broad bone bridge in the spinous processes L I—IV. Large exostosis on the right side of the spinous process of L V.

Commentary.—At the beginning of treatment (C. S. A.) the lesion involved the anterior part of the body of L I and the greater portion of the body of L II—III. After corrective treatment for three years a bone-graft was inserted into the spinous processes of L I—V. The inflexion did not change appreciably after the operation, there was some diminution of the lordosis below the spondylitic process. Four months after the operation a defect appeared in the graft at the level of the undamaged intervertebral junction L I—II, and another at the level of the intact intervertebral junction L IV—V.—Four years after the operation the proximal defect had consolidated; at the site of the distal defect a broad pseudarthrosis had developed.—Both defects are in this case located on a level with undamaged intervertebral junctions; the inflexion has not altered since the operation.

CASE 26. M. F. E., female, born 1923.—Has had symptoms of spondylitis since January 1928; was admitted to C. S. A. Dec. 20th, 1928.

Condition on adm.—General condition impaired, patient somewhat pale and thin. Internal organs normal. *Rtg. ex. lungs*.—Calcified primary complex. *Spine*.—Patient keeps the whole spine rigid, walks unsteadily. A moderate, fairly firm gibbus, tender on percussion, in the lumbar region. No abscess. Reflexes normal. *Rtg. ex. Dec. 18th, 1928*.—Lateral view: the greater part of the bodies of L II—III are destroyed, the distal contour of L I ragged, the proximal contour of L IV blurred. Anterior distal border and distal contour of S I blurred and irregular, S I is ventrally protruding beyond S II.—Antero-posterior view: LI—IV collapsed.

Patient was corrected in plaster bed, the gibbus slowly diminished in size. Skiagrams show slightly increased destruction of L I, which on April 10th, 1931, showed good localisation.

July 23rd, 1931. Albee op. (Og-Jn.).—A somewhat bent tibial graft including the crest was inserted edgewise into the spinous processes of D XII—L V (crest dorsally). Slight tension of the end sutures. Healing by first intention. After two months the patient was out of bed, wearing a plaster corset.

Rtg. ex. Feb. 23rd, 1932.—Lateral view: position and lesion unaltered. Within the spinous processes D XII—L V a bone-graft; spinous processes L IV—V largely fused. Antero-posterior view: Narrow graft in the spinous processes, surrounded by large deposits. Bone structure between spinous processes L III—IV irregular.

As the patient was suspected of having sacral spondylitis she was again put in plaster bed. *Rtg. ex. May 11th, 1932.*—Unaltered destruction and position. In the graft there is a broad defect with a small angle, open ventrally; between the graft fragments. The defect is located on a level with the distal part of the intervertebral joints L III—IV, between the spinous processes of those vertebrae. On the dorsal and lateral aspects of the defect there are periosteal deposits.—*Sept. 20th, 1932.*—New plaster corset, patient free from symptoms.—*Jan. 26th, 1933.*—General condition good. Patient free from symptoms, her walk unhampered. Operative field firm and not tender. Over the defect there is a hard bony swelling, not tender. No crepitation or false mobility there.

Rtg. ex., lateral view.—L I—III show unaltered position, lesions better localised, bone structure clear. The proximal contour of L IV is sharply defined, with new-formed epiphysis. The defect in the graft is partly filled up with dense bone shadows. Evidence of spongy structure throughout, can not be observed, however. Coherent deposits over the dorsal aspect of the defect. No displacement between the fragments observed on movements of the back. Antero-posterior view: Spondylitic process unchanged. Large deposits around the spinous processes L III—IV. The defect through the graft and the deposits on its right side can still be seen. Patient was discharged with leather corset, free from symptoms. *Feb. 23rd, 1934.*—After-examination (v. Rosen): General condition good. Patient small and thin, but in good health and free from symptoms. Skiagram shows better localisation of the lesions. Position unaltered, vertebral epiphyses have grown still further. The graft defect is filled up with bone without any definite spongy structure; intervertebral joints L III—IV do not appear.

Commentary.—At the beginning of treatment the lesion involved almost the entire bodies of L II—III, besides parts of the bodies of L I and IV. S I—II show irregular contours (?spondylitis). In the course of treatment the lesions became localised. At the operation a bone graft was inserted into the spinous processes of D XII—L V. Ten months after the operation the relative position of the vertebrae had undergone no visible change. On a level with the distal part of the intervertebral

joints L III—IV a broad graft defect was discovered, the fragments of which formed a moderately-sized angle, open ventrally. The defect was surrounded by deposits.—Two years 7 months after the operation the repair of the defect was far advanced.—The inflexion has not undergone any changes after the operation. The graft defect is situated in the narrow space between the spinous processes of L III and L IV, on the distal aspect of the apparently undamaged intervertebral disc L III—IV.

CASE 27. E. E. O. N., female, born 1921.—The patient has had a gibbus of the lower lumbar region since 1924—1925. Admitted to C. S. A. Feb. 11th, 1927.

Condition on adm.—General condition fairly good. Short, thin and pale. Internal organs normal. *Spine.*—Large gibbus, tender to pressure, in the lumbar region; the whole back kept rigid, pains on attempting to move. Abscess in the left iliac fossa.

Rtg. ex. Feb. 17th, 1927.—Lesions involve the distal part of the body of L II, nearly the whole of those of L III—V, and the proximal surface of the body of S I. The remnants of the vertebral bodies are collapsed. Large rounded gibbus.

The patient was treated in supine position on a hard mattress; from 1928, inclusive, correction was carried out in plaster bed. The hump diminished and disappeared almost completely. Skiagrams show no increase of the destruction. There is bony fusion between the peduncles and articular processes of L III—V.

July 2nd, 1929: Albee op. (RH).—A broad, straight tibial graft including the crest was inserted edgewise into the spinous processes of L I-sacrum, (the processes being split all the way to the sacral canal). After the operation there was necrosis of the skin-flap; part of the graft separated. About 2½ months after the operation the patient was out of bed wearing a plaster corset.—*Rtg. ex. Dec. 13th, 1929.*—Lateral view: Destruction and position unaltered. Bone graft within the spinous processes of L II-sacrum. Antero-posterior view: Position unaltered. In the spinous process of L I a small remnant of the graft. Narrow bone graft with deposits in the spinous processes of L II-sacrum.

In January, 1930, the patient was free from symptoms; returned home with leather corset.—*After-examination Jan. 26th, 1931.*—Operative field in good condition. Free from symptoms. *Rtg. ex.*—Lateral view: Destruction the same. The remnant of L II has fallen down against those of L III—IV. The intervertebral joints L II—III show maintained joint spaces. In the spinous processes of L I—II a coherent bone bridge. Level with the intervertebral joints of L II—III, just below the spinous process of L II there is an irregular defect, 5 mm. broad, transversely through the graft, covered dorsally by a thin deposit. In the spinous process of L III

—V (? S I) a powerful bone bridge. Antero-posterior view: Graft partly rebuilt, its lowermost part 1 cm. broad. On the distal side of the spinous process of L II is seen an indistinct transverse rarefaction.

After-examination May 11th, 1932.—General condition good. Thorax flat, costal arch reaching down to iliac crest. Patient has grown considerably.—Of the thoracic kyphosis there is a little left in the cervico-thoracic region. The back is otherwise quite straight, yet with indication of lordosis from the uppermost dorsal region down to the operative field, quite mobile down to the spinous process of L I. The operative field is firm and non-tender, in its middle can be felt a broad plate of bone without break or false mobility. The whole operative area forms a small flat kyphosis. The pelvic tilt is normal, patients walks unhampered.

Rtg. ex. lateral view: Destruction and position unaltered since Jan, 1931. Vertebral bodies have grown. Fusion of arches of L III—V. In the spinous process of L I—V there is a light dorso-convex coherent bone bridge unconnected with the sacrum. The narrow bone bridge between the spinous processes of L I—II shows a blurred bone structure. The defect between the spinous processes of L II—III is filled up with dense bone shadows and covered dorsally by a dense coherent deposit. Antero-posterior view: Bone bridge, distally 12 mm. broad, in the spinous process of L I-sacrum.—*Rtg. ex. Feb. 14th, 1934.*—Destruction and position unaltered, both graft defects consolidated.—Patient is without corset, in good health and free from symptoms. (Hall).

Commentary.—The lesion involved the greater portion of the bodies of L III—V besides part of those of L II and L IV. A bone graft was applied in the spinous processes of L I-sacrum. Within five months of the operation a defect appeared in the graft, at the level of the intervertebral joints L I—II. The inflexion between the remnants of L II and L III gradually increased. Eightteen months after the operation, the proximal graft defect had consolidated. Instead, a new defect appeared at the level of the undamaged intervertebral joints L II—III.—Four years seven months after the operation both defects had consolidated.

The proximal defect is situated on a level with an undamaged intervertebral junction, the distal one at the level of the axis of an inflexion movement between L II—III, the intervertebral joints of which seem to be intact in spite of the vertebral destruction.

CASE 28. L. E. G., male, born 1921.—The patient has had symptoms from his back since Christmas 1923. Since 1924 he has been under treatment for lumbar spondylitis. Admitted to C. S. A. May 31st, 1924.

Condition on adm.—Large but only slightly tender gibbus in the lumbar region, sinus at the right iliac crest.—*Rtg. ex.*—Lateral view: Bodies of L III—IV largely absorbed, distal contour of L II and proximal contour

of L V torn, irregular and blurred. Large gibbus within the area of L II—V. Antero-posterior view: L II—V collapsed.

In Aug., 1926, the patient was discharged in good general condition. the sinus was healed, skiagrams showed a clearer spongy structure, and a better localisation of the affected part. Gibbus somewhat reduced.—Was readmitted to C. S. A. April 28th, 1930.—General condition good. Internal organs normal. *Spine*.—In the lumbar region a nontender gibbus yielding to pressure, corresponding to L III—IV. Above the right iliac crest a sinus cicatrix. No signs of abscess, reflexes normal. *Rtg. ex. April 30th, 1930*.—Lateral view: Considerable growth of vertebrae. L II and L V show irregular forms and bone structure, outlines fairly sharp. The slight remnants of L III—IV have fused, L II has fallen down against the remnant of L III. The intervertebral space L IV—V is high. Moderate gibbus. Antero-posterior view: Bodies of L II—IV collapsed.

The gibbus was rapidly reduced by correction in plaster bed. Skiagrams show unaltered inflexion, gibbus much reduced by paragibbous lordosation.

June 6th, 1930: Albee op. (Og.-Jn.).—A straight tibial graft was placed edgewise in the spinous processes of L I—V. Healing by first intention. After two months patient was out of bed with plaster corset.—Nov. 18th, 1930: general condition good, free from symptoms. Bursa over the upper end of the graft.—*Rtg. ex.*—Lateral view: Position in the main unaltered since April 30th, destruction not increased. Straight graft within the spinous processes of L I—V. At the level of the intervertebral joints L I—II, immediately below the spinous process of L I, there is a blurred rarefaction through the graft, surrounded by thin deposits. Antero-posterior view: Position and destruction unaltered. In the spinous process of L I—IV and to the right of L V but unconnected with the latter a bone-graft surrounded by deposits. Immediately below the spinous process of L I an irregular, sharply defined defect through the graft and deposits. The intervertebral joints L I—II show, on the skiagrams, the intervertebral spaces maintained.—Patient discharged home free from symptoms, with leather corset.

After-examination Oct. 25th, 1932.—General condition good; the patient is free from symptoms, and has not been wearing any corset for the last six months.—Back straight, at the top part of the dorsal region a slight kyphosis. Regular lordosis D VII-sacrum. Good mobility above and below operative field, which is firm and not tender, rigid within area L II—IV. There is evident mobility between spinous processes L I—II.

Rtg. ex.—Lateral view: No further destruction since Nov. 18th, 1930; position unaltered, bone structure clearer. The remnants of L II—IV are lying close together (? block). In the spinous processes of L II—IV a powerful bone bridge, intervertebral joints not apparent. Between the

spinous process of L I and the proximal apex of the bone bridge there is an irregular space, 1 cm. broad; its breadth varies on flexion and extension of the back. Antero-posterior view: Position and destruction unaltered. In the right part of the spinous processes of L II—IV and to the right of the spinous process of L V there is a powerful bone bridge, separated from the spinous process of L I by a broad gap.

Commentary.—The patient had been treated for lumbar spondylitis for 6½ years prior to the operation. At the time of the latter, the lesions involved the distal part of the body of L II and the greater part of the bodies of L III and L IV. The large gibbus was obliterated by correction; inflexion was unaltered. A bone graft was inserted into the spinous processes of L I—V. Five months after the operation the lesion had undergone no changes whatever, and the position was not visibly affected. At the level of the undamaged intervertebral joints L I—II a graft defect had arisen, the graft had lost its attachment to the spinous process of L V. Two years and four months after the operation a mobile pseudarthrosis developed at the site of the defect. The inflexion has not altered since the operation, the graft defect is located on a level with the undamaged intervertebral junction L I—II.

CASE 29. S. K. S., female, born 1904.—The patient had pleurisy in 1926, lumbago in 1927, and was admitted to C. S. A. on May 22nd, 1929 for lumbar spondylitis.

Condition on adm.—General condition good. Dullness and impaired breadth-sounds over the right base. Internal organs otherwise normal. The tendovaginitis of the flexor sheath of the right hand. *Spine.*—Lumbar lordosis diminished, the whole lumbar region rigid, no gibbus. Elongated swelling of the right psoas.—*Rtg. ex. May 24th, 1929.*—Lesions in opposing parts of the bodies of L III—IV, remnants collapsed, with an angle open towards the left.

Patient was corrected in plaster bed, the lordosis appeared as soon as the contracture of the lumbar muscles had subsided.—*July 5th, 1929.* Flexor sheath of right hand removed.

Aug. 30th, 1929; Albee op. (RH).—A straight tibial graft was placed edgewise into the spinous processes of L II—V, without tension.—Healing by first intention. Subsequent course uneventful.—*Aug. 26th, 1930:* General condition good. No symptoms from back and hand. Operative field in good condition. Skiagrams show unaltered position and destruction. To the right of the midline there is a graft in the spinous processes of L II—V. Discharged home with corset.

Patient discharged her corset October 30th, and felt quite well until July, 1931, when she without known cause developed pains in the upper part of the operative field.—*July 24th, 1931:* Just above the middle of the graft there is distinct tenderness and crepitation on pressure.

Back otherwise in good order. Skiagrams show a narrow, irregular, line of rarefaction through the graft, on a level with the intervertebral joints L II—III, between the spinous processes of L II—III.—In a short time the symptoms disappeared entirely. At the end of Aug., 1931, the defect in the graft appeared as a defect 2 mm. broad between the spinous processes of L II—III.

After-examination Sept. 29th, 1932.—No trouble in the back. Lumbar region straight and not tender, its lower part firmly rigid. On movements of the back, a clear displacement can be felt between the spinous processes L II—III.

Rtg. ex. Aug. 6th, 1932.—Lateral view: Between the spinous processes of L II—III there is a defect 12 mm. broad, which sharp outlines. On the dorsal aspect of the distal fragment there is a small deposit. Position unaltered, bony union between the bodies of L III—IV. Antero-posterior view: Powerful bone bridge to the left of the midline in the spinous processes of L III—V, extending into a point proximally to the left. Between the spinous processes of L II—III there is a broad, regular defect; in the left area of the spinous process of L II there is a broad remnant of the graft.

Commentary.—At the time of the operation the lesion involved the distal part of the body of L III and the proximal part of the body of L IV; the remnants collapsed. A bone graft was inserted into the spinous processes of L II—V. Two years after the operation a defect arose in the graft, without any known cause, on a level with the undamaged intervertebral junction L II—III; the position has not altered since the operation. Three years after the operation there is bony union between the remnants of L III—IV. At the seat of the graft defect there is now a gap, 12 mm. broad, surrounded by exceedingly slight deposits. There is normal mobility between L II and L III.

CASE 30. O. V. J., male, born 1902.—The patient has been under treatment for lumbar spondylitis since Feb. 1926; he was admitted to C. S. A. on April 14th, 1927.

Condition on adm.—General condition affected, the patient is thin and pale. Internal organs normal. *Spine.*—Small tender gibbus in the lumbar region. In both iliac fossae tense swellings. Tendon reflexes exaggerated, Babinsky negative.

Rtg. ex. April 19th, 1927.—Deep destruction of the opposite parts of the bodies of L III—IV; remnants collapsed.

At first, the patient was kept on his back with a sandbag under the hump; afterwards, correction in plaster bed. The abscesses were punctured. His general condition improved. Skiagrams show no marked changes.

Feb. 21st, 1928. Albee op. (RH).—A tibial graft, 12 cm. long, was inserted, with the periosteum directed dorsally, into the spinous processes

of L I—IV (? V).—Healing by first intention. Subsequent course normal. In July, 1928, the patient was discharged, free from symptoms, with leather corset.

After-examination, July 23rd, 1929.—General condition very good. Round regular kyphosis in the thoracic region, which cannot be fully extended. Operative field not tender. Over the middle of the graft a small, slightly tender swelling can be felt. On movements a dislocation can be felt between the fragments of the graft. No pains on movements; no abscess.

Rtg. ex.—Lateral view: Destruction and position unaltered, well localised. In the spinous processes of L I—IV there is a bone bridge which at the level of the intervertebral joints L II—III shows a 2 mm. broad, sharply outlined defect, without any recent deposits. Antero-posterior view: Position unaltered. Bone bridge to the left of the midline, united with the spinous processes L I—IV. Above the spinous process of L III there is an oblique defect, 2 mm. broad, without any considerable surrounding deposits.

Commentary.—At the time of operation the lesion involved large parts of the bodies of L III—IV. A bone-graft was inserted into the spinous processes L I—IV. The inflexion did not change after the operation. Seventeen months after the operation a mobile pseudarthrosis has developed on a level with the intervertebral connection L II—III.

CASE 31. A. K. O., female, born 1923.—Back symptoms since April 1927, admitted to C. S. A. May 24th, 1928, for lumbar spondylitis.

Condition on adm.—General condition fairly good. Internal organs normal. *Spine.*—Small gibbus at the site of L III. The whole back is carried rigidly, the patient can only sit with difficulty without support. No abscess, reflexes normal.—*Rtg. ex. May 26th, 1928.*—Extensive destructions in the opposite parts of bodies of L III—IV, remnants collapsed. Abscess shadow, the size of a walnut, and rich in lime salts, on the left side of the lesion.

Correction was carried out in plaster bed; the gibbus disappeared rapidly, the inflexion did not change.

Sept. 28th, 1928, Albee op. (Og-Jn).—A straight tibial graft with periosteum directed dorsally was inserted into the spinous processes D XII—L V. Healing by first intention. In December, 1928, whooping cough.

Rtg. ex. April 15th, 1929.—Lateral view: Absorption from remnants of L III—IV has increased, the body of L II has fallen down against the remnants of L III. The graft in the spinous processes of D XII—L IV seems to have lost its attachment to L V. At the level of the intervertebral joints L II—III, immediately below the spinous process of L II, a 5 mm. broad defect is seen through the graft, the fragments of which form an

angle, open ventrally.—At the seat of the defect is felt a tender bony enlargement.—Patient was put back in plaster bed. As the defect showed no tendency to heal, re-operation was decided upon.

Aug. 16th, 1929, op. (RH).—A graft from the right tibia was placed in a groove, made in the left border of the old graft and into the spinous processes of L I—S I. On the dorsal aspect of the defect a small extra graft was inserted subperiosteally. Healing by first intention.—*March 7th, 1930:* General condition good. Patient free from symptoms, operative field in good condition. Skiagrams show some increase of the destruction in L III—IV. In the spinous process of D XII—L V there is a straight bone bridge, surrounded by deposits; its attachment to the sacrum is doubtful.—Returned home wearing corset, which was discarded in March, 1931.

In May, 1931, the patient got pains in her back and became «crooked-backed». *July 8th, 1931.*—General condition affected. Arc-shaped flat kyphosis, not tender, including the whole lumbar region, the distal part of the graft protruding. No tenderness. *Rtg. ex.*—Lateral view: Bodies of L III—IV almost entirely absorbed. Proximal contour of L V blurred and ragged. In the posterior lower part of the body of L II and the lower parts of its peduncles there is a deep defect with ragged outlines. Indistinct bone structure in the posterior lower part of the body of L I. The bony bridge in the spinous processes is intact and bent, lacks attachment to L V—S I. Antero-posterior view: Lumbar scoliosis with convexity towards the right. Both grafts united. The left lateral psoas outline is convex.

The patient was again put in plaster bed in July 1931. She improved fairly rapidly, the sideways malposition disappeared. In the left psoas a large abscess was evacuated by puncture in March—April, 1932.

April 4th, 1933.—General condition good. Slight kyphosis in lumbar section. In the midline can be felt a broad bony bridge, terminating distally in a point which can be displaced towards the sacrum. The patient has some difficulty in raising herself from a stooping position without support. Mobility normal immediately above the bony bridge. The whole thoracic region is hyperextended, with a slight kyphosis in the upper part. No abscess.—Skiagrams show the lesions to be fairly well localised. In the spinous processes of D XII—L IV a dorsally convex bony bridge had fused, extending down over the sacrum, without attachment to the spinous process of L V and sacrum. Discharged home with leather corset. On after-examination on Sept. 18th, 1933, no changes were observed.

Commentary.—At the beginning of treatment the destruction involved the distal surface of the body of L III and the proximal surface of the body of L IV. The slight hump disappeared on correction, inflexion remained. A bone graft was inserted into the spinous processes of D XII—L V.—Seven months after the Albee operation the destruction in L III

—IV had increased, the remnants had collapsed still further, L II had fallen down against the remnant of L III. At the level of the intervertebral joints L II—III a graft defect appeared, the fragments of which formed an angle, open ventrally. The tendency to healing of the defect was slight. Eleven months after the Albee operation a new graft was inserted, parallel with the old one, into the spinous process of L I—sacrum. The graft defect consolidated, and the patient remained free from symptoms for a long time.—Three years after the Albee operation new lesions were found in the posterior lower part of the bodies of L I and L II and the proximal part of the body of L V. The lumbar region collapsed, the graft, which was lacking attachment to the spinous process of L V and sacrum, formed a dorso-convex arc over the spondylitic area.—Four and a half years after the Albee operation the lesions seemed to be localised, and the patient was free from symptoms.—In this case the graft defect arose in connection with an inflexion movement after the operation within the area L II—IV, on a level with an inflexion axis through the intervertebral joints L II—III.

CASE 32. M. K. M., female, born 1917.—Symptoms of spondylitis since the spring 1929; admitted to C. S. A. April 4th, 1930, for lumbar spondylitis.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—In the middle of the lumbar region there is a small kyphoscoliosis, convex towards the right, yielding to pressure, and slightly tender on percussion. No abscess; reflexes normal.

Rtg. ex. April 17th, 1930.—Lateral view: Extensive destruction in the proximal part of the body of L IV; the distal outline of the body of L III is not quite sharply defined. The body of L III has fallen down into the defect in the upper part of L IV. Antero-posterior view: Destruction in the upper and left part of L IV, L III descended into the defect, causing an angle open towards the left. The lesion is fairly well localised.

Correction was carried out in plaster bed. The hump diminished, as well as the scoliosis. Skiagrams show no definite change of the position of the vertebrae.

July 11th, 1930, Albee op. (RH).—A straight tibial graft was placed edgewise into the spinous processes of L II—S I. Healing by first intention. After two months patient was allowed to get up in plaster corset.—*Dec. 3rd, 1930:* operative field firm and not tender; at the level of the spinous process of L IV there is a small gibbus. The whole lumbar and the distal part of the thoracic region are kept rigid. *Rtg. ex.*—Lateral view: Destruction and position not appreciably altered. The spinous processes of L II—S II enclose a powerful bone graft. On a level with the intervertebral joints L II—III, immediately below the spinous process of L II, is seen an irregular rarefied line through the graft. On a level

with the intervertebral joints L IV—V, in the distal part of the spinous process of L IV, is a defect passing obliquely through the graft. Antero-posterior view: angulation is somewhat less prominent, than on April 17th, 1930; destruction unaltered. A narrow graft surrounded by deposits is enclosed within the spinous processes of L II—S II. Below the spinous process of L II there is an irregular line of rarefaction through the graft and deposits. At the level of the spinous process of L IV, indication of a similar rarefaction. There is a slight angle, open towards the right, between the 14 mm. long fragment in the spinous process of L II and the 39 mm. long fragment in the spinous processes of L III—IV, as also between the latter and the distal, 60 mm. long fragment. Patient free from symptoms, operative field not tender. Discharged home with leather corset.—*After-examination Jan. 27th, 1933:* Patient in good health since her discharge; she has been without the corset since the spring of 1932, has been to school and taken part in the activities of daily life at home. General condition good. She has grown considerably. *Spine.*—Large flat »lumbar lordosis« from the height of D VIII to the sacrum; good mobility above operative field. The bony bridge in the spinous processes is firm, not tender; there is a slight bony enlargement over its centre. On flexion of the spine a small depression is formed immediately above this enlargement. *Rt. Feb. 2nd, 1933, lateral view.*—Destruction in the body of L IV well localised, L III descended into the defect. No definite block formation. Intervertebral space L IV—V high. In the spinous processes L II—S II there is a coarse bony bridge of spongy structure. The proximal graft defect is consolidated, its site is marked by a large irregular exostosis on the ventral part of the bony bridge. At the seat of the distal defect there is now seen a defect, several millimetres broad, through the graft; on flexion of the back this defect becomes broader still. There is no bony union between the graft and the spinous process of L V. The intervertebral joints L IV—V show well-maintained joint spaces. On flexion and extension of the back a displacement of the graft fragments can be observed, especially when the patient is lying on her side.—Antero-posterior view: the left proximal third of L IV is absorbed, L III is descended into the defect. Angle of 165° is open towards the left. Massive bony bridge in the spinous processes of L II—S II. Below the spinous process of L IV there is an indistinct transverse rarefaction; below this the bony bridge measures 18 mm. in breadth.

Commentary.—During the whole period of observation the lesion involved the left proximal part of the body of L IV and portions of the distal surface of L III; at the time of operation the bodies were collapsed; their position did not alter appreciably under correction (as evidenced by skiagrams). A bone graft was inserted into the spinous processes of L II—S II. Five months after the operation the position remained the same. The graft showed a defect on a level with the in-

tervertebral joints L II—III and another on a level with the intervertebral joints L IV—V.—Two years and ten months after the operation the proximal defect had consolidated; at the site of the distal defect a mobile pseudarthrosis had developed enabling movements to take place between L IV and L V; possibly also between L V and S I. Patient is free from symptoms.

The inflexion has not altered since the operation. The defects are located at the level respectively of the undamaged intervertebral junctions L II—III and of L IV—V.

CASE 33. B. G. P., male, born 1921.—The patient has had symptoms of spondylitis since May, 1927, and was admitted to C. S. A. on Dec. 2nd, 1927.

Condition on adm.—Thin and pale. Internal organs normal. *Spine.*—In the middle and upper lumbar region a rounded hump, not tender. No abscess. Reflexes normal.

Rtg. ex. Jan. 5th, 1928.—Extensive destructions in the opposite parts of the bodies of L III—IV; remnants collapsed, no block formation. Small gibbus. Abscess in the right psoas.

Correction was carried out in plaster bed; the gibbus completely disappeared. Skiagrams show unchanged lesions, localisation and bone structure better defined.

Oct. 5th, 1928, Albee op. (Og-Ju).—A straight tibial graft was placed edgewise into the spinous processes L I—V.—Healing by first intention. After about 2 months the patient was fitted with a plaster corset and allowed to get up.—*March 15th, 1929:* Back straight, general condition good, no symptoms.*Rtg. March 6th, 1929.*—Lateral view: Destruction and position unaltered. Graft enclosed in the spinous processes of L I—IV, separated by a rarefaction, 4 mm. broad, from that of L V, in which small graft remnants are observed. Antero-posterior view: narrow graft surrounded by deposits in the spinous processes L I—V. Immediately above the spinous process L V is seen an irregular rarefaction through the graft and deposits.—Returned home with leather corset.

After-examination, Sept. 19th, 1932.—Back straight, patient free from symptoms, has been without corset for the past twelve months. Good mobility above and below the operative field, probably between the spinous processes L IV—V. *Rtg. lateral view.*—Block formation with spongy bone structure throughout between the bodies of L III and L IV. Firm bony bridge in the spinous processes of L I—IV. At the level of the intervertebral joints L IV—V is a 2 mm. broad, irregular defect. Antero-posterior view: L III—IV form a block. Other vertebrae and intervertebral spaces normal. The graft forms a broad bridge between the spinous processes L I—IV, separated from the V spinous proc. by a defect 2 mm. broad.

Commentary.—The lesion involved portions of the bodies of L III—IV.

A bone-graft was inserted into the spinous processes L I—V. Five months after the operation the position remained unaltered. On a level with the intervertebral joints L IV—V the graft showed a defect; at the seat of this a mobile pseudarthrosis developed.

The inflexion has not changed since the operation; the graft defect is located on a level with the undamaged intervertebral junction L IV—V.

CASE 34. K. Y. L., male, born 1907.—The patient was taken ill with backache during military service in 1928, and was admitted to C. S. A. May 8th, 1929.

Condition on adm.—General condition good. Internal organs normal. *Spine.*—Spinous processes of the middle lumbar vertebrae somewhat prominent, no gibbus. Lumbar region rigid, lordosis straightened out. Otherwise good mobility in the back. Pain on jarring the spine; no tenderness. Swelling in the right iliac fossa. Reflexes normal.

Rtg. May 11th, 1929.—Lateral view: Distal outline of body of L IV blurred and irregular. The proximal two-thirds of the body of L V destroyed and partly absorbed. L IV—V fallen together. Intervertebral spaces L III—IV and L V—S I abnormally broad. Basal surface of L V nearly horizontal. Antero-posterior view: extensive lesion in the upper left part of L V; L IV descended into the defect. The intervertebral space L V—S I appears on an ordinary antero-posterior picture (with the central ray at right angles to the long axis of the body).

Correction was carried out in plaster bed, the abscess was evacuated by puncture. Skiagrams show that L IV and L V have become separated. Destruction not aggravated.

Feb. 12th, 1930. Albee op. (RH).—A bent tibial graft was placed edge-wise into the spinous processes L III—S II with the periosteum directed towards the left.—Healing by first intention. After 2 months the patient was out of bed wearing a corset. Swelling remained in right iliac fossa.—*July 7th, 1930:* Patient free from symptoms, operative field in good condition. *Rtg.* lateral view.—Increased absorption from the remnant of L V and from the basal surface of L IV. L IV and L V have again collapsed. In the spinous processes of L III—S II there is a powerful graft, a rarefaction separating it from the spinous process L III.—Antero-posterior view: graft to the left of the midline surrounded by deposits. Patient returned home with leather corset. Free from symptoms until Feb. 1931, when he, without any known cause, got a sensation of pressure and swelling right in the middle of the operative field. On examination an enlargement was felt there.—*Rtg.* April 20th, 1931.—Lateral view: destruction in L IV—V still further increased, vertebral remnants still more collapsed. The remnant of L IV shows unaltered position in relation to the bone graft; the same is the case with the spinous process of L V. L III has united with the graft. The remnant of the body of L V has

approached the remnant of L IV, and has at the same time changed its position in relation to its own spinous process and to the graft. (This change can have taken place only as the result of some alteration of form, probably in connection with some bone defect of the vertebral arch between the spinous process of L V and its body). Below the intervertebral joints L V—S I, in the distal contour of the spinous process of L V, there is a sharply outlined, gaping crack-like defect, dorsally 2 mm. broad, through the graft. The proximal fragment protrudes dorsally beyond the distal fragment. Antero-posterior view: a transverse rarefaction below the spinous process of L V.

On examination on Aug. 12th, 1931, the patient was unable to bend forward and downwards without support; no tenderness of the back. Skiagrams show progressive absorption of the remnants of L IV—V, which have fallen together still more. The graft defect is now 15 mm. broad, and the proximal fragment still more protruding. There are deposits on the ventral aspect of the defect. The patient had been without corset since 1931. In the spring of 1933 he again developed severe pains in the back and right leg, and was readmitted to C. S. A. *On Rtg. ex. June 20th, 1933*, the remnants of the bodies of L IV—V formed a wedge. At the seat of the graft defect a mobile pseudarthrosis had developed. Around the pseudarthrosis, especially laterally and ventrally, there are massive deposits.—The patient's symptoms persisting reoperation was decided upon with a view to fixing L V to the sacrum.

Aug. 17th, 1933, op. (RH).—The spinous processes L V—S II were exposed. The periosteum was detached, together with a superficial bony shell from the right area of the spinous processes and arches. A broad tibial graft with the periosteum towards the left was fixed subperiosteally in the bed. *Rtg.* Oct. 25th, 1933, shows position and destruction unaltered. To the right of the midline and the old graft there is a powerful graft lying level with the spinous processes of L V—S II. The gap of the pseudarthrosis is somewhat narrower, and seems to be covered on the left side by deposits. (Antero-posterior view). Patient was free from symptoms, and was discharged home with corset. (Fig. 13, 14).

Commentary.—At the beginning of treatment the lesion involved the left proximal part of the body of L V; L IV—V were collapsed, the intervertebral space obliterated. At the operation the remnants of L IV—V were forced apart by the correction, causing the intervertebral space to be of normal height. A bone graft was inserted into the spinous processes L III—S II. After the operation the destruction was progressive in L V and the distal part of L IV, the remnants of L IV—V collapsed.—Fourteen months after the operation the remnant of the vertebral body of L V had approached that of L IV, though the spinous process of the former showed no displacement in relation to the spinous process of L IV

and the bone graft. For a displacement of that nature to take place a change of form must have occurred, probably owing to some bone defect of the arch between the spinous process and body of L V. Below the intervertebral joints L V—S I, on the distal side of the spinous process of L V, a sharply outlined defect is seen through the bone graft. Absorption and collapse of the remnants of L IV—V continued.—Three years and four months after the Albee operation the vertebral remnants of L IV—V formed a wedge. At the seat of the graft defect a mobile pseudarthrosis developed, surrounded by deposits.—Three years and six months after the Albee operation a new bone graft was inserted against the lateral part of the arches of L V—S II, parallel with the old graft. Three years and eight months after the Albee operation the operation wound had healed and the patient was up and about, wearing a corset and free from symptoms.

CASE 35. S. E. R., female, born 1911.—Back trouble since 1925. Since the summer of 1926, the patient had been in bed for lumbar spondylitis. Admitted to C. S. A. March 4th, 1927.

Condition on adm.—General condition fairly good. Internal organs normal. *Spine.*—Gibbus including several lumbar vertebrae, unyielding to pressure, not tender to percussion. Swelling in the left iliac fossa. Reflexes normal.

Rtg. March 7th, 1927.—Lesions involve the lower part of the body of L III, the whole body of L IV, and the proximal two-thirds of the body of L V. L III has fallen down against the remnant of L V, between them dense detritus.

In the summer of 1927, the patient had sinuses in the left groin, which healed up. Since the autumn of 1927 she had been under correction in plaster bed, the gibbus clearly diminishing. Skiagrams show increased distance between the remnants of L III and L V, and diminution of the gaping intervertebral space L V—S I.

Nov. 9th, 1928, Albee op. (RH).—A straight tibial graft was inserted edgewise into the spinous processes of L II—S I. Healing by first intention. Since the middle of Jan. 1929, the patient was out of bed in plaster corset.—*April 16th, 1929.* General condition good. Freedom from symptoms, operative field in good condition. *Rtg. lateral view.*—Destruction unaltered. Since Nov. 9th, 1928, the vertebral bodies have resumed their original position. A bone graft is situated in the spinous process of L II—S I. On a level with the vertebral joints L III—IV, below the spinous process of L III, there is a graft defect, 6 mm. broad, with sharply defined contours and a ventrally open angle between the fragments. Antero-posterior view.—Bone graft located in the spinous process of L II—sacrum. Its spongy structure is partly maintained, the graft is surrounded by deposits. Above the spinous process of L IV there is a sharply outlined

defect, 2 mm. broad, passing right through the graft. Patient discharged with leather corset.

On *after-ex.* May 4th, 1933 (*Hinricsson*), the patient was found in good health and able to work. Mild kyphosis in the lower part of the lumbar region. »Graft fracture is suspected, and abnormal mobility is believed to be present at the seat of fracture. No crepitation«. Otherwise good mobility in the back.—*Rtg.* lateral view.—Destruction and position unaltered since April 16th, 1929. On the ventral side of the bodies of L III—V there is a coherent osteophyte (? block formation). From the spinous process of L III there is an uninterrupted bony bridge passing downwards with attachments to L IV and L V, but unconnected with the sacrum. Between the spinous processes of L II and L III there is a bone defect, a little more than 5 mm. broad, without deposits. Antero-posterior view.—Position unaltered. Intervertebral joints L III—IV and L IV—V are not apparent. The bone bridge does not differ from the bone structure in the vertebrae. (The mobility found on examination within the operation field must be referred to a movement between L II and L III).

Commentary.—For three years before the operation, the patient had been under treatment for lumbar spondylitis, with destruction of the distal part of the body of L III, the whole of that of L IV and the proximal part of that of L V. By correction the remnants were forced apart, causing a gap to appear between the remnants of L III and L V.—A bone graft was inserted into the spinous processes of L II—S I. Five months after the operation the vertebral remnants had again fallen together, in the bone graft a defect appeared on a level with the intervertebral joints L III—IV; the graft fragments formed an angle, open ventrally.

Four years and six months after the operation there were signs of early bony fusion between the bodies of L III and L V. The graft defect had consolidated. At the level of the intervertebral joints L II—III and between the spinous processes of these vertebrae a defect 5 mm. broad was seen in the graft, without surrounding deposits.—Inflexion increased after the operation. In connection with this a graft defect arose on a level with the axis of an inflexion movement between the remnants of L III and L IV. On a level with the undamaged junction between L II and L III a defect, 5 mm. broad, has arisen in the bone-graft, permitting movement to take place between L II and L III.

CASE 36. E. I. M., male, born 1924.—Symptoms of spondylitis since the spring of 1929. Admitted to C. S. A. October 31st, 1930.

Condition on adm.—General condition good, internal organs normal. *Spine.*—In the lower lumbar region the spinous process of L IV protrudes beyond the adjacent processes, forming a small, non-tender gibbus, yielding to pressure. *Rtg.* Nov. 7th, 1930.—Extensive lesion in the bodies of

L IV—V; remnants collapsed. Small destruction in the anterior upper border of S I. In front of the lesion a partly calcified abscess.

Correction was carried out in plaster bed; the gibbus diminished in size. Skiagrams show no increased destruction; between the vertebral remnants of L IV and L V there is a small space.

May 29th, 1931, Albee op. (RH).—A tibial graft with the periosteum directed dorsally was inserted into the spinous processes L II—S I.—Healing by first intention. Patient out of bed in plaster corset after about two months. *Oct. 22nd, 1931*, tender swelling over the middle of the graft; the graft appears to be bent in an angle.

Rtg. Nov. 11th, 1931.—Lateral view: Destruction and position unaltered. Narrow graft in the spinous processes of L II—S I. On the distal aspect of the intervertebral joints L III—IV, immediately above the spinous process of L IV there is a 5 mm. broad defect, and immediately below the intervertebral joints L IV—V, below the spinous process of L IV a similar defect, about 5 mm. broad, dorsally covered by thin deposits. The fragments of the graft form a ventrally open angle. Antero-posterior view: Broad graft in the midline of the spinous processes L II—III, and another in the processes of L V—S I. No graft remnant visible in the spinous process of L IV. The patient was again put in plaster bed, and as no bony union took place re-operation was decided upon.

May 23rd, 1932, op. (RH).—After the defects around the spinous process of L IV had been exposed, respiratory movements were observed between this process and the adjacent spinous processes and the graft fragment. A plate of the graft with bone defect, 2.5 mm. thick, was removed. A tibial graft, 7.5 mm. broad, was inserted into the split spinous processes L III—S I, with the periosteum dorsally.—*Patho-anat. ex.* of the excised specimen showed »rarefied bone tissue with fairly cellular bone marrow. Through the bony tissue there is a strand of cartilage with fairly abundant amount of new bone formation in the borders. The bone marrow related to this cartilaginous island is richer in cells than other areas. Beyond this nothing specific. C. O. F-s.« Healing by first intention. After two months the patient was out of bed, wearing a plaster corset.—*Rtg. Sept. 7th, 1932.*—Lateral view: Bony union between spinous processes L II—III. Between the spinous processes L IV—V there is a narrow bony bridge, between the spinous processes L III—IV a defect, 1 cm. broad, with small deposits on the dorsal borders of the fragments. Intervertebral joints L III—IV show maintained joint spaces. Spondylitic process unaltered. Antero-posterior view: Bony unions between spinous processes L IV—V (spina bifida)—S I; otherwise no changes.

In Oct. 1932, the patient was again out of bed in corset, free from symptoms. *April 4th, 1933*: the whole lumbar region shows mild kyphosis. In the midline there is a broad bony plate, with some irregularity over

its middle. Movement is observed there on flexion and extension of the back. Dorsal spine quite straight. Skiagrams show unaltered position and destruction. In the bony bridge there is a defect between the spinous processes of L III—IV; its breadth varies with the movements of the back. At the same time the height of the »intervertebral space« between L III and the remnant block L IV—V varies. The distal contour of L III is sharply defined. The intervertebral joints L III—IV present sharp outlines and maintained interarticular spaces.

After-ex. Oct. 5th, 1933. (Thunström).—General condition good. Operative field in good condition. Freedom from symptoms. Skiagrams show more sharply defined demarcation of the remnants of L IV—V, with commencing block formation between these.

Commentary.—The lesion involved the distal three-fourths of the body of L IV, the proximal three-fourths of the body of L V, and the anterior proximal border of S I. The previously collapsed remnants of the bodies of L IV—V were slightly forced apart by the correction.—A bone graft was placed in the spinous processes of L II—S I. Five months after the Albee operation there was no visible change in the position. In the graft a defect appeared above the spinous process of L IV below the intervertebral joints L III—IV, and another below the spinous process of L IV and below the intervertebral joints L IV—V. The graft fragments formed a ventrally open angle. On re-operation twelve months after the Albee operation, mobility was found to be present on respiratory movements, as well between the graft fragments themselves as between these and the spinous process of L IV. A new bone graft was inserted beyond the defects, parallel with the old graft.—Two years and five months after the Albee operation the distal defect had consolidated; at the seat of the proximal defect a movable pseudarthrosis had developed, permitting movement between the remnants of L III and L IV. In this case there has been no visible change of the inflexion since the operation; after the occurrence of the defect, however, the graft fragments show a ventrally open angle. After re-operation the distal graft defect was consolidated, located immediately on the distal aspect of the axis of the inflexion movement between the remnants of L IV—V. The proximal defect, on a level with the intact intervertebral junction L III—IV, has developed into a pseudarthrosis.

CASE 37. G. T. E., male, born 1898.—The patient has been under treatment for pulmonary tuberculosis since 1925; since 1928 he has shown symptoms of lumbar spondylitis. Admitted to C. S. A. Jan. 30th, 1930.

Condition on adm.—General condition good. *Lungs.*—Slight dullness. Altered breath-sounds over the right apex, no râles. Internal organs otherwise normal. *Spine.*—Lumbar lordosis straightened out, no gibbus. In the middle dorsal region a rounded, fairly fixed kyphosis, not tender. No abscess, reflexes normal.

Rtg. Feb. 20th, 1930.—Lateral view: Destruction, with absorption, of the distal half of the body of L V. Destruction of the anterior proximal contour of S I. Intervertebral space L V—S I obliterated. (In the middle part of the dorsal region a Scheuermann-like process). Antero-posterior view: Blurred bone structure in the distal part of L V (no separate view of L V). No abscess shadow.

Patient was treated in a correcting plaster bed.

May 2nd, 1930, Albee op. (Og-Jn).—A bent tibial graft was inserted into the spinous processes L III—S II. Healing by first intention. After about two months the patient was out of bed, in plaster corset.

An abscess gradually appeared on the outside of the right thigh. In the summer of 1931 it was punctured and disappeared. Skiagrams Sept. 1930 show unaltered position and destruction. The graft is intact.—In the beginning of March, 1931, the patient slipped on a stone while walking, and in doing so felt a sudden pain in the operative field.

Rtg. March 13th, 1931.—Lateral view: Position unaltered. On a level with the intervertebral joints L V—S I, above the spinous process of L V, there is a 8 mm. broad, sharply defined defect through the graft. Antero-posterior view: Large deposits around the graft. A defect, 6 mm. broad, through the graft and deposits.—The patient was out of bed, wearing a corset, which he was allowed to discard in August, 1931. In Dec. 1931 and Jan. 1932 he suffered from pain in his back, but got better when resuming the corset. *After-ex. Sept. 26th, 1932.*—The lower part of the lumbar region is kept rigid, good mobility above operative field. No tenderness. Just above the middle of the graft can be felt a firm, not tender, bony enlargement. No abscess.

Rtg. lateral view: Position and destruction unaltered. Bone graft in the spinous processes L III—S II. The defect in the graft is somewhat narrower, with large deposits ventrally, and smaller deposits dorsally. Antero-posterior view.—Considerable deposits on both sides of the defect. —On *after-examination* Jan. 19th, 1934, the patient was found free from symptoms. There was no change in the back; on skiagrams a movable pseudarthrosis remained at the seat of the defect.

Commentary.—The lesion involved the distal part of the body of L V and the proximal part of the body of S I. The position was not appreciably affected by the correction. A bone graft was inserted into the spinous processes of L III—S II. Fourteen months after the operation the position remained unaltered. On a level with the intervertebral joints L V—S I a defect appeared in the graft. Three years and eight months after the operation a movable pseudarthrosis remained at the site of the defect, surrounded by deposits.—In this case the inflexion has not visibly changed after the operation. The graft defect is situated at the level of the axis of the inflexion movement between L V and S I.

CASE S. T. I., male, born 1910.—Left-sided pleurisy in 1929; in the autumn 1930 trouble with his back. On May 18th, 1931, he was admitted into the department for surgical tuberculosis of S:t Göran's Hospital, and was treated there under the diagnosis of dorsal the spondylitis.

Condition on adm.—General condition good. Dullness over the left base, internal organs otherwise normal. *Spine.*—In the lower dorsal region a rounded kyphosis with its maximum point at D XII. Difficulty in bending forward without support, indirect tenderness. Moderate muscular contracture. Reflexes normal.

Rtg.—Lateral view: Destruction of the distal third of the body of D XI and the upper surface of that of D XII; the remnants collapsed, causing the intervertebral space to become smaller.—Was treated by plaster bed and plaster corset.

Oct. 6th, 1931, Albee op. (Waldenström).—Transplantation of a tibial graft, 13 cm. long, which was inserted into the spinous processes of D X—L I without tension. Healing by first intention. After seven weeks in plaster corset.

Rtg. Jan. 18th, 1932.—Lateral view: Destruction in the upper part of D XII somewhat increased, remnants of vertebral bodies still further collapsed. The bone graft in the spinous processes D X—L I is bent in a dorso-convex curve, but is intact.—During Jan.—April 1932 he had pains in his back, the knee jerks were exaggerated. He was put back in plaster bed.—On May 19th, 1932, a small gibbus was detected in the centre of the Albee graft, which showed a palpable enlargement. *Rtg. ex.*—Remnants of D XI—XII still further destroyed and collapsed. On a level with intervertebral joints D XI—XII, below the spinous process of D XI, there is a sharply outlined graft defect, with ventrally open angle between the fragments.

June 9th, 1932, op. (W-m).—A new, chiselled osteo-periosteal graft was inserted on the dorsal side of the old bone graft, covering the defect, which passed transversely through the united graft.—Healing by first intention; plaster corset after 2½ months.

Rtg. ex. July 30th, 1933, shows the outline of the distal surface of D X blurred, and the body of D X has fallen down upon that of D XI. The bone graft is bent but intact. Sept. 20th, 1933.—While riding in a bus the patient felt, at a sudden jerk, something clicking in his back, in the middle of the operative field. He immediately noticed definite tenderness over the bone graft in the upper part of the operative field.—*Rtg. ex. Sept. 21st, 1933.*—Lateral view: Destruction distally in the body of D X, increase of inflexion between D X and D XI. On a level with the intervertebral joints D X—XI, below the spinous process of D X, there is a narrow sharply outlined graft defect.

Oct. 4th, 1933, op. (W-m).—When the old bone graft was exposed, its

proximal part revealed a narrow fissure, the breadth of which varied on respiratory movements. The dorsal part of the defect was excised for microscopical examination. On the dorsal aspect of the old graft a soft, osteo-periosteal graft from the tibia was inserted subperiosteally. Healing by first intention. Skiagram of Feb. 19th, 1934, shows increased distance between the vertebral remnants of D X and D XI; a small defect is present in the basal part of the body of D X. Dorsally the graft defect is covered by a thin bone lamella. *March 21st, 1934.*—Patient discharged free from symptoms, with leather corset.

Commentary.—At the beginning of the treatment the destruction involved the distal third of the body of D XI and the proximal surface of the body of D XII. After the Albee operation destruction and inflexion increased. Fifteen months after the Albee operation re-operation was performed, the graft defect being covered on a level with the inflexion axis through the intervertebral joints D XI—XII. Twenty-one months after the operation the body of D X was found to have fallen down upon the remnant of D XI, the distal contour of D X was blurred. In close connection with a trauma 23 months after the Albee operation the patient felt a local pain in the upper part of the operative field. The following day a sharply outlined defect was found in the graft, at the seat of this pain, on a level with the axis of the new inflexion between D X—XI through the intervertebral joints of these vertebrae. In the basal part of the body of D X there is obvious bone destruction.

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