POSTERIOR FUSION OF THE SPINE FOR SCOLIOSIS
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This clinical and radiographic study of a series of patients treated for idiopathic, paralytic and congenital scoliosis was made to determine how far posterior spinal fusion could be relied upon to prevent increasing deformity, and how far it could be depended upon to maintain correction of deformity secured by various types of plaster jacket with or without preliminary operation.

In the Robert Jones and Agnes Hunt Orthopaedic Hospital there has been an experience of correction of scoliosis by plaster jackets of the Abbott type over a period of more than thirty years, the late McCrae Aitken making this the greatest of his life endeavours. He tried to derotate the more mobile vertebrae, fixing prominent parts of the chest wall by the plaster jacket and encouraging respiratory excursion of the flattened ribs through windows cut in the plaster. Hour after hour the staff of the hospital applied and reapplied the jackets, instructed the patients day by day in their deep breathing, and encouraged and cajoled them to use that part of the chest wall that would derotate the curve. Figures 1 to 3 show the type of Abbott jacket applied, though it must be noted that McCrae Aitken would have insisted upon larger windows over the left chest anteriorly and the right chest posteriorly than were used in this particular patient. In many patients excellent correction was achieved and sometimes it was maintained (Figs. 4 and 5). Unfortunately the regime of plaster jackets

Fig. 1
Patient on the Abbott frame prepared for application of Abbott plaster jacket.
with respiratory exercise needed to be continued for several years. Moreover, even when good correction had been secured there was often relapse.

Quicker methods of correcting the deformity were developed by Risser (1948) with his turnbuckle jacket (Fig. 6). A still simpler and even more rapid method of correction was developed in this hospital by Sister H. Arthur and the plaster-room staff under the direction of Mr H. Osmond-Clarke and others by a simple wedging jacket which incorporated either one upper limb or one lower limb, according to the level of the curve, the plaster being wedged at twice-weekly or thrice-weekly intervals (Fig. 7). In this way the angulatory element was attacked primarily, with secondary correction of the rotation, in contradistinction to the Abbott principle of attacking the rotational element first.

![Corrective Abbott jacket applied.](image1)

**Fig. 2**

Corrective Abbott jacket applied. Note the holes cut over the front of the chest on the left side and the back of the chest on the right side to help respiratory exercise in derotating the scoliotic spine (in this particular case the holes should have been still larger).

![Note holes cut over the front of the chest.](image2)

**Fig. 3**

No matter what technique was used to secure such correction as was possible of the scoliotic curve, the problem of relapse remained. Attempts have been made throughout the world to achieve stability of the corrected deformity by posterior spinal fusion (Hibbs, Risser and Ferguson 1931; Cobb 1948 and 1952; von Lackum 1948). Most of these operations have been done after preliminary correction of the deformity by plasters of the Abbott, Risser or wedge type. In some there has been a preliminary excision of the posterior spinal elements of four or five adjacent segments of the vertebral column by which to gain still greater initial correction, as suggested by Somerville (1952); or resection of multiple wedges composed of vertebral bodies and disc at the apex of the curve, as practised in this hospital by Roaf (1955). In other patients the posterior spinal fusion was intended primarily to stabilise the existing position of the deformed spine without special regard to preventing increasing deformity, as for example in severe poliomyelitis where bone fusion of the spine could help to prevent collapse of the trunk from extensive paralysis; or in older patients where aching pain in the
back and radicular pain, together with pain from impingement of the collapsed thoracic frame against the pelvic brim, might be relieved.

**CLINICAL MATERIAL**

It is perhaps open to criticism that so many types of scoliosis are being grouped for one clinical study. It may be said that there are so many variables in the etiology and curve patterns, the skeletal and chronological ages of the patients, the stature and weight, the endocrine balance and the varying techniques of plaster correction with or without operative resection of bone before posterior spinal fusion, that the study is invalidated. Nevertheless it must surely be true that the forces producing, perpetuating and aggravating curvatures of the spine have a basic similarity whether in idiopathic, poliomyelitic or congenital curves. It must be useful to know how far these tendencies to increasing deformity of the spine can be controlled by operative spinal fusion by posterior grafting. Therefore, a series of nearly one thousand patients with scoliosis treated at this hospital, of whom sixty-six had surgical fusion of the thoraco-lumbar spine as part of their treatment, has been reviewed. The proportion of patients with scoliosis who had fusion operations represents 7 per cent of the total. This compares with 6 per cent in Cobb's (1948) series.

It will be understood, therefore, that only the more difficult and the more severe scoliotic deformities were subjected to operative treatment. In studying the tables of analysis it should
be remembered that no single patient with a primary
curve measuring less than 22 degrees was so treated.
There were no lumbar pattern curves in the idiopathic
group that needed fusion; they were treated in other
ways without difficulty. Though radiographic and strictly
mathematical measurement might have suggested a
deformity of severe degree they were not deformities of
clinical significance.

Of the sixty-six patients now reviewed only those with
a follow-up period of from three to ten years are included;
eleven patients with a review of only two years are
excluded. This leaves fifty-five patients: idiopathic scoliosis
thirty-three; paralytic scoliosis eleven; congenital scoliosis
eleven (Table I).

Age—The age of the patients at the time of fusion is shown
in Table II. Only one patient was under ten; most patients
were between eleven and twenty, with an average age of
fifteen. Only five patients were over twenty at the time of
operation, and in them the operation was undertaken for
pain or instability.

METHOD OF TREATMENT

In every case, after initial correction or reduction of
the deformity, the spine was exposed through a midline
incision, the laminae and spinous processes were freshened
subperiosteally and fragmented, the facet joints were denuded of cartilage so far as this was
possible, and the area was packed with thin slivers of bone shaved from the tibia, together
usually with strips of cancellous bone cut from the crest of the ilium on one or both sides,
and sometimes supplemented by frozen bone from the bone bank. As a rule the operation was
done through a large "window" while the corrective plaster was still in position.

<table>
<thead>
<tr>
<th>TABLE I</th>
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<tbody>
<tr>
<td><strong>CLINICAL MATERIAL (FIFTY-FIVE CASES)</strong></td>
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<tr>
<td>---------</td>
</tr>
<tr>
<td>Idiopathic scoliosis ... 33</td>
</tr>
<tr>
<td>Paralytic scoliosis ... 11</td>
</tr>
<tr>
<td>Congenital scoliosis ... 11</td>
</tr>
</tbody>
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<table>
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<tr>
<th>TABLE II</th>
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<tr>
<td><strong>AGE AT WHICH FUSION WAS UNDERTAKEN</strong></td>
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<tr>
<td>---------</td>
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<tr>
<td>* 5-10 years</td>
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<tr>
<td>---------</td>
</tr>
<tr>
<td><strong>Idiopathic scoliosis</strong></td>
</tr>
<tr>
<td><strong>Paralytic scoliosis</strong></td>
</tr>
<tr>
<td><strong>Congenital scoliosis</strong></td>
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* Average age of this group fifteen years.
† In these patients the operation was not done to prevent increasing
deformity but to stabilise a collapsing spine, or to relieve pain.

Usually a new plaster was applied three weeks after operation. An important point in
treatment arises here. No matter what correction by wedged or turnbuckled jackets may have
been gained before operation, a still greater degree of correction was often possible at the time

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This simple wedging jacket is easy to apply, includes an arm or leg (or both), and correction is achieved in stages by spreading the jacket open over a block placed at the fulcrum.

of application of a new plaster three weeks after operation. Sometimes when this plaster was applied on the Abbott frame a surprising degree of additional correction was obtained. Thereafter the spine was immobilised in plaster in recumbency for about six months (sometimes rather less) and continued in an ambulatory plaster jacket for at least a further six months (sometimes rather longer). The plaster jacket was not discontinued until it was thought that there was radiographic evidence of sound union of the surgically fused area of the spine. It must be noted, however, even before examining the results of the study, that radiographic interpretation of "sound fusion" of the bone-grafted spine can always be fallacious.

RESULTS

Table III shows the incidence of relapse after spinal fusion in the three types of scoliosis—the term "relapse" implying a failure to maintain the full correction obtained before operation, not a return to the original deformity.

<table>
<thead>
<tr>
<th></th>
<th>Spines fused</th>
<th>Relapsed</th>
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<tbody>
<tr>
<td>Idiopathic scoliosis</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>Paralytic scoliosis</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Congenital scoliosis</td>
<td>11</td>
<td>6</td>
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</table>

* In this table the term "relapsed" means that the full correction was not maintained. It does not mean that the deformity recurred to its original degree. Many classified as "relapse" were clinically much improved.

The important feature was that in forty-four cases out of the fifty-five (80 per cent) relapse occurred to a greater or lesser degree. This figure is higher than was expected from clinical reviews.
The fact that the highest incidence of relapse occurred in patients with idiopathic scoliosis is also surprising; it was expected that those with paralytic curves would show the highest rate because of their instability and the effects of superincumbent body weight. Another unexpected finding was that the congenital curves were held most successfully, despite the fact that nine of the eleven curves were progressing when treatment was begun.

Table IV shows that, when some correction was gained before operation, relapse occurred after fusion in forty-one out of forty-five cases. This is a disturbing number, and it is to be noted that all the idiopathic curves relapsed, regardless of their pattern. All except two of the paralytic curves relapsed, and those two were in patients over twenty-one in whom fusion was done to stabilise the spine rather than to prevent progression. Two congenital curves remained corrected, but one had full compensation, was not progressing, and was corrected only very slightly: the other, in a boy aged eight, was corrected by 14 per cent and the correction was fully maintained for over ten years.

Of the cases in which no correction was gained before operation (ten in number) three curves became worse: these were progressive when treatment was started. Of the seven that did not become worse four were progressing at the time of treatment but growth of the spine was nearly complete; and the other three were not progressing and growth of the spine was complete.

Fusion therefore failed to maintain the corrected spine but succeeded in holding the uncorrected curve.

**TABLE IV**

<table>
<thead>
<tr>
<th>Type of scoliosis</th>
<th>Curvature corrected before fusion</th>
<th>Relapse after fusion</th>
<th>Curvature not corrected before fusion</th>
<th>Relapse after fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idiopathic</td>
<td>28</td>
<td>28</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Paralytic</td>
<td>11</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Congenital</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>2</td>
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</table>

It is worth mentioning at this point that it is difficult in any type of scoliosis to obtain a true correction of more than 40 degrees by conservative means: in this series only six patients out of the fifty-five gained that amount of correction. Correction of over 20 degrees was common both in thoraco-lumbar idiopathic curves and paralytic curves, but was uncommon in thoracic idiopathic curves and congenital curves—the latter two resembling each other in many respects. Nearly all the thoracic curves that relapsed were in the group corrected by less than 20 degrees: this indicates how resistant they are to correction and how prone they are to relapse.
In Table V the curves are divided into two groups—those corrected by more than 20 degrees and those corrected by less than 20 degrees. The figures show that relapse bore no relation to the amount of correction achieved.

It may thus be safely stated that relapse is to be expected when any correction has been gained.

**ASSESSMENT OF AMOUNT OF RELAPSE**

It has been found preferable, in assessing the amount both of correction and of relapse in a curve, to record figures as a percentage rather than in degrees. For example, a curve of 100 degrees that is corrected to 60 degrees has been corrected by 40 per cent. If that 60-degree curve subsequently relapses to 80 degrees after fusion, a 50 per cent relapse has occurred. This method of recording gives a much clearer picture of the success or failure of the treatment.

Table VI shows that an average correction of 38 per cent in all curves treated was achieved by plaster-jacket correction. The least correction was in the thoracic idiopathic and congenital curves, which showed 26 per cent and 23 per cent correction respectively. The greatest correction (averaging 52 per cent) was achieved, not unexpectedly, in the thoraco-lumbar idiopathic curve patterns.

The important finding is that in all groups the average correction finally maintained after fusion was only 14 per cent. The least correction maintained was in the thoracic idiopathic curve pattern (4 per cent) and the greatest (28 per cent) was in the thoraco-lumbar idiopathic curve pattern, although it could have been as easily seen in the paralytic group.

**TABLE VI**

<table>
<thead>
<tr>
<th>Average Correction Gained by Plaster Jacket and Average Correction Maintained by Surgical Fusion</th>
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<tbody>
<tr>
<td>Average correction gained by plaster jacket</td>
</tr>
<tr>
<td>Idiopathic scoliosis</td>
</tr>
<tr>
<td>Thoracic</td>
</tr>
<tr>
<td>Thoraco-lumbar</td>
</tr>
<tr>
<td>Combined</td>
</tr>
<tr>
<td>Paralytic scoliosis</td>
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<tr>
<td>Congenital scoliosis</td>
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</table>

The other observations summarised in Table VI were the same as would be expected, except that in combined idiopathic curves an average of only 8 per cent correction was maintained when an average of 49 per cent initial correction had been gained: the radiographs of these curves, however, showed that four out of the five had been classified and treated incorrectly as thoraco-lumbar curves rather than as combined curves and, in consequence, fusions inadequate in extent were performed.

Finally, the results confirm that thoracic curves (involving the thorax only) relapsed most of all and that those curves which included more mobile parts of the spine (especially the thoraco-lumbar junction) showed better maintenance of correction.

In brief, as judged from radiographic measurements the amount of correction maintained after fusion was disappointing in the great majority of patients.

**CAUSES OF RELAPSE**

On the basis of these results, some possible causes for relapse after posterior fusion are offered. Some accepted theories are criticised. *Faulty radiographic measurements*—Few authors have mentioned one common finding when considering their "relapsed" cases: it is that an erroneous estimate of correction was made
in the first instance. Often one finds that measurements of curves may be so inaccurate that correction (and therefore subsequent relapse) is more apparent than real. This is illustrated in Figure 8, which shows the standard method by which a curve is measured, using the Lipmann-Cobb construction. The lines drawn between the two end-vertebrae of a curve (these being the vertebrae which are most nearly neutral in tilt and rotation) may be difficult to place in the first instance, and a slight inaccuracy in angle construction may produce quite marked errors when the perpendiculars are drawn to form the angle of tilt. Further, these end-vertebrae are those that have the greatest degree of mobility, and so are easily altered in position to become part of the secondary or compensating curves. Thus even a slight change in the position of such transitional vertebrae will produce marked differences in the angle of measurement of the curve, when clearly the major part of the curve (and certainly the positions of the four central vertebrae) has been unaltered. The end-vertebrae take the greatest strain of superincumbent body weight when the upright position is regained, and all the forces responsible for aggravating a scoliosis encourage these vertebrae to revert to their former position in the primary curve; this happens quickly when they are still insecurely tethered by the recently grafted bone. Measurement of the same curve at this stage will show apparently a “relapse” when no alteration in the position of the central vertebrae in the primary curve has occurred. Figure 9 simplifies this observation.

A false estimate of correction (and so of relapse) can thus easily be made when the Lipmann-Cobb method is used. This happened with several fixed curves in this series and so presumably occurred to a lesser degree with partly fixed curves. What really happened during these various corrections was that the primary curve was altered slightly at each end and the secondary curves were increased or lengthened to produce “compensation.” This term—used now in preference to correction—is difficult to define, but compensation exists when primary and secondary curves come to lie symmetrically on either side of an axis which ideally (but not necessarily) runs between occiput and midline of sacrum. It may involve bringing into the picture a tilt of the head and neck or of the pelvis, but it is usually achieved.

Figure 8—The Lipmann-Cobb method of measuring a curve. It is clear that the 90-degree angle of the four central vertebrae has been unchanged whereas the remainder of the primary curve has been reduced from 143 degrees to 65 degrees.

Figure 9—The black line shows the curve before correction, the dotted line after correction. The common central part of the curve remains unchanged in position and degree.

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within the limits of the spine if there are enough mobile vertebrae above and below the fixed part of the primary curve to form two secondary curves whose measurements together equal the measurement of a primary curve. If head, neck and shoulders, or pelvis and hip joints, take part in the compensatory mechanism it is an indication that true natural spinal compensation has failed.

**Insufficient correction**—True relapse after fusion occurs more readily when the fullest possible correction of the primary curve has not been attempted, on the supposition that compensatory curves could not be fully developed on account of structural changes in them. It is doubtful whether over-correction of a primary curve in such an instance could ever be a danger. Since relapse in the primary curve is almost invariable after posterior fusion, the aim should be to obtain as much correction as possible, disregarding the measurements of compensatory curves. Under-correction is a greater fault than over-correction which—should it ever happen—would always be adjusted later by the normal balancing forces of the body.

**Inadequate fusion**—True relapse may occur when too short an area of the spine has been fused. There is no reliable guide to the extent of spine that should be fused; it depends largely upon the way in which a curve reacts to compensation, on the age of the patient, on the etiology of the scoliosis and its pattern. In children scoliosis may recur after an apparently sound fusion, just as deformity at the hip may recur after arthrodesis of the hip. It is therefore clear that grafting of the growing spine must include not only all the vertebral segments where an established abnormal growth pattern exists, but also an area of apparently unaffected spine which, in the absence of treatment, might have been taken into the primary curve. In adolescent and adult patients the fusion should usually extend from a neutral vertebra at the upper end of the main curve to a vertebra parallel to it at the lower end; and if it be accepted that over-correction is no danger the junctions of primary and secondary curves should be fused most securely. The risk of holding a primary curve over-corrected by immature grafts is negligible, but the chances of an insufficient fusion of a primary curve are great.

**Pseudarthroses**—Another cause of true relapse is a pseudarthrosis in the grafted area. In this series only two examples of pseudarthrosis were found and, in both, continued immobilisation led eventually to sound fusion.

Some surgeons inspect the grafted area of the spine some months after fusion to close, by further grafting, any pseudarthrosis that may be found. If the inspection fails to reveal a pseudarthrosis it does not necessarily mean that the fusion is sound: unless the broad sheet of bone that is usually seen is firmly united with the underlying laminae of all the vertebrae in the fused area (this point cannot easily be determined) pseudarthrosis exists and deformity can progress. We have had an opportunity of examining at operation several spines that appeared soundly fused, but in which there was some recurrence of deformity after correction and fusion over an adequate extent. Nevertheless I do not regard pseudarthrosis as an important or even a common cause of relapse.
POSTERIOR FUSION OF THE SPINE FOR SCOLIOSIS

SUMMARY AND CONCLUSIONS

1. Posterior fusion of the spine in scoliosis cannot be relied upon to maintain correction of the curve or to prevent progression of a vicious resistant curve. It can, however, hold to some extent the correction of a mobile curve and the compensation of a fixed curve.

2. Despite generally poor results as assessed radiographically, the clinical improvement is often gratifying. Most patients claim to be greatly improved: the spine feels stronger, there is less fatigue, and balance is better controlled. Moreover, visible deformity may be improved markedly even though the anatomical correction as observed radiographically is slight (Figs. 10 and 11).

3. It is believed that the true cause of relapse is that the bone formed from sliver grafts remains immature for a long time. Even when incorporated with the immature bone of the child's spine or the mature bone of the adult spine, it remains soft and resilient. When subjected to the stresses and strains of weight bearing and gravity, and then to the unnatural forces which initiated or perpetuated the scoliosis, this immature bone undergoes remodelling to Wolff's Law—like the neck of the femur after slipping of the upper femoral epiphysis. The forces that alter the grafted bone are not only lateral forces but also—perhaps more important—rotational forces. There seems to be a definite link between the degree of rotation and the amount of relapse, correction being maintained best when rotation is least.

I am indebted for much help to Mr H. Osmond-Clarke at whose suggestion this investigation was undertaken. Many of the patients examined were under his care at Oswestry. I am also grateful to Mr Robert Roaf for his help and advice in the preparation of this paper and for the loan of illustrations.

REFERENCES


