ANTERIOR FUSION OF THE SPINE FOR INFECTIVE LESIONS IN ADULTS

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Although anterior fusion was described by Ito, Tsuchiya and Asami in 1934, the technique was not widely applied until Hodgson and Stock published their results in tuberculosis of the spine in 1960. They showed that anterior grafting was more successful, in terms of bony fusion between the affected vertebral bodies, compared with the posterior grafting of Albee (1911) and of Hibbs (1912) or the antero-lateral clearance and grafting advocated by Wilkinson (1950).

At the Royal National Orthopaedic Hospital the management of patients with infections of the spine was essentially conservative before 1955. A review of seventy-two of these patients by Stevenson and Manning in 1962 showed an average period of immobilisation of twelve months. Primary fusion by bone occurred in 56 per cent, fibrous ankylosis in 37 per cent and relapse in 7 per cent. A more radical approach was then adopted and in 1963 Shaw and Thomas reported a parallel series of seventy-two patients. Thirty underwent exploration from the front, with grafting in twenty-two; forty patients were operated on by a costo-transversectomy or by a lumbar transversectomy, with grafting in fourteen. In those patients without grafting, fusion by bone occurred in 61 per cent, whereas in those receiving grafts the incidence of bony fusion was increased by 16 per cent. Since then virtually all patients admitted to this hospital with infections of the spine have been treated by operation.

MATERIAL

This paper reports the management of 131 patients over a period of eleven years. A preliminary review in 1967 suggested that for adults the method of grafting used for young patients by Hodgson and Stock was unsatisfactory. The subsequent alterations in surgical

TABLE I
THE RACIAL DISTRIBUTION OF THE 131 PATIENTS

Tuberculous lesions	Non-tuberculous lesions
European 85 (British 59), average age 40	European 12 (British 11), average age 51
African 10, average age 36	African 1, aged 38
Indian 22, average age 29	Indian 1, aged 36

technique and methods of grafting and some advances in management before and after operation will be described.

The average age of the patients with tuberculous lesions was 37·6 years, and with non-tuberculous disease 48·5 years (Fig. 1). These figures are considerably higher than in any previous series (Martin 1970). The ethnic pattern is shown in Table I, coupled with the average age of each racial group. The sex distribution was eighty-one men to fifty women.

DIAGNOSIS

Most of the patients were referred from other hospitals, rarely direct by a general practitioner. It was not possible clinically to differentiate between tuberculous and non-tuberculous disease of the spine. There was a wide variation in the presentation: some patients had only minimal symptoms and local physical signs, while others were severely ill. Occasionally an immigrant patient with tuberculous disease of the spine presented with systemic manifestations resembling pyogenic septicaemia. Two such patients had a persistent pyrexia of 38 to 39 degrees Celsius associated with high sedimentation rates.

FIG. 1

Histograms to show the age distribution of patients with tuberculous and non-tuberculous infections. (Black represents male, and stippling female patients.)

Among patients shown to be suffering from tuberculosis, sixty-nine presented with a kyphos, including twenty-three with reactivation. Five of the latter had previously been treated by posterior fusion. Nine patients had other active or quiescent lesions of bone or joint; twenty-two had active or healed pulmonary disease; seven had genito-urinary involvement and four had had cervical lymphadenitis. One patient had tuberculous thyroiditis. Sixteen patients had presenting tuberculous abscesses and six had sinuses related to the spinal disease. Neurological involvement in thirty-two patients (24 per cent) varied from incipient to complete paraplegia.

Routine investigations—The radiological and laboratory investigations of these patients have been given by Kemp, Johns, McAlister and Godlee (1973) in a paper describing the use of scintigraphy employing Strontium-87m or Fluorine-18, a routine of particular value in the diagnosis of reactivation of spinal disease.

Haemoglobin level—There was no evidence of anaemia in these patients (Fig. 2), despite the general belief that it is a feature of such disorders.

Erythrocyte sedimentation rate (E.S.R.)—This investigation was performed as a routine every four weeks; the serial estimations were incomplete in only two instances. The investigation was of no value in establishing an initial diagnosis. The findings on admission are shown in Figure 3. The six patients with a rate above 100 millimetres/hour included three patients with tuberculous disease of the spine and a woman with multifocal skeletal tuberculosis, pulmonary tuberculosis and tertiary syphilis who had had ineffectual chemotherapy. She was the only patient in the series whose rate remained raised for more than six months (Fig. 3). Of the remaining two patients, one had a *B. proteus* infection of the spine, and one with complete paraplegia due to an *E. coli* osteomyelitis also had an *E. coli* urinary infection.

When the sedimentation rate was initially raised, serial measurements were invaluable.

In a patient who presented after this series, material removed at operation showed the characteristic histological appearances of tuberculosis, but the bacillus was not isolated. The sedimentation rate stayed raised, despite radiological evidence of incorporation of the graft. Rifampicin and ethambutol were substituted for para-aminosalicylic acid and isoniazid; within six weeks the rate fell to normal and the patient's general state improved.

The final estimations performed are also shown in Figure 3. Only one patient had a raised rate at this stage; she had developed disseminated lupus erythematosus during the course of treatment. In cases of reactivation of the disease, the rate rose concurrently.

FIG. 2
A histogram of the haemoglobin percentages on admission of 129 of the 131 patients.

Staphylococcal antibodies—The levels of anti-alpha haemolysin and anti-Panton Valentine leucocidin were estimated in ninety-eight of the 131 patients, the former alone in six patients. In ten patients out of ninety-four with proven tuberculosis, significant elevation of one or both of these antibodies were found. In no such case was there evidence of secondary infection with *Staph. pyogenes* at any stage, but the possibility could not be excluded. Of five patients with proven *Staph. pyogenes* infection of the spine, only three had raised titres. In three cases the organism was not isolated but the diagnosis was supported by elevated titres.

The Mantoux test—This was positive in all patients with active tuberculous disease and in some with non-tuberculous lesions. In patients with negative tests it was found that the infections were due to organisms other than tubercle (Table II).

The value of comprehensive laboratory tests in the diagnosis of infections of the spine cannot be over-emphasised. Some indication of their importance is shown in Table III and in Figure 4.

PRE-OPERATIVE MANAGEMENT

Nursing in a plaster bed has been almost entirely abandoned over the past five years, and is now only used for a patient with extensive destruction of one or both pedicles or articular facets in order to reduce the risk of cord involvement. The recognition of such widespread disease depends upon the radiological findings. Unilateral loss of spinal stability

is shown in the antero-posterior radiograph by rotation of the proximal vertebra away from the destroyed facet. When both facets are destroyed, spondylolisthesis of the proximal vertebra can be seen in the lateral tomograph.

Patients with cervical lesions are now placed in halo-pelvic traction (O'Brien, Yau, Smith and Hodgson 1971) in order to correct deformity and control movement while permitting the patient to be ambulant. Paraplegic patients with stable spines are now more successfully managed on low-loss air beds (Scales and Hopkins 1971), which prevent bed-sores and reduce the problems of decubitus (Scales 1973).

Chemotherapy—The present routine conforms to the universally accepted standard, namely, injections of streptomycin 0.75–1 gramme daily for three to six months, and oral para-aminosalicylic acid (PAS) 12 grammes and isoniazid (INAH) 300 milligrams daily in combined form

FIG. 3

Three histograms recording sedimentation rates (Westergren). The first shows the wide variation in the readings at the time of admission. The second shows the response to six months of treatment; the lowered rates are expressed as a shift to the left. The third histogram, based on the latest readings, shows the shift to the left even more pronounced. About 15 per cent of patients had a normal rate on admission and about 70 per cent at the time of discharge.

for two years. If the patient cannot be relied upon to take drugs regularly, then intermittent supervised therapy using streptomycin and INAH is instituted after the first three months. Streptomycin is not given to patients over the age of sixty-five. Rifampicin, pirazinamide or ethambutol are used as alternatives in patients with drug intolerance or drug sensitivity and for organisms resistant to streptomycin, PAS or INAH. Rifampicin, which is bacteriocidal, may become one of the primary drugs used for initial treatment.

For non-tuberculous disease the initial treatment with antibiotics has been empirical. If the organism could be isolated and the sensitivities determined, the appropriate antibiotics were given for three months after the sedimentation rate had returned to normal.

Of the ninety-four patients with proven tuberculosis, the organism was isolated in sixty-seven. The drug sensitivities, however, were determined in only fifty-seven, an indication of the difficulty of isolating the organism in osseous tuberculosis. In only three instances was a

resistance shown to drugs. One Pakistani had tubercle bacilli resistant to PAS; he had been treated with streptomycin and PAS for five weeks before the organism was isolated from material removed at operation. Two English patients were infected by organisms with partial drug resistance. The first had been treated for three months with streptomycin and PAS six years previously, and the bacilli were resistant to streptomycin. The second had received no treatment, but the organisms were resistant to streptomycin and to INAH. This represents

TABLE II
THE RESPONSE TO THE MANTOUX TEST IN 101 OUT OF 131 PATIENTS

Response	Number	Tuberculous lesions			Infecting organism not known	Non-tuberculous lesions with method of diagnosis in brackets
		Diagnosis confirmed by biopsy	Diagnosis suggested by concurrent tuberculous lesions	Diagnosis unconfirmed but past history of tuberculous lesions		
Strongly positive 1/10,000 or 1/5,000	94	71	4	3	8	E. coli (culture) . . . 1 B. proteus (culture) . . . 2 Staph. pyogenes (culture) . . . 2 Staph. pyogenes (serology) . . . 2 T. pallidum (serology) . . . 1*
Weakly positive 1/1,000 or 1/500	3	2	1	—	—	—
Negative	4	—	—	—	—	Staph. pyogenes (culture) . . . 2 Staph. pyogenes (serology) . . . 1 T. pallidum (serology) . . . 1
Mantoux test not done	30	21	3	3	1	E. coli (culture) . . . 1 Staph. pyogenes (culture) . . . 1

* See Johns 1970.

TABLE III
LABORATORY EXAMINATIONS OF BIOPSY MATERIAL IN 129 PATIENTS

Number of examinations per specimen	Number of specimens examined	Number of positive results	Percentage of positive results
1	7	4	57
2	7	5	71
3	44	36	82
4	71	60	84.5

The four examinations referred to are staining by the Ziehl-Neelsen technique, culture on Lowenstein-Jensen medium, guinea-pig inoculation, and histology. This table illustrates that the likelihood of obtaining positive findings from operative material is increased by multiple examinations.

a resistance rate of 5.3 per cent of the organisms with sensitivities determined. The number of strains with partial or complete resistance to the standard drugs is increasing, and in the past few years the figure has risen to about 10 per cent. This fact, coupled with the data given in Table IV, would suggest that the organism should be isolated before chemotherapy is begun.

With certain exceptions, all patients with uncomplicated disease were operated upon within six weeks of beginning chemotherapy. During the past four years this period has been

reduced to an average of three weeks. The exceptions were patients with localised lesions considered to be stable and healing, and patients who were unfit for operation. The latter are typified by two patients.

FIG. 4

Two histograms showing the percentages of positive findings given by each of four methods of examining material obtained at operation. The first histogram shows the results expressed as a percentile for all 131 patients with spinal infections; the second shows the adjusted results for patients with tuberculous infection. The key to the columns is as follows: 1—Positive examination of Ziehl-Neelsen stained film. 2—(Shaded) positive Lowenstein-Jensen culture; (white) positive culture of organisms other than the tubercle bacillus. 3—Positive guinea-pig inoculation. 4—(Shaded) histological findings typical of tuberculosis; (white) histological appearance of an acute inflammatory process.

TABLE IV
THE INFLUENCE OF INADEQUATE CHEMOTHERAPY ON THE DRUG SENSITIVITY OF THE TUBERCLE BACILLUS

Number of patients	Numbers adequately investigated	Number in which the organism was not isolated	Drug sensitivities of isolated organisms	
			Fully sensitive	Partially resistant
Group A, 63*	55	13 (24 per cent)	41 (74 per cent)	1 (2 per cent)
Group B, 32†	30	15 (50 per cent)	13 (43 per cent)	2 (7 per cent)

* Group A patients had received either no chemotherapy at all or adequate chemotherapy for less than four weeks in the pre-operative period.

† Group B patients had received chemotherapy inadequate by present standards either for varying periods during the course of the disease or for more than four weeks prior to the time of operation.

The first, a Nigerian man aged twenty-four, had widespread destruction of no less than twelve vertebrae, from T.2 to L.2, as well as disseminated disease; he died of cerebral tuberculosis eight weeks after admission. The second patient, a white man aged twenty-four with incomplete paraplegia, suffered from recurrent pulmonary emboli soon after admission. He was treated with anticoagulants and eventually his paraplegia was relieved by costotransversectomy.

The distribution of lesions is shown in Figure 5. The pattern for tuberculosis resembles that observed in adults by Konstam and Blesovsky (1962).

THE SURGICAL APPROACH TO THE LESION

Surgical approaches to the vertebral bodies at different levels, either anterior or anterolateral, have been described by Southwick and Robinson (1957), Hodgson and Stock (1960) and Kirkaldy-Willis and Thomas (1965). Although these techniques have been generally used, we have either modified or changed the approach at certain levels in order to improve the exposure.

Cervical spine—No patients in this series had disease involving the first two vertebrae. The third to the seventh vertebrae were approached through the exposure described by Southwick and Robinson.

FIG. 5

Histograms showing the levels of the vertebrae affected in the tuberculous and in the non-tuberculous infections of the spine.

Cervico-thoracic junction—Lesions involving the lower two cervical and upper two thoracic vertebrae can be exposed through a cervical incision, because the latter lie above the level of the suprasternal notch. The anaesthetised patient is intubated and the head slightly extended on a neurosurgical head rest. The skin incision extends along the anterior border of the right sternomastoid muscle, and the platysma is divided in the same line. The pretracheal fascia is divided longitudinally to the right of the midline over the sternohyoid and the sternothyroid muscles, which may be divided transversely if wider access is required. The carotid sheath is retracted laterally, separating it from the midline structures, namely, oesophagus, trachea and thyroid, which are gently retracted to the left of the midline. The middle thyroid vein and the inferior thyroid artery are divided separately between ligatures. The recurrent laryngeal nerve is identified and protected.

Third and fourth thoracic vertebrae—This is the most difficult area of the spine to expose by an anterior approach. Southwick and Robinson (1957) relied upon costotransversectomy and lateral rachotomy to explore this region. Hodgson and Stock exposed these vertebrae through the bed of the third rib. Cauchoix and Binet (1957) described an approach from the left side of the neck which entailed ligation and division of the left innominate vein. An approach from the right side allows easier access and the vein can be preserved.

The procedure is an extension of the exposure for the cervico-thoracic junction. The skin incision is prolonged in the midline down the sternum to the xiphoid process. The anterior mediastinal tissues are progressively cleared by blunt dissection behind the manubrium, working distally from the suprasternal notch and proximally from the xiphoid process.

The sternum is divided sagittally with an oscillating saw; the two halves can then be retracted laterally. With this free exposure it is possible to retract the vessels and midline structures more widely. The recurrent laryngeal nerve is freely mobilised so that it lies obliquely across the operative field; it is protected and kept moist with isotonic saline during the course of the surgical manoeuvres; laryngoscopy after the operation has not shown any paralysis of the right vocal cord.

Before exploring the spine, the vertebral artery is identified behind the carotid sheath, passing upwards and backwards to the foramen in the sixth cervical vertebra. The advantage of this approach from the right side is that the innominate artery takes origin from the aorta at a lower level than the left common carotid and left subclavian vessels, and similarly the left innominate vein runs obliquely and distally to join the right innominate vein, permitting easier access to the vertebrae. The thoracic duct can also be avoided.

At the end of the operation suction drains are inserted and the sternum is repaired with interrupted stainless steel wire sutures. If the pleura has been inadvertently opened, it is drained with a large-bore tube for forty-eight hours.

Thoracic spine below T.4—Normally a left thoracotomy is employed, using the method described by Hodgson and Stock. If there is a severe kyphosis, a right thoracotomy is preferred because kinking of the aorta causes it to overlie the affected vertebrae on the left. The chest is opened along the upper border of the appropriate rib, one or two above the level of the vertebral lesion. The rib is not removed. Usually the lung is free or can be separated by digital stripping, though adhesions may require sharp dissection; decortication is rarely necessary. If an abscess is present, the contents are aspirated and sent for routine examination.

The aortic sheath should be opened and the intercostal arteries identified by blunt dissection of the areolar tissues. The intercostal arteries related to the lesion are ligated in continuity. In our experience the ligation of intercostal arteries rarely disturbs cord function, though in one case, after the bilateral ligation of three pairs, there was some impairment for several weeks. If a right thoracotomy is indicated, the intercostal arteries are individually clamped and transfixed with sutures in the medial wall of the abscess cavity as it is opened. The azygos vein can be divided and ligated with impunity.

On closure, the aortic sheath and the wall of the abscess cavity are loosely approximated with interrupted sutures. The chest is closed with one or two large-bore drains in position.

Thoracolumbar junction—Disease involving the twelfth thoracic vertebra and the upper two lumbar vertebrae is more widely exposed by a thoracolumbar incision, with equal facility from either side because the inferior vena cava is essentially a midline structure and lies more anteriorly than the aorta. Access is obtained through the bed of the tenth rib. The diaphragm is divided along its costal attachment. The renal fascia is opened, giving access to the perinephric space. The kidney and peritoneum are reflected forward in order to expose the lesion. Lumbar arteries and veins, including the ascending lumbar and the lumbar azygos veins, are clipped or tied as necessary. During closure the diaphragm is repaired using interrupted linen sutures. The perinephric space and the chest are drained separately.

Lumbar spine—The middle and lower parts of the lumbar spine are usually approached through a left oblique incision, extending from the angle between the twelfth rib and the erector spinae, downwards and forwards towards the anterior superior iliac spine. Otherwise the approach does not differ from that described by previous authors.

Lumbo-sacral region—In our experience the generally accepted approaches do not provide adequate exposure. Accordingly, the oblique renal incision is extended anteriorly, or a horizontal "hemisection" incision is used. In exposing the diseased vertebrae, a retroperitoneal approach is made, the abdominal structures being reflected forwards. The psoas muscle need not be divided and the sympathetic trunk can usually be preserved. The common iliac vessels are mobilised and reflected forward. It is necessary to clip or ligate the ascending lumbar, the lumbar and the ilio-lumbar vessels in order to free the common iliac vessels. Particular

care is taken in mobilising the common iliac vein, which receives unnamed tributaries from the adjacent vertebral bodies and muscles. If these small vessels are not carefully identified and ligated, the thin wall of the vein may be torn. Once the iliac vessels are mobilised, it is possible to approach the affected bodies by dividing the anterior longitudinal ligament in the midline.

CLEARANCE AND GRAFTING

At all levels the anterior longitudinal ligament is divided in the midline. In the cervical region the two halves are stripped laterally towards the longus cervicis muscles. In the lumbar region they are reflected towards the psoas. In the thoracic region the ligament, intimately related to the abscess wall, can be readily reflected forward to expose the affected vertebrae, allowing the insertion of malleable retractors to protect the mediastinal structures.

With the affected vertebrae exposed, all diseased and sequestered bone, sequestered disc and granulomatous tissue are removed. When long tract signs are present, the exposure is more radical. It may be necessary to remove healthy bone in order to expose the dura at the site of compression. The posterior parts of the proximal and distal vertebral bodies are progressively removed with rongeurs until the dura can be seen to pulsate freely.

Granulations may invest the dura. Unlike Hodgson and Stock, we have found no evidence of tuberculous granulations invading the dura. Such granulomatous tissue tends to strip freely and is relatively easily removed by sharp dissection with a scalpel or dissecting scissors. In contrast, pyogenic granulation tissue is difficult to remove because it often invades the dura and occasionally penetrates the cord.

Preparation of the host bed—In the cervical region it is necessary to cut the graft bed from the front and for this reason chisels and rongeurs should be used judiciously. A slot one centimetre wide is cut sagittally in the centre of the vertebral bodies and extended proximally and distally into healthy bone, which is undercut in order to “key” the graft when it is inserted. The bed for the graft in the thoracic and lumbar region is prepared by cutting a slot one centimetre wide in the coronal plane across the full width of the bodies. The slot is similarly extended proximally and distally into healthy bone.

The grafts are cut so that they are slightly longer than is the bed after the spinal deformity has been corrected. A cervical graft is cut from the outer table of the ilium. A graft for the thoracic or lumbar region is cut as a full-thickness block from the iliac crest. The preparation of the grafts is shown in Figure 6.

In the cervical region, the neck is extended in order to key the graft so that it is stable when the halo-pelvic appliance is reapplied at the end of the operation. In the thoracic and lumbar regions the spine is extended by an assistant pressing manually against the kyphos, a technique found to be more effective than the use of mechanical divaricators. A specially designed punch (Fig. 7) is used to drive the graft into the prepared bed. It is usually stable.

Grafting material—The successful use by Hodgson and Stock of whole or split rib grafts, inserted as fascicles in young patients, proved almost totally unsatisfactory in the management of adults. The rate of union of these grafts was slow and they often failed to incorporate. In 32 per cent the grafts broke between four and thirty months after operation, the average being thirteen months. In 12 per cent the grafts prevented fusion until they broke; the vertebral bodies then were brought into apposition and delayed union occurred in most cases. The average increase in kyphosis in this group was 20 degrees. Partial collapse occurred in some patients because the ends of the rib grafts penetrated the vertebral plates. The other disadvantage of rib grafts was that they invariably became absorbed if they crossed a relatively intact intervertebral disc.

Because of this failure of rib grafts in the adult, various alternative materials were used, such as Kiel bone and homologous banked bone. The results were again unsatisfactory, for although the grafts broke less often, incorporation and subsequent bony union were invariably delayed.

FIG. 6

For defects of the thoracic or lumbar spine, a full thickness graft (b) is cut from the iliac crest (a), including the iliac tubercle. The cortical margins are removed (c) and the prepared graft is inserted into a coronal slot cut into the bodies (d). For the cervical region (f), the graft is cut from the outer table of the ilium (e) and inserted into a bed (h) cut in the sagittal plane.

A paradoxical process of repair occurred in approximately 50 per cent of patients who received grafts of both homologous and heterologous bone. The entire graft was progressively surrounded by bone so that ultimately the affected vertebrae were bridged. Serial tomographs, however, showed that the grafts remained in total isolation (Jackson 1971). It can be postulated that the grafting material stimulated either an inflammatory reaction or an immunological response by the host which led to an attempt to isolate the graft by the formation of new bone.

Kiel bone is now used only for defects too extensive to be bridged by available autologous bone, and then it is supplemented by iliac chip grafts (Fig. 8).

FIG. 7

The head of the introducer used for insertion of a graft in the thoracic or lumbar region has four teeth to prevent it from slipping.

Since the introduction of iliac bone as the routine material, and in particular since the use of block grafts across the entire width of the vertebral bodies, the rate of incorporation has increased and collapse of the vertebrae has been reduced to a minimum. Consequently it has been possible to mobilise the patients sooner.

Posterior grafting is now used only occasionally to ensure stability of the spine. The two special indications are the total destruction of more than two vertebral bodies in the cervical or lumbar region so that stability is not obtained by anterior grafting, and the

destruction of articular facets with secondary sUBLuxation. Posterior fusion is usually performed six weeks after the primary procedure. The surgical approach and the type of grafts employed are shown in Table V. The results obtained with the various types of grafting materials are shown in Table VI. The radiological features of the types of grafts that were used are shown in Figures 9 to 19.

ANTERO-LATERAL DECOMPRESSION

This procedure was only used in those patients with incomplete or complete paraplegia in whom an anterior approach was technically impossible. The indication for its use was kyphosis so acute that the apposition of the vertebral bodies proximal and distal to the lesion would prevent adequate access by an anterior approach to decompress the cord. The operation was performed as described by Seddon (1956) on twelve patients, who are not included in this series. Total recovery occurred in eleven, but one of these patients, despite adequate chemotherapy, later developed further signs of paraplegia from recurrent abscess formation, and six months after a second successful operation died from congestive cardiac failure due to cor pulmonale. The twelfth patient had an almost complete paraplegia of late onset with sparing of the sphincters, due to mechanical ischaemia of an attenuated cord. After decompression at the seventh to ninth thoracic level, she developed irreversible total paraplegia. Because of the level, it was assumed that the surgical procedure had impaired the function of the artery of Adamkiewicz.

FIG. 8

Radiographs of the tuberculous lumbar spine of a woman aged 45 previously treated by repeated transversectomy and grafting. Because the destruction was too extensive to be bridged by an iliac graft, a strut graft of Kiel bone was used and autologous chip grafts were packed into the defect. A posterior fusion was also performed.

POST-OPERATIVE MANAGEMENT

After operation the patient lies free in bed and is given physiotherapy on regaining consciousness. In the management of cervical lesions halo-pelvic traction is replaced after eight weeks by a modified Minerva jacket, which is retained for four weeks. In thoracic cases radiographs of the chest are taken soon after operation and again after twenty-four hours; the drain is removed at forty-eight hours and a further radiograph is taken at seventy-two hours; the patient is mobilised after eight weeks. Patients with lumbar lesions are allowed up after twelve weeks. A Gauvain brace, which is retained for a further six months is used to restrict flexion in patients with thoracic or lumbar lesions.

The average duration of in-patient treatment was twenty-three weeks, and from operation to discharge, seventeen weeks. In the last three years it has been possible to reduce these times considerably in straightforward cases. The average stay in hospital for cervical and thoracic lesions is now only twelve weeks, and for lumbar lesions, sixteen weeks.

TABLE V
THE ANTERIOR APPROACH USED, AND THE TYPES OF GRAFT EMPLOYED

Numbers	Cervical and sternal	Transthoracic		Retroperitoneal		Trans-peritoneal
		Left	Right	Left	Right	
Anterior exploration, 132*	4	81	12	28	6	1
Anterior grafts, 117	2	74	10	26	4	1
No grafts, 15	2	7	2	2	2	—
Autologous grafts						
Rib, 63	—	59		4		—
Ilium, 41	2	15		23		1
Homologous grafts						
Rib, 1	—	—		1		—
Tibia, 7	—	7		—		—
Heterologous grafts						
Kiel bone, 4	—	3		1		—
Mixed grafts						
Kiel bone and ilium, 1	—	—		1		—

* One patient had a second transthoracic exploration and grafting for reactivation of disease below the site of the original lesion.

Morbidity—Early or late sequelae developed in thirty-one patients (33 per cent) after a thoracic approach and eight (20.5 per cent) after a cervical or retroperitoneal operation.

Respiratory complications—Five patients developed pleural effusions; two required aspiration once and one three times. Two patients developed pulmonary atelectasis, one requiring bronchoscopy twice. There were five mild infections. All of these patients had had a transthoracic exploration.

Vascular complications—Three patients with a clinical diagnosis of deep vein thrombosis were treated with anticoagulants. One of these had a small pulmonary embolus.

FIG. 9
Antero-posterior and lateral radiographs showing a coronal graft of the thoracic spine *in situ*.

TABLE VI
ANALYSIS OF RESULTS IN RELATION TO TYPE OF GRAFT

Type of graft	Number	No follow-up	Non-union or incomplete fusion	Bony fusion	Average time to fusion (months)	Final kyphosis		
						Decreased	Static	Increased (and average)
Autologous rib .	63	8	21	34 (62 per cent)	24	1	30	24 (13 degrees)
Autologous ilium Series I	23	—	6	17 (74 per cent)	14	1	21	1 (nil)
Autologous ilium Series II	18	—	1	17 (94.5 per cent)	10	2	11	5 (7 degrees)
Homologous rib .	1	—	—	1	24	—	1	—
Homologous tibia .	7	—	2	5 (71 per cent)	28	—	5	2
Heterologous Kiel bone, 4 Kiel bone + ilium, 1 }	5	—	1	4 (80 per cent)	18.5	—	3	2

Autologous ilium: Series I denotes full thickness ilium used as an inlay graft. Series II denotes full thickness ilium crossing the coronal diameters of the affected vertebrae. The difference between the rate of fusion for autologous rib and autologous ilium was statistically significant ($P < 0.001$).

Wound infections—Eight patients had a superficial infection of the incision after transthoracic exploration. Two required a limited secondary suture, and a patient with diabetes, who subsequently died, developed a total wound dehiscence requiring complete resuture.

FIG. 10

Antero-posterior and lateral radiographs of a tuberculous spine taken six months after the insertion of Kiel bone to bridge the defect. The graft can still be clearly seen in both projections as a sequestrum, no incorporation having occurred.

FIG. 11

The same case as Figure 10. Two years later the radiographs show partial absorption of the graft and the translucent zone around the graft is more pronounced. Fusion by bone is occurring between the two affected vertebrae, an appearance which was little changed over the next four years.

Pressure sores—Seven patients in plaster beds had minor pressure sores which responded to conservative treatment.

Drug reactions—Of four cases only two were of any consequence—a case of exfoliative dermatitis due to PAS and a case of peripheral neuropathy due to Furadantin.

Neurological complications—The patients admitted with neurological signs showed a total recovery, with one exception.

FIG. 12

FIG. 13

FIG. 14

FIG. 15

Figure 12—A lateral tomograph of a tuberculous lesion of thoraco-lumbar region. Figure 13—The radiograph taken immediately after operation shows the residual parts of the two affected bodies separated by rib grafts. Figure 14—Twelve months later there is no evidence of healing and the vertebral bodies have collapsed around the grafts, which have not been incorporated and show evidence of absorption and fracture. Figure 15—Three and a half years later, fusion has occurred after further collapse of the vertebral remnants around the grafts. There is a kyphos of 50 degrees.

This patient, a woman aged forty-five, had extensive disease with retrospondylolisthesis of the fifth lumbar vertebra in relation to the sacrum (Fig. 8) and incomplete paraplegia with upper motor neurone signs presumed to be due to traction on the cord *via* the cauda equina. Recovery was incomplete in that power in the muscles below the left knee remains at Grade IV two years after operation.

Coincidental complications—These included cholecystitis in one patient.

Mortality—Of the whole series of 131 patients, ninety-eight were adequately followed up. Excluding those who died, the remainder either defaulted or returned to their country of origin.

There were two early deaths, both attributable to the disease.

A man aged fifty-four with uncontrollable diabetes had a successful anterior decompression at another hospital for total paraplegia due to staphylococcal osteomyelitis. Five months later the

FIG. 16

To show an example of successful rib grafting for a tuberculous lesion. The first lateral radiograph was taken immediately after operation. One of the grafts has penetrated the upper vertebral plate. Two years later there is bony fusion, even though the grafts have not been remodelled.

FIG. 17

A lateral radiograph of a tuberculous lesion of the lower thoracic spine. Iliac grafting was performed, crossing the full diameter of the lesion. Fifteen months later the graft is partially incorporated and there is sound fusion of the vertebral bodies.

paraplegia recurred. Two weeks after a successful decompression and grafting through a right thoracotomy, he died from a fulminating staphylococcal pneumonia.

The second patient, a totally paraplegic man of sixty-nine, died of bronchopneumonia and empyema eleven weeks after an unsuccessful decompression.

There were four late deaths.

A man aged forty-two with associated pulmonary tuberculosis failed to take his drugs and died five years later from a secondary bronchopneumonia; the second died seven years after operation from a haematemesis due to a duodenal ulcer; the third died forty months after operation from

FIG. 18

FIG. 19

Figure 18—Antero-posterior and lateral radiographs of a lumbar spine showing a tuberculous lesion involving the articular facets on the right side. After anterior grafting with iliac bone the spine was still unstable and was therefore grafted posteriorly. Figure 19—The radiographs taken twelve months later clearly show incorporation of the grafts and sound bony fusion.

carcinoma of the bronchus; and the fourth patient died from carcinoma of the uterus sixteen months after operation.

Rehabilitation—Patients who recovered were encouraged to return to their original occupations; professional, sedentary and light manual workers usually did so within six months of operation.

The major problems were heavy manual workers who had difficulty in obtaining alternative employment. The average time from operation to return to work was forty-four weeks.

DISCUSSION

The place of operation in the management of tuberculous disease of the spine has been widely debated. Konstam and Blesovsky (1962), understandably influenced by the economics and facilities in Nigeria, treated their patients conservatively, using plaster jackets and chemotherapy. Their series, however, consisted mainly of children and adolescents, 65 per cent being under the age of twelve. Although this method was apparently successful in young Africans, Martin (1970) treated 133 older patients in Northern Ireland by a similar method, with unsatisfactory results in 47 per cent.

In their preliminary study of patients treated by radical clearance and anterior fusion, Hodgson and Stock (1956) obtained results comparable with those obtained by Konstam and Blesovsky. These patients were even younger, the average age being less than three years. In a later paper Hodgson and Stock (1960) reported a significant morbidity and mortality after operation. This makes it difficult to justify operative treatment in childhood, unless it can be shown to diminish the incidence of kyphosis and its complications and also to reduce the risk of reactivation.

Tuberculous disease of the spine in adults presents different problems from those in childhood. The patients obviously require rapid rehabilitation for social and economic reasons. In adults the potential for repair progressively diminishes with age; healing by bony fusion occurs less often, and the bridging of affected vertebrae seen in children is rare. Radiologically there is little evidence of removal of caseous or sequestered materials; repair demands the collapse of affected vertebrae allowing contact between healthy bone, and even then healing is often by fibrous union. Vertebral collapse of any magnitude in the thoracic region leads to structural changes of the chest wall which may impair respiratory function. Vertebral collapse may also lead to kyphosis with its attendant problems. Furthermore, despite recent laboratory evidence that chemotherapeutic drugs can permeate caseous and sequestered tissue (Barclay, Ebert, Le Roy, Manthei and Roth 1953), there is clinical evidence that patients treated conservatively with adequate chemotherapy may still suffer reactivation.

Reference must here be made to reactivation after operation, although there were only three examples among our 120 patients with tuberculous lesions. Occasionally the diseased area may be so extensive that eradication is impossible. Further, it is these patients who are most likely to have received previous chemotherapy, making isolation of the bacillus and the determination of sensitivities difficult or impossible.

Martin (1970) reviewed 740 patients with tuberculous disease of the spine. He had performed anterior spondylectomy on 101 patients. Although he did not publish details of the numbers of patients receiving grafts, the type of graft used or the final degree of collapse, he obtained healing by bone in 96.2 per cent of patients with focal lesions. His overall fusion rate was 86 per cent and the longest time for this to occur was three years.

We believe that, in the adult, in order to obtain a stable bony fusion with least collapse, it is necessary to perform a radical clearance preserving all apparently normal tissues. In our experience, the only successful graft material has been autologous iliac crest used as an inlay or coronal block graft, depending upon the level. To obtain incorporation of the graft and fusion between the vertebral bodies, the disc or its remnants should be removed whenever the graft crosses a disc space. A graft should only be regarded as incorporated when there is radiological evidence of trabecular continuity with the host; in doubtful cases this can be demonstrated by lateral tomography. If the surgical technique has been successful there should be little or no collapse at the site of grafting. Secondary posterior fusion need be performed only if there is destruction of two or more vertebral bodies, or if there is instability from destruction of the posterior vertebral elements.

Martin (1971) advocated postero-lateral decompression in the management of paraplegia. It has been our practice to decompress the cord by way of an anterior approach if possible, because this facilitates a wide exposure of the dura before grafting. In those patients in whom this approach is unsuitable because of the severity of the kyphos, antero-lateral decompression is employed. The disadvantages of the postero-lateral approach are that occasionally it causes spinal instability and subluxation; it does not permit the application of the principles for decompression so clearly expounded by Seddon in 1956; and as Martin stated, it is virtually impossible to deal with an internal gibbus (Kemp, Jackson and Shaw 1973).

SUMMARY

1. The results of treatment of 117 tuberculous and fourteen other types of infection of the spine in adults by anterior fusion and chemotherapy have been reviewed.
2. It is suggested that anterior fusion is justified because: *a*) it permits isolation of the organism, and hence the determination of drug sensitivities and appropriate chemotherapy; *b*) removal of the diseased tissue and the stabilisation of the affected segment by iliac bone grafts can be effected, leading to rapid healing by bony fusion with little further collapse; *c*) rehabilitation of the patient is hastened; and *d*) the incidence of reactivation is probably diminished.

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