Excision of Hemivertebrae and Wedge Resection in the Treatment of Congenital Scoliosis

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ABSTRACT: The results of anterior and posterior excision or wedge resection of a hemivertebra and arthrodesis of the spine were reviewed retrospectively for thirty-seven patients. The degree of correction that was obtained and maintained, the balance and alignment of the trunk, changes in pelvic obliquity, and associated complications were evaluated. The average age at the time of the operation was twelve years (range, six months to forty-two years). The average duration of follow-up was six years (range, two to nineteen years). The resection was at the mid-thoracic level in six patients, at the thoracolumbar level in nine, at the mid-lumbar level in seven, and at the lumbar-sacral level in seventeen. (Two patients had an excision of a hemivertebra at two levels.) Instrumentation was used in twenty-eight patients. Postoperatively, all patients were managed with a body cast, with a unilateral or bilateral pantaloon extension, for four to six months. The instrumentation allowed early walking and the use of a unilateral rather than a bilateral pantaloon extension.

The index curve (the curve containing the hemivertebra) averaged 54 degrees (range, 18 to 132 degrees) preoperatively, 33 degrees (range, 0 to 105 degrees) postoperatively, and 35 degrees (range, 0 to 110 degrees) at the most recent follow-up evaluation. A measurable improvement in balance was achieved and maintained in nineteen patients. Pelvic obliquity did not change appreciably, as it was related primarily to limb-length inequality in this series.

Complications included a temporary nerve-root lesion in seven patients, a permanent neurological deficit involving the first sacral nerve root in one patient, a pseudarthrosis in three patients, and a wound infection in three patients. Six patients had extension of the arthrodesis to include additional vertebrae.

The natural history of congenital scoliosis associated with hemivertebrae is unpredictable: the condition can have a totally benign course or one of severe, relentless progression, especially when it is combined with a unilateral unsegmented bar. The curves that progress often necessitate operative treatment, and the usual procedure has been posterior spinal arthrodesis. The degree of correction achieved with operative intervention is limited because of the rigid nature of the curve in congenital scoliosis.

Anterior and posterior hemiepiphyseodesis combined with arthrodesis of the convexity of the curve has been used to treat scoliosis secondary to hemivertebrae. Andrew and Piggott, as well as Winter et al., found that, although this procedure can arrest progression and provide the opportunity for subsequent improvement of the curve, the results are somewhat unpredictable. The excision of hemivertebrae has long intrigued spinal surgeons; as early as 1928, Royle reported on such a procedure in a patient in Australia. Compere, in 1932, reported a good short-term result in each of two patients who had had excision of a hemivertebra; however, one patient died of pneumonia eighteen months after the operation, and the other patient had severe, progressive kyphosis. Wiles, in 1951, reported on two patients (one had been operated on in 1941 and the other, in
1946) who had a 90-degree kyphosis after the operation. These reports of poor results and serious complications probably dampened surgeons’ enthusiasm for excision of hemivertebrae.

In the past, some surgeons removed the hemivertebra only, hoping to achieve a fusion of that level. However, healing sometimes failed to occur, resulting in progressive kyphosis, as noted by Compere and by Wiles. Modern surgeons, led by Leatherman\(^7\), realized that inclusion of the entire index curve in the arthrodesis was essential to obtain a solid fusion. The concept that shortening of the convexity of a curve, especially in patients who have congenital scoliosis, may be much safer than pure lengthening of the concavity probably originated with Leatherman. Leatherman began to perform excisions of hemivertebrae in the early 1960’s. His first report\(^7\) was published in 1973 and was followed by a more detailed, extensive report\(^8\) in 1979. In the latter report, Leatherman and Dickson reviewed the results of an anterior wedge resection and a subsequent posterior wedge resection with instrumentation in sixty patients, fifty of whom had scoliosis. The authors reported an average correction of 44 per cent (from 77 to 43 degrees).

A review of the most recent literature\(^2,7,12\) suggests that earlier pessimism about excision of hemivertebrae has been overcome and that single-stage procedures have become relatively safe and acceptable when performed by highly skilled spine surgeons. However, despite the initial good results with these procedures, previous experience with congenital deformities has shown that longer follow-up is needed in order to evaluate the effectiveness of operative intervention. We present the long-term results of excision of hemivertebrae in thirty-seven patients.

Materials and Methods

Of 1750 patients seen at Fairview Riverside Hospital, Minneapolis, and Gillette Children’s Hospital, St. Paul, because of a congenital spinal deformity, 862 were managed with some form of operative intervention. Forty-three of these patients had an excision of a hemivertebra or a wedge resection, and thirty-seven of them were followed for at least two years (average, six years; maximum, nineteen years). Six of the patients were male and thirty-one were female. The hospital and clinic records were reviewed with respect to the demographic data; the medical and operative histories; the results of preoperative diagnostic studies; the operative data, including the type of instrumentation, the levels of the arthrodesis, and the type of external immobilization; the postoperative management; and any complications. Measurements of the frontal and sagittal curves, the degree of decompensation of the spine, and pelvic obliquity were obtained from roentgenograms that had been made at the initial visit; at the preoperative evaluation; immediately postoperatively; at the time of discharge; and at the six-month, one-year, two-year, and most recent follow-up examinations. All of the roentgenograms were measured again by one of us (D. C. H.), to ensure consistency in the evaluation of the landmarks and the measurements of the curve.

The average age was two years (range, newborn to thirteen years) at the time of the initial diagnosis, eleven years (range, newborn to forty-two years) at the time of presentation at our institutions, twelve years (range, six months to forty-two years) at the time of the index operation, and eighteen years (range, nine to forty-five years) at the time of the latest follow-up evaluation.

Clinical examination revealed neurological deficits (sensory, motor, or mixed) in seventeen of the thirty-seven patients, decompensation of the trunk of more than one centimeter in twenty-five of thirty patients for whom this information was available, and a limb-length discrepancy of more than one centimeter in nine of twenty-one patients for whom measurements were available.

Preoperatively, twenty-five patients had been able to walk independently, eleven were community ambulators, and one was paraplegic. Three patients had used a prosthesis and five had used some type of orthosis for assistance with walking; one patient had used a wheelchair. None of the patients had a myelomeningocele, although many had a less severe form of dysraphism.

Myelograms revealed abnormal findings in eight of the twenty-four patients for whom they were available, and intravenous pyelograms showed abnormalities in ten of the twenty-eight patients who had such studies. As these findings were addressed by the appropriate specialists, the details are not relevant for the purposes of this paper. Magnetic resonance imaging studies, performed for three patients, were normal.

Preoperatively, none of the twenty-four patients who were less than thirteen years old had symptoms, whereas seven of the thirteen patients who were thirteen years old or more reported low-back pain. The indications for operative intervention were progression of the curve in thirty patients, progression and pain in three, progression and concerns about the cosmetic appearance in three, and a poor cosmetic appearance and dyspnea on exertion in one patient.

Eighteen patients had had a previous arthrodoses of the spine, twenty-two had had an operation for another medical or orthopaedic condition, and nineteen had used a spinal orthosis for an average of five years (range, six months to fourteen years) before the index operation.

The index curve, which was always structural, included the hemivertebra that was excised and the level of the wedge resection. Curves cephalad and caudad to the index curve were considered secondary curves and were not always structural. In order to minimize the inaccuracy inherent in determining the exact level of the anomalous vertebrae, we arbitrarily divided the spine into four segments: a mid-thoracic segment (the fifth
through ninth thoracic vertebrae), a thoracolumbar segment (the tenth thoracic through second lumbar vertebrae), a mid-lumbar segment (the third and fourth lumbar vertebrae), and a lumbosacral segment (the fifth lumbar through first sacral vertebrae). Decompensation was defined as the lateral deviation, from the middle of the sacrum, of a vertical line dropped from the spinous process of the seventh cervical vertebra to the horizontal. This deviation was measured on an anteroposterior roentgenogram of the entire length of the spine, made with the patient standing or sitting (Fig. 1). The degree of pelvic obliquity was determined either by measurement of the height between the most proximal point of each iliac crest and the horizontal and calculation of the difference between the two heights, or as the angle between a line connecting the most proximal points on the iliac crests and the horizontal (Fig. 2).

All patients had an anterior and a posterior procedure. With the anterior approach, twenty-six patients had an excision of a hemivertebra, ten had an excision and a wedge resection, and one had a wedge resection. With the posterior approach, eighteen patients had an excision of a hemivertebra, seventeen had an excision and a wedge resection, and two had a wedge resection. The excision was at the mid-thoracic level (between the fifth and ninth thoracic vertebrae) in six patients, at the thoracolumbar level (between the tenth thoracic and the second lumbar vertebrae) in nine, at the mid-lumbar level (the third or fourth lumbar vertebra) in seven, and at the lumbosacral level (between the fifth lumbar and the first sacral vertebra) in seventeen. (Two patients had an excision of a hemivertebra at two levels.)

There were two single-stage procedures, thirty two-stage procedures, four three-stage procedures, and one four-stage procedure.

Of the two patients who had a single-stage procedure, one was a six-month-old infant who had excision of the second lumbar vertebra, performed through a single oblique incision, while in the left lateral decubitus position. The other patient had a combined anterior and posterior excision of the third lumbar vertebra.

Of the four patients who had a three-stage procedure, one had a first stage (one year before the second and third stages) that consisted of an arthrodesis at each end of the curve; this was done in an effort to stimulate new-bone formation and to increase bone stock so that secure fixation of the instrumentation could be obtained. In two patients, the third stage consisted of retightening or adjustment of the instrumentation to achieve additional correction. For the fourth patient, the second stage was cut short because of an excessive operative time and concerns about bleeding, necessitating an additional stage to place the instrumentation.

The one patient who had a four-stage procedure had initially been placed in halo-femoral traction after anterior disectomies from the twelfth thoracic to the first sacral vertebra and excision of the hemivertebra at the level of the second lumbar vertebra. This was followed
by a release of the tethered cord (the second stage), an anterior resection of the hemivertebra at the level of the eighth and tenth thoracic vertebrae (the third stage), and a posterior arthrodensis from the fifth cervical to the first sacral vertebra after a posterior resection of the hemivertebrae at the eighth and tenth thoracic and the second lumbar vertebrae (the fourth stage).

**Operative Technique**

Several different methods were used to excise the hemivertebra and to perform a wedge resection. In most of the patients, this was a two-stage procedure: an anterior resection, followed by a posterior procedure approximately seven days later. More recently, we have performed the anterior and posterior procedures simultaneously.

The anterior resection was done through a retroperitoneal, retopleural, or transpleural approach, depending on the level of the resection. The disc material on either side of the hemivertebra was removed first, and this was followed by removal of the cancellous bone of the vertebral body. The posterior cortex of the vertebral body and the anterior half of the pedicle were the last osseous structures to be removed. The dura was always visualized. Autologous bone graft from either the ribs or the vertebra was morselized and placed loosely in the resected area; the use of large quantities of bone graft was avoided because this could limit the degree of correction. The posterior resection was done through a posterior midline incision. The posterior elements at the level corresponding to the anterior resection were removed. A posterior arthrodensis of the entire curve was then performed. Instrumentation was used in twenty-eight patients. Autogenous bone grafts were usually used, but allografts were used occasionally.

Anterior instrumentation was not used in any patient. Twenty-eight patients had posterior instrumentation. Harrington compression rods were inserted in twelve; Harrington compression and distraction rods, in twelve; Harrington compression and Luque rods, in one; Luque rods alone, in one; a Luque-Galveston construct, in one; and a Cotrel-Dubousset transverse traction-compression device, in one.

For the first four to six months after the operation, all patients wore some form of cast or brace full-time. Some patients remained at complete bed rest for several months, while others were permitted to walk for a specified period of time each day. The duration of immobilization varied, depending on the type of curve, the age of the patient, the type of instrumentation, and the discretion of the surgeon. The average duration of brace wear was two years (range, four months to nine years). Patients who did not have instrumentation had external support for an average of five years, compared with one year for those who did have instrumentation. The prolonged use of a brace was necessary in patients who had a curve that involved another segment of the spine that had not been considered to need operative intervention.

The patients were allowed to walk at an average of eighty days (range, three to 201 days) postoperatively (137 days [range, seventy-eight to 183 days] for the patients who had not had instrumentation, compared with fifty-five days [range, three to 201 days] for those who had).

**Results**

For the anterior procedures, the average operative time was 179 minutes (range, eighty to 345 minutes) and

**TABLE 1**

<table>
<thead>
<tr>
<th>Correction</th>
<th>Index Curve* (Degrees)</th>
<th>Degrees*</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop.</td>
<td>54 (18-132)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-op.</td>
<td>33 (0-105)</td>
<td>21 (6-56)</td>
<td>39</td>
</tr>
<tr>
<td>Follow-up</td>
<td>1-yr. 36 (0-105)</td>
<td>18 (2-47)</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>2-yr. 35 (0-110)</td>
<td>19 (0-42)</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Latest 35 (0-110)</td>
<td>19 (2-40)</td>
<td>35</td>
</tr>
</tbody>
</table>

*The measurements are given as averages, with the ranges in parentheses.

Graph showing the improvement in the index curve at the most recent follow-up examination. The values above the bars represent the number of patients who had the degree of improvement.
the average estimated blood loss was 885 milliliters (range, 100 to 7200 milliliters). If the patient who had a laceration of the iliac vein and a blood loss of 7200 milliliters was excluded from the calculations, the average estimated blood loss would be 668 milliliters (range, 100 to 2600 milliliters). For the posterior procedures, the average operative time was 225 minutes (range, 120 to 375 minutes) and the average estimated blood loss was 910 milliliters (range, fifty to 5100 milliliters). If the patient who had a dural tear (5100 milliliters of blood loss) was excluded, the average estimated blood loss would be 775 milliliters (range, fifty to 2700 milliliters).

**Correction of the Index Curve**

The average index curve was 54 degrees (range, 18 to 132 degrees) preoperatively, 33 degrees (range, 0 to 105 degrees) postoperatively, and 35 degrees (range, 0 to 110 degrees) at the latest follow-up examination. There was an average correction of 21 degrees (range, 6 to 56 degrees) immediately postoperatively and of 19 degrees (range, 2 to 40 degrees) at the latest follow-up evaluation (Table I).

It is important to evaluate improvement with respect to the severity of the preoperative curve; therefore, the amount of improvement was calculated individually for each patient. This was done by comparing the amount of improvement at the latest follow-up evaluation with the preoperative measurement of the index curve. The curves improved an average of 44 per cent (range, 2 to 100 per cent) (Table II). At the latest follow-up visit, the index curve in twenty-four patients had improved by more than 15 degrees (Fig. 3). No difference was found in the amount of correction obtained and maintained in patients who did and did not have instrumentation. The average index curve was 21 degrees postoperatively, 20 degrees at one year, and 20 degrees at the latest follow-up examination in the patients who had instrumentation, compared with 24, 21, and 19 degrees, respectively, in the patients who did not have instrumentation.

**Correction of the Secondary Curve**

Roentgenographic evaluation was possible for fifty-two secondary curves postoperatively and fifty-eight curves at the latest follow-up examination. Some patients had more than one secondary curve. The average secondary curve was 35 degrees (range, 5 to 125 degrees) preoperatively, 23 degrees (range, 1 to 29 degrees) postoperatively, and 28 degrees (range, 0 to 80 degrees) at the latest follow-up evaluation.

At the latest follow-up examination, twelve secondary curves were immediately caudad to the index curve and forty-six were cephalad. Of the forty-six cephalad curves, thirty were adjacent to the index curve, thirteen were one curve cephalad, and three were two curves cephalad. At the latest follow-up examination, thirty-five of the fifty-eight secondary curves had improved, twelve had not changed, and eleven had become worse. Seven of the twelve secondary curves caudad to the index curve had improved and five had not changed. Twenty-eight of the forty-six secondary curves cephalad to the index curve had improved, seven had not changed, and eleven had become worse. Of the eleven curves that had increased, only one was immediately cephalad to the index curve; the others were at least one curve cephalad.
Measurements of decompensation preoperatively (squares) and postoperatively (circles) for thirty-three patients. The degree and direction of the change in decompensation is shown by the lines connecting the two measurements for each patient.

**Kyphosis and Lordosis**

The average thoracic kyphosis was 39 degrees (range, –19 to 132 degrees) preoperatively and 36 degrees (range, –25 to 90 degrees) at the latest follow-up examination. The average lumbar lordosis was –38 degrees (range, –100 to 25 degrees) preoperatively and –37 degrees (range, –92 to 21 degrees) at the latest follow-up evaluation. While these measurements do not show much change over-all, some patients had a dramatic improvement in the sagittal curve. The changes in the amount of kyphosis ranged from an increase of 15 degrees to a decrease of 53 degrees. Similarly, the changes in lordosis ranged from an increase of 35 degrees to a decrease of 27 degrees. No patient had a loss of lumbar lordosis as a result of operative intervention.

**Balance**

Comparative measurements of the alignment of the trunk (decompensation), obtained from anteroposterior roentgenograms that were made with the patient stand-

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**Fig. 5-A, 5-B, and 5-C**: Case 17. Roentgenograms of a four-year-old girl who had marked decompensation of the spine to the left as the result of a hemivertebra on the right side at the fifth lumbar level. PO = pelvic obliquity.

Fig. 5-A: The index curve and the secondary curve cephalad to it each measured 21 degrees.

Fig. 5-B: One year after resection of the lumbosacral hemivertebra and an arthrodesis from the fourth lumbar vertebra to the sacrum, performed in two stages. A Harrington compression rod was used to close the wedge. The decompensation was corrected from thirty-two to nine millimeters; the primary curve, from 21 to 0 degrees; and the secondary curve, from 21 to 8 degrees.

Fig. 5-C: Eleven years after the operation, when the patient was fifteen years old, the decompensation was six millimeters, the index curve had remained at 0 degrees, and the secondary curve had fully corrected to 0 degrees.
TABLE III
DATA ON THE EIGHT PATIENTS WHO HAD POSTOPERATIVE NEUROLOGICAL DEFICITS

<table>
<thead>
<tr>
<th>Case</th>
<th>Level of Excision</th>
<th>Side of Convexity</th>
<th>Deficit</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>T10</td>
<td>R</td>
<td>Weakness, L lower extrem.: bladder incontinence</td>
<td>Resolved after tethering of cord released</td>
</tr>
<tr>
<td>16</td>
<td>L5</td>
<td>L</td>
<td>Weakness, L quad. (L4); loss of patellar reflex; hypoesthesia along dermatome (L4)</td>
<td>Resolved spontaneously after discharge from hospital</td>
</tr>
<tr>
<td>26</td>
<td>T9</td>
<td>L</td>
<td>Weakness, R ext. hallucis longus (L5); bowel incontinence</td>
<td>Resolved after lessening of traction</td>
</tr>
<tr>
<td>32</td>
<td>S1</td>
<td>L</td>
<td>Weakness, R ext. hallucis longus (L5)</td>
<td>Resolved spontaneously before 2nd stage of operation</td>
</tr>
<tr>
<td>33</td>
<td>L5</td>
<td>R</td>
<td>Weakness, R quad. (L4); loss of patellar reflex; hypoesthesia along dermatome (L4)</td>
<td>Resolved spontaneously</td>
</tr>
<tr>
<td>34</td>
<td>L5</td>
<td>R</td>
<td>Weakness, R quad. (L4); loss of patellar reflex; hypoesthesia along dermatome (L4)</td>
<td>Resolved spontaneously before discharge from hospital</td>
</tr>
<tr>
<td>36</td>
<td>L5</td>
<td>L</td>
<td>Brachial plexopathy</td>
<td>Resolved spontaneously</td>
</tr>
<tr>
<td>37</td>
<td>L5</td>
<td>R</td>
<td>Weakness, R gastroc. (S1)</td>
<td>Permanent</td>
</tr>
</tbody>
</table>

ing or sitting, were available for thirty-three patients (Fig. 4). Preoperatively, the average deccompensation was thirty-seven millimeters (range, seven to 157 millimeters); one year after the operation, it was nineteen millimeters (range, zero to sixty-six millimeters); and at the latest follow-up examination, it was twenty-five millimeters (range, zero to ninety-seven millimeters). We arbitrarily decided that a change of less than ten millimeters was not important. According to this parameter, alignment of the trunk was improved in seventeen patients, unchanged in thirteen, and worse in three at the latest follow-up evaluation.

We compared the improvement in deccompensation in patients who had had operative correction with and without instrumentation. The amount of initial correction was better without instrumentation, but this improvement was not maintained. There was a considerable difference between the two groups with regard to maintenance of the correction. When instrumentation had not been used, the average improvement was twenty-five millimeters at one year, sixteen millimeters at two years, and two millimeters at the latest follow-up examination; when instrumentation had been used, the average improvement was thirteen, fifteen, and fifteen millimeters, respectively.

**Pelvic Obliquity**

The average difference in height between the most proximal point on the iliac crests was seventeen millimeters (range, zero to 108 millimeters) preoperatively and seventeen millimeters (range, zero to eighty-three millimeters) at the latest follow-up examination. The average angle between the line joining the iliac crests and the horizontal was 7 degrees (range, 0 to 27 degrees) preoperatively and 6 degrees (range, 0 to 24 degrees) at the latest follow-up evaluation; this represented no change. We arbitrarily decided that a change of less than five millimeters was normal. According to this criterion, pelvic obliquity improved in six patients, was unchanged in sixteen, and was worse in eleven at the latest follow-up visit. These measurements suggest that it was the limb-length discrepancy, rather than the changes in the spine, that affected pelvic obliquity in our patients.

**Illustrative Case Reports**

The following case reports highlight the principles underlying the treatment of congenital scoliosis secondary to a hemivertebra and the long-term results that can be achieved by excision of a hemivertebra in a patient who has decomposition.

**Case 6.** The course of events in the case of this nine-year-old girl highlights the difficulties in obtaining normal or improved alignment of the spine with only a posterior arthrodesis. The patient was first seen by the senior one of us (R. B. W.) in 1975. She had had a posterior arthrodesis of the involved segments when she was three years old. At presentation, she had a long curve that extended from the second thoracic to the second lumbar vertebra and that measured 70 degrees (Fig. 6-A).

A double anterior wedge osteotomy was performed in two separate procedures, two weeks apart; the cephalad wedge was between the ninth and tenth thoracic vertebrae and the caudal wedge, between the eleventh and twelfth thoracic vertebrae. Correction was
obtained postoperatively, over a period of five months, with use of a halo-turnbuckle cast. At the end of the five months, the correction was 38 degrees (Fig. 6-B).

Eight months after the operation, the curve was 36 degrees (Fig. 6-C). Nineteen years after the operation, the curve was 33 degrees and decompensation was twenty-five millimeters (Fig. 6-D). The improvements in alignment and appearance were maintained (Figs. 6-E and 6-F).

Case 10. A nineteen-month-old girl had a rigid curve and severe decompensation of the spine. The preoperative roentgenogram showed a 35-degree angular deformity in the mid-lumbar segment of the spine and a severe pelvic obliquity (Fig. 7-A). A forced side-bending roentgenogram of the spine, made with the patient supine, clearly showed that the pelvis and spine could not be brought into normal alignment without excision of the hemivertebra (Fig. 7-B). The index operation with insertion of a Cotrel-Dubousset compression rod resulted in complete correction of the curve (Fig. 7-C).

At the two-year follow-up examination, there was maintenance of correction and alignment (Fig. 7-D).

Case 8. The sequence of events in the case of this thirteen-year-old girl who had multiple congenital anomalies of the spine highlights the problems that can result from a failure to analyze all of the components of the curve before the operation. The patient was first seen in 1975 with a 48-degree left lumbar-sacral curve secondary to a hemivertebra at the fourth lumbar level. She also had a rigid right thoracolumbar curve. If the hemivertebra had been excised and the third and fifth lumbar vertebrae had been brought into alignment, the patient would have had decompensation to the left because of the rigid right thoracolumbar curve (Fig. 8-A). Thus, she was managed with an anterior excision of the hemivertebra followed, a week later, by a posterior arthrodesis with Harrington compression and distraction rods extending from the mid-thoracic level to the sacrum. The two curves were corrected to 29 degrees each, with an improvement in alignment (Fig. 8-B).

One year after the index operation, a pseudarthrosis was repaired with bone-grafting and replacement of the instrumentation with two Harrington compression rods.

Five years after the second operation, a solid fusion was seen roentgenographically, with maintenance of correction and alignment (Fig. 8-C).

Complications

One patient had an intraoperative dural tear, which was repaired. Another patient had a laceration of an iliac vein, which resulted in excessive blood loss (7200 milliliters) and necessitated repair by a vascular surgeon. The patient had a previous anterior excision of a hemivertebra, done at another hospital, and the common iliac vein was incorporated in scar tissue and adherent to the vertebrae.

Neurological complications occurred in eight patients (22 per cent) (Table III). Three patients (Cases 16, 33, and 34) had a radiculopathy along the fourth lumbar nerve root, characterized by weakness of the quadriceps, absence of the patellar ligament reflex, and hypoesthesia along the fourth lumbar dermatome. These signs and symptoms resolved without any intervention. Two pa-
tients had weakness of muscles innervated by the fifth lumbar nerve root. In one (Case 32), the weakness resolved spontaneously within a few days. In the other (Case 26), who had bowel incontinence, a neurological deficit resolved after the weight on the skeletal traction had been decreased. Another patient (Case 12), who had been managed initially with anterior lumbar discectomies followed by halo-femoral traction, had paresthesias and weakness in the left lower extremity. A myelogram and a computerized tomography scan showed a low-lying conus and a tight filum terminale. After the tethering of the cord had been released, the deficit resolved completely. One patient (Case 36) had a brachial plexopathy, caused by the intraoperative positioning, which resolved spontaneously. Only one patient (Case 37) had a permanent deficit, after excision of a hemivertebra at the fifth lumbar level. She had severe weakness of the right calf that improved partially with time but was still considerable nine years later. Three of the unilateral radiculopathies occurred on the concave side of the index curve and four, on the convex side; this raises the possibility that the nerve root can be trapped either by closure of the wedge or by stretching of the opposite side.

There were a variety of additional postoperative complications. Three patients had a pseudarthrosis, identified on routine roentgenograms; the pseudarthrosis was repaired in all three, and a solid fusion was obtained. Three wound infections occurred in two patients. One patient had a superficial wound infection with gram-positive Staphylococcus aureus, but the cultures of deep tissue were negative. The infection resolved after treatment with antibiotics and a single debridement with primary closure. The second patient had an ante-
rior wound infection with coagulase-negative Staphylococcus, which responded to antibiotics and a single débridement. This patient subsequently had a posterior wound infection with Enterobacter cloacae and Escherichia coli, which was treated with two débridements and was allowed to heal by secondary intention. A urinary tract infection developed in two patients but resolved after treatment with antibiotics. Cast sores occurred in two patients, one of whom needed operative débridement; the other patient was managed with changes of the dressing. A superior mesenteric artery syndrome developed in one patient a few days after the second stage of the correction; this resolved with nasogastric suction in three to five days.

Additional Operations

Thirteen patients had an additional operation. Six had extension of the arthrodesis; four because of progression of the curve, as manifested by the incorporation of additional vertebrae in the curve; one because of an increasing thoracic kyphosis; and one for correction of a secondary curve and of a lumbar kyphosis. Of the remaining seven patients, three had additional operations to treat an infection; three, to treat a pseudarthrosis; three, to treat a problem related to the instrumentation; and one had débridement of cast sores.

Discussion

The first excision of a hemivertebra was performed by Royle in the 1920's. Langenskiöld, in an effort to correct severe decompensation of the spine, excised a hemivertebra at the fourth lumbar level in two stages. A Milwaukee brace was used postoperatively, and the patient was allowed to walk three weeks after the operation. Although the operation was successful, little final correction was achieved, probably because the Milwaukee brace failed to immobilize the lower lumbar spine adequately and because the patient walked too early. The failures of the early operations discouraged others from performing the procedure, and it was only with a better understanding of congenital deformities of the spine and with improvements in anesthesia, blood storage, and operative technique that excision of hemivertebrae could be undertaken with both safety and success. Several studies have shown that improved instrumentation is not a critical factor in the better results, although instrumentation can reduce the duration of immobilization in a cast and can permit earlier mobility. McCarthy, as well as Bradfor and Boachie-Adjei, reported good results both with and without the use of instrumentation.

McCarthy reported an average of 48 per cent correction in four patients, who were an average of four-
Fig. 7-C: At the time of removal of the cast, there was total correction of the angular deformity. The operation was done in a single stage with use of the Cotrel-Dubousset compression system.

Fig. 7-D: At the two-year follow-up examination, correction of the curve had been maintained and there was normal alignment of the remainder of the spine.

teen months old and who had had a one-stage anterior and posterior excision of a hemivertebra. The duration of follow-up was less than two years. There were no neurological deficits. Bergoin et al. reported on sixteen patients who had had a one-stage excision of a hemivertebra at an average age of five years. Twelve resections were in the lumbar region and four, in the thoracic region. The average duration of follow-up was four years. The average correction was 36 per cent (from 33 to 21 degrees). Bergoin et al. recommended operative treatment before a child is five years old. In 1990, Bradford and Boachie-Adjei reported on seven patients who had had one-stage anterior and posterior excisions. The average duration of follow-up was forty-five months. The curve averaged 47 degrees preoperatively and 15 degrees at the latest follow-up evaluation.

Carcassonne et al. reported on six children who had had resection of a lumbar hemivertebra. Onimus and Michel recommended excision of a hemivertebra at the fifth lumbar level during the first twelve months of life. Slot, in 1981, reported on eight patients who had had excision of a hemivertebra. Fister et al. reported an average correction of 46 per cent at the time of the operation and of 31 per cent at the latest follow-up evaluation in fifteen patients who had had excision of a hemivertebra. Freedman et al. reported an average correction of the primary curve of 61 per cent in seven patients who had had a one-stage excision of a hemi-

vertebra in the lower lumbar spine. There was one complica-
tion, transient weakness of the leg.

Winter et al. analyzed the results after posterior spinal arthrodensis for congenital scoliosis in 290 patients. They reported an average correction of 38 degrees (28 per cent) in 163 patients who had had instrumentation and 37 degrees (36 per cent) in 127 patients who had not had instrumentation. Bending of the fusion mass occurred in forty patients (14 per cent), with an average increase in the curve of 10 degrees. It has been suggested that posterior spinal arthrodensis alone can lead to progression of the curve because of bending of the posterior solid fusion mass caused by continued activity of the anterior growth plates. Winter and Moe analyzed the results of posterior arthrodensis for the treatment of a congenital spinal deformity in nine children who were five years old or younger. They followed three of the children to the end of growth (average duration of follow-up, sixteen years) and found an increase in the curve of more than 5 degrees.

Patients who have congenital scoliosis can have complex problems, as did sixteen patients in the current study who had pre-existing dysraphic neurological deficits. Ten patients had abnormal findings on an intravenous pyelogram and eight had abnormal myelographic findings. It is therefore critical that these patients be evaluated thoroughly. We believe that all candidates for a resection of a hemivertebra should have a preopera-
The primary indication for operative intervention is rigid decompensation of the spine. Whether the operation is done in two stages a week apart or during one session of anesthesia does not appear to be critical. Of much greater importance is the skill of the surgeon because the spinal canal is entered both anteriorly and posteriorly. The surgeon must ensure that, at closure, no osseous fragment is pressing on the spinal cord and no nerve roots are exiting at the level of the excision.

It is still not clear what degree of correction is necessary, since maximum correction is often both risky and undesirable. The goals of intervention are to achieve a balanced spine and to prevent progression of the curve. The surgeon should attempt to obtain correction not only of the index curve but also of the secondary curve, thereby improving over-all balance and alignment. Unlike other authors who have reported only on the correction of the index curve, we studied the secondary curves and the decompensation of the spine as well.

The optimum age for resection of a hemivertebra cannot be determined precisely. The need for excision may not be evident in a very young child, and the small, soft bones are not well suited for internal fixation; however, the development of structural changes in a secondary curve is a strong indication for early resection.

The indications for excision of a hemivertebra were not clarified in the current study or in any of the earlier reports. If a patient has a progressive thoracolumbar scoliosis that is due to a hemivertebra but has normal alignment of the trunk, a less radical operative procedure, such as an epiphysodesis or a combined anterior and posterior arthrodesis, may be sufficient. Our findings suggest that a decompensated, more rigid curve in a patient who has scoliosis secondary to a hemivertebra is best treated with a wedge resection of the hemivertebra. Careful attention must be paid to proper selection and evaluation of the patients, meticulous operative technique, arthrodesis of the entire index curve, external immobilization until fusion has occurred, and follow-up to the end of osseous growth.

Figs. 8-A, 8-B, and 8-C: Case 8. Roentgenograms of a thirteen-year-old girl, first seen in 1975, who had several congenital anomalies of the spine. PO = pelvic obliquity.

- Fig. 8-A: A 48-degree lumbosacral curve secondary to a hemivertebra at the fourth lumbar level and a 47-degree right thoracolumbar curve extending from the eleventh thoracic to the third lumbar vertebrae are seen. The latter curve was not compensatory but was secondary to congenital anomalies in this segment of the spine.
- Fig. 8-B: One year after the two-stage procedure, which consisted of an anterior excision of the hemivertebra and an arthrodesis extending from the mid-thoracic segment of the spine to the sacrum with use of Harrington compression and distraction rods and correction of the lumbosacral and thoracic curves. There was balanced correction of each curve to 29 degrees and an improvement in decompensation.
- Fig. 8-C: Five years after the index operation and four years after repair of a pseudarthrosis, there was a solid fusion.

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References