PSEUDARTHROSIS AFTER SPINAL FUSION FOR SCOLIOSIS

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A series of 246 patients with scoliosis and attempted fusion had exploration performed six months later in order to detect and treat any pseudarthrosis at an early stage and so prevent subsequent loss of correction. Bilateral or unilateral pseudarthroses occurred in 25 per cent and were of three types—definite, hairline and doubtful. Single unilateral pseudarthroses accounted for 6 per cent and were of little if any clinical significance. The hairline pseudarthroses could not be seen radiologically and were easily missed at exploration. In general the pseudarthroses were least common in the more rigid parts of the spine and in curves which by nature of their etiology or long duration had become most rigid. Neither the initial severity of the curve nor the degree of correction obtained before the initial attempted fusion had any apparent effect on the incidence. Follow-up for an average of four years has shown that a pseudarthrosis is of little significance with regard to the ultimate result provided it is recognised early and repaired.

The major cause of deterioration in a scoliotic curve following attempted spinal fusion is a pseudarthrosis; the curve may relapse to its former severity or even worse if the patient is still growing (Risser 1964).

The reported incidence of pseudarthrosis using radiographs for detection has varied considerably; without internal fixation it has varied from 3 to 68-3 per cent (Ponseti and Friedman 1950; Cobb 1952; Gucker 1956; Blount, Schmidt, Keever and Leonard 1958; Risser and Norquist 1958; Moe 1958; Goldstein 1959; Moe and Gustilo 1964; Winter, Moe and Eilers 1968; Pavon and Manning 1970), with an average of 22-5 per cent. Following the introduction of Harrington instrumentation the reported incidence based on radiographic findings alone has declined and now ranges from 2 to 17 per cent (Winter et al. 1968; Moe and Valuska 1968; Goldstein 1969; Hall and Gillespie 1971; Hall and Spira 1973; Leider, Moe and Winter 1973; Dickson and Harrington 1973), with an average of 6-4 per cent.

Cobb (1952) has stated that the only way to be accurate in a study of pseudarthrosis is to explore each spine, and even then one may be overlooked. Few surgeons have done this routinely at an early stage (Outland, McDowell and Flynn 1964; May and Mauch 1966; Ashley 1967; Graham 1968; Donaldson, Wissinger and Stone 1969; Mathews and Stelling 1970). These series are relatively small but have revealed a much higher incidence, namely, 11 to 69 per cent with an average of 42-3 per cent.

James (1965) reported that his earlier review of 400 patients with scoliosis treated before 1958 was of little value because radiographs were unreliable. Since 1958 it has been his policy to explore all fusion masses at six months. The purpose of this paper is to report the findings and to discuss the various factors that may influence the development of a pseudarthrosis.

CLINICAL MATERIAL

At the Princess Margaret Rose Orthopaedic Hospital, Edinburgh, during the period 1962 to 1973, 246 patients with scoliosis had exploration performed six months after the attempted fusion. There were 162 girls and eighty-four boys, whose ages at spinal fusion ranged from three to twenty-eight years (Fig. 1). One hundred and twenty patients had idiopathic scoliosis, sixty-five had congenital scoliosis and forty-six paralytic scoliosis (Table I). Of the fourteen patients in a miscellaneous group seven had neurofibromatosis, two cerebral palsy, two Kugelberg-Welander syndrome, two Marfan's syndrome and one amyotonia congenita.

Correction before operation in this series was by Risser localiser jacket in 242 patients. In twenty-five patients further correction was obtained by means of

<table>
<thead>
<tr>
<th>Aetiology of scoliosis</th>
<th>Number of patients</th>
<th>Solid fusion</th>
<th>Number of pseudarthroses and incidence (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bilateral</td>
</tr>
<tr>
<td>Idiopathic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>—adolescent</td>
<td>64</td>
<td>44</td>
<td>17 (26-5)</td>
</tr>
<tr>
<td>—juvenile</td>
<td>35</td>
<td>25</td>
<td>4 (11)</td>
</tr>
<tr>
<td>—infantile</td>
<td>22</td>
<td>19</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Congenital</td>
<td>65</td>
<td>54</td>
<td>7 (11)</td>
</tr>
<tr>
<td>Paralytic</td>
<td>46</td>
<td>32</td>
<td>13 (28)</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>14</td>
<td>11</td>
<td>3 (21)</td>
</tr>
<tr>
<td>Totals</td>
<td>246</td>
<td>185</td>
<td>47 (19)</td>
</tr>
</tbody>
</table>

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Harrington instrumentation, a technique now used routinely for the more severe curves. Halo-pelvic traction (O’Brien, Yau and Hodgson 1973) was used in four patients.

Spinal fusion was performed by the technique described by Moe (1958), in which small carefully-shaped blocks of iliac cortico-cancellous bone are punched into the excised interfacetal joints. After operation the patient was kept in bed for four weeks before being allowed home in his Risser jacket. At six months the spine was explored; if solidly fused, the patient wore a Milwaukee brace continuously for six months.

If a pseudarthrosis was discovered it was excised leaving a trench in the fusion mass about 7 millimetres wide over the length of the defect but not down to ligamentum flavum (Fig. 2). The walls were undercut to expose bleeding cancellous bone. A small carefully-shaped block of cortico-cancellous bone from the iliac crest was gently impacted into the trench, leaving the cortical surface of the graft just beneath that of the fusion mass (Fig. 3). The patient was then placed in a new Risser localiser jacket. After five months re-exploration limited to the area of repair was performed, and if solid a Milwaukee brace was worn for six months.
FINDINGS AT EXPLORATION OF THE FUSION MASS

Usually the periosteum strips easily, exposing a sheet of cortical bone which extends between the neutral vertebra above and below and out to the tips of the transverse processes in the thoracic region (Fig. 4). Often the only recognisable structures are the spinous processes, now just small rounded projections between which may be partially across the fusion mass. Any movement at the pseudarthrosis is minimal, and unless all the soft tissue is carefully cleared it will be missed. Histological examination has shown that the crack contains fibrocartilage.

Thirdly there is the doubtful pseudarthrosis. By this we mean an area in which the periosteum is more adherent than in adjacent areas and the cortical bone appears soft. If this bone is curetted away a defective area in the cancellous bone is exposed.

Small gaps representing the interlaminar spaces. In the lumbar region the bony anatomy is not quite so completely obliterated and the sites of the interfacetal joints can often be located.

The first suspicion of a pseudarthrosis comes during the stripping of the periosteum. If it does not strip easily and is bound to the underlying bone by fibrous tissue, that area should be carefully inspected for the presence of a pseudarthrosis. Starting from the top of the fusion mass, each segment of the vertebral column is meticulously cleared of all soft tissue. The spinous processes of neighbouring vertebrae are grasped by sequestrum forceps and any movement, however small, is noted.

Types of pseudarthrosis—There are three basic types. Firstly, there is the definite pseudarthrosis, which is the most common type and presents as an irregular crevice filled by fibrous tissue (Fig. 5). The crevice may extend completely across the fusion mass (bilateral pseudarthrosis), when motion between the vertebrae is easily elicited, or only part of the way across either on the concave or convex side of the curve (unilateral pseudarthrosis), with a solid bar of bone on the other side.

Secondly, there is the hairline pseudarthrosis, which is much less common and very difficult to see at exploration. Again it may extend either completely or only on the side opposite the concavity of the curve.

Patients with pseudarthrosis—Fifty-four out of the 246 patients were found to have a pseudarthrosis at exploration. Seven patients thought to have a solid fusion at revision later developed increasing deformity and required re-exploration. This was performed from twelve to thirty-three months (average twenty-one months) after the original attempt at fusion, and all seven patients were found to have a pseudarthrosis. Three had only a single bilateral hairline pseudarthrosis, which despite a rather innocuous appearance had already given rise to a serious loss in correction (average 21 degrees). Of the remaining four patients, three had a single bilateral definite pseudarthrosis and one had two bilateral definite pseudarthroses.

The total number of patients developing a pseudarthrosis was therefore sixty-one, giving an overall rate of 25 per cent. Fourteen of these patients had only a single unilateral pseudarthrosis of doubtful importance. Therefore if we consider only the forty-seven patients with bilateral pseudarthroses, the rate is 19 per cent (Table 1).

Number of pseudarthroses—Thirty-seven of the sixty-one patients had a pseudarthrosis at only one level, fourteen at two, five at three, four at four and one at seven levels. This gives a total of 103 pseudarthroses after 2,040

![Figure 3](attachment:image3.png)

**FIG. 3**
Same case as in Figure 2. Blocks of cortico-cancellous bone from the iliac crest have been punched into the trench.
attempts at fusion at the various vertebral levels. The overall risk of pseudarthrosis at any one level was therefore 5 per cent.

Site of the pseudarthroses—The distribution of the various types of pseudarthrosis is shown in Figure 6. There were fifty-eight definite bilateral pseudarthroses. There were sixty-one patients who had their pseudarthroses repaired, thirty-five underwent re-exploration three to fourteen months later (average six months). This is now done routinely.

Six patients were found to have a single bilateral definite pseudarthrosis which had remained unhealed, but thirty-seven definite unilateral pseudarthroses, twenty-two on the convex side and fifteen on the concave side. There were four hairline pseudarthroses, all bilateral. Four pseudarthroses were of the doubtful variety, two on the concave side and two bilateral.

Re-exploration of the repaired pseudarthroses—Of the remaining twenty-nine had solid fusion. Of the six unhealed pseudarthroses, two were between T.9 and T.10, two between T.12 and L.1 and two in the lumbar region. All six were again repaired as before. Only one spine was re-explored for a second time five months after the second repair and had soundly fused.

Fig. 4
A photograph taken at exploration showing solid fusion in the thoracic region.

Fig. 5
In this photograph two definite bilateral pseudarthroses in the thoracic region are clearly seen.

THE JOURNAL OF BONE AND JOINT SURGERY
FOLLOW-UP

The 246 patients were followed for periods varying from one to sixteen years (average four years). The average follow-up for the thoracic, thoraco-lumbar and double curves of each aetiology is shown in Tables II, III and IV, along with the loss in correction during and after the first year. No patient was dismissed until skeletally mature.

Loss of correction in the first year—In those patients whose spinal fusion was found to be solid the average loss of correction in the first year for a thoracic curve was 5 degrees and for a thoraco-lumbar curve 6 degrees. The greatest loss occurred in paralytic scoliosis and the least in congenital scoliosis.

Aetiology of the scoliosis (Table I)—The lowest incidences occurred in infantile idiopathic scoliosis (14 per cent) and congenital scoliosis (17 per cent). These curves by nature of their long duration are often the most rigid types of scoliosis and therefore we think the most likely to proceed to solid fusion.

Two of seven patients with neurofibromatosis and one of two patients with Marfan’s syndrome developed a pseudarthrosis but these numbers are too small for statistical analysis. Of the six patients found to have a pseudarthrosis still present after attempted repair, three had adolescent idiopathic scoliosis, two congenital scoliosis and one Marfan’s syndrome.

Site of the curve—The only level at which a pseudarthrosis did not occur was between T.2 and T.3. Fusion at this level, however, was attempted only twenty-three times. The majority were found between T.6 and L.3, where the greatest number of fusion attempts took place (Fig. 6). However, if we compare the number of pseudarthroses at each vertebral level and compare this with the number of times fusion was attempted at that level we see that the highest incidence of pseudarthroses occurred from T.9 to S.1 and the lowest in the mid-thoracic region (Fig. 7).

The vertebral levels with the highest rates of pseudarthrosis were in the more mobile part of the spine. This mobility we think is probably a predisposing factor.

Unilateral pseudarthroses were more common on the convex side of the curve where the grafted areas were subject to a distracting force and therefore we think more at risk.

Initial severity of the curve—The size of the initial curve before correction had no apparent effect (Tables II, III and IV).

Degree of correction—There was no significant difference...

![Histogram showing the number and type of pseudarthroses at each vertebral level.](image)

In those patients who were found to have a pseudarthrosis the average loss for a thoracic curve was 7 degrees and for a thoraco-lumbar curve 9 degrees.

Loss of correction after the first year—Both those patients with a solid fusion and those who had had a pseudarthrosis repaired lost a little correction after the Milwaukee brace was removed. In those with sound fusion the thoracic curves lost on average 7 degrees and the thoraco-lumbar curves 4 degrees.

In those patients with a proven pseudarthrosis which had been repaired the thoracic curves lost on average 6 degrees and the thoraco-lumbar curves 8 degrees. The greatest loss occurred in paralytic scoliosis.

FACTORS INFLUENCING THE DEVELOPMENT OF A PSEUDARTHROSIS

Age and sex—No one age group was found to be more susceptible (Fig. 1) and the distribution between the sexes was equal.
in the degree of correction obtained in those spines which
developed a pseudarthrosis and those that did not (Tables
II, III and IV). Risser and Norquist (1958), however,
found pseudarthrosis more common in patients with the
most correction.

**Technique of fusion**—The interfacetal type of fusion
popularised by Moe (1958) gives fewer pseudarthroses
spine. In our series seven out of twenty-five patients with
Harrington instrumentation were affected (28 per cent).
Graham (1968) explored forty-five patients with idiopathic
scoliosis one to two years after a spinal fusion with
Harrington rod correction and found an incidence of
55.5 per cent. In our experience the presence of a
Harrington rod does not seem to lower the pseudarthrosis

![Figure 7](image)

**FIG. 7**
A histogram showing the incidence of pseudarthrosis at each vertebral level.

**TABLE II**
**Details of 120 Cases of Idiopathic Scoliosis (Infantile, Juvenile, Adolescent)**

<table>
<thead>
<tr>
<th>Solid fusion</th>
<th>Pseudarthrosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of curve</strong></td>
<td><strong>Number of patients</strong></td>
</tr>
<tr>
<td>Thoracic</td>
<td>68</td>
</tr>
<tr>
<td>Thoraco-lumbar</td>
<td>16</td>
</tr>
<tr>
<td>Double</td>
<td>2</td>
</tr>
</tbody>
</table>

(Blount et al. 1958). We have not found it necessary to
decorticlate the bone or to add bone grafts because we
feel that the careful stripping of the periosteum and
meticulous clearance of all soft tissues provide an osteogenic
stimulus in the growing child.

Harrington instrumentation is said to have helped
lower the incidence of pseudarthrosis by stabilising the
rate, although the support offered by the rod may prevent
the loss of correction which is often the only indication of
a pseudarthrosis, and once the spine stops growing the
tendency to lose correction becomes very much less.

**Plaster jacket immobilisation**—The majority of our
patients were allowed to walk at four weeks in a localiser
jacket. The use of localiser jackets is said to have lowered

THE JOURNAL OF BONE AND JOINT SURGERY
the incidence of pseudarthrosis (Risser and Norquist 1958; Brown 1965) and to have allowed earlier mobilisation of the patient without apparent increase in the pseudarthrosis rate (Risser and Norquist 1958; Leider et al. 1973).

Ponseti and Friedman (1950) found that the pseudarthrosis rate was not influenced by the use of a cast for longer than five months. We have found, however, that even though a fusion was seen to be solid at six months the bone mass was not sufficiently mature to prevent bending and required further protection for six months in a Milwaukee brace. Even when the brace was removed at one year a solid fusion mass would bend a little, causing a slight loss of correction before becoming stable.

**DISCUSSION**

This study has shown that a pseudarthrosis after spinal fusion for scoliosis is a not uncommon finding when every spine is explored at six months. Most surgeons do not do this, but rely on various oblique radiographic projections to detect a pseudarthrosis. Unfortunately these radiographs are often equivocal. A hairline pseudarthrosis cannot be seen radiographically. This type is seen only at exploration and even then it is easily missed, as were three in our series.

A rapid loss of correction of over 15 to 20 degrees is generally accepted as an indication of a pseudarthrosis, which may or may not be visible radiographically. The seven patients in our series with a pseudarthrosis which had been missed at exploration presented in this manner. James (1965) found that it was easier to prevent the loss of correction due to a pseudarthrosis by routine re-exploration and repair if necessary, rather than to wait and try to regain correction once it had been lost.

The follow-up in the present series has shown that in the first year both those patients with a solid fusion and those who had had a pseudarthrosis repaired lost a little correction while still in a cast or Milwaukee brace. This loss was on average 3 degrees greater in patients

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with a repaired pseudarthrosis. After the first year there was again a slight loss in correction after the Milwaukee brace had been removed and while the fusion was maturing, and this was on average 2 degrees greater when a pseudarthrosis had been repaired. From these findings we see that the final difference in the amount of correction lost between curves which had been found solid and those with a pseudarthrosis successfully treated is small, being of the order of 5 degrees. Therefore we can say that the presence of a pseudarthrosis is of little significance with regard to the ultimate result provided it is recognised early and repaired.

ADDENDUM

Nineteen surgeons of all grades of experience were involved in fusing these 246 spines. During the year 1975–76 sixty-two spines were fused by the two authors. Forty-four of these patients had Harrington rod instrumentation. All of these spines have now been re-explored and a single pseudarthrosis was found in only two patients, giving a pseudarthrosis rate of 3.2 per cent. One was a hairline pseudarthrosis found between the twelfth thoracic and first lumbar vertebrae in a long idiopathic thoraco-lumbar curve, and the other a definite bilateral pseudarthrosis at the lumbo-sacral junction in a patient with neurofibromatosis. Both of these patients had Harrington rod instrumentation.

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REFERENCES


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