SCHEUERMANN'S KYPHOSIS

THE PORTUGUESE TECHNIQUE OF SURGICAL TREATMENT

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Between 1969 and 1989, we performed posterior segmental instrumentation on 38 patients with thoracic Scheuermann's kyphosis. We used a dynamic system without sublaminar fixation, and a kyphosis of 50° was the main indication for surgery. The mean initial angle was 68° (50 to 100) and the mean final kyphosis was 43° at five-year follow-up, with a mean final loss after surgery of 3.7°.

Reconstruction of the vertebral bodies, vertebral wedging and the anterior-body height ratio were observed even in skeletally mature patients. There were no medical complications. There were three cases of loss of correction by more than 10° and one of rod fracture with pseudarthrosis. The role of non-operative treatment is evaluated and early surgical treatment is advocated.

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Over the last 30 years much has been written about the pathology and treatment of scoliosis but there have been very few studies of Scheuermann's kyphosis. In 1921 Scheuermann first defined juvenile kyphosis (Scheuermann 1977), but it was not until 1993 that Murray, Weinstein and Spratt presented one of the best and most complete descriptions of the natural history and the long-term follow-up of this disease. Nevertheless, the aetiology remains unknown and treatment is still controversial.

Non-operative treatment with a cast or orthosis can produce good correction of the adolescent deformity and effective remodelling of the vertebral bodies, but patients often do not use the brace for long enough and there is consequent loss of correction. The results achieved at the

Twin Cities Scoliosis Center (Sachs et al 1987) showed that about 31% of patients with Scheuermann's kyphosis were corrected to less than 45°, but only after a long period of treatment. The mean time for the use of a brace was 14 months continuously and 18 months intermittently (5 to 111). This treatment has proved effective, but it is time-consuming and requires full co-operation from the patient and family, which is not always possible.

Poor results because treatment has been abandoned too early may lead to the need for anterior and posterior surgery in the adult, and such operations are associated with known difficulties and complications. Problems have occurred with posterior surgery in the selection of instrumentation and the consequent mechanical and biological risks. There is still no agreement as to the best time for operation (Hall and Nachemson 1977).

Our aim was to analyse the results in 38 adolescent patients with Scheuermann's kyphosis operated on by our technique, and, based on this experience, to assess the value of earlier surgical intervention.

PATIENTS AND METHODS

From 1969 to 1989, 38 patients with Scheuermann's kyphosis underwent surgery at the Hospital de Gaia and Hospital Ortopédico do Outão using our technique of posterior segmental instrumentation for vertebral reduction and fusion (Resina 1963). The same surgical technique and postoperative regime were followed for all cases. The mean age of the patients at the time of operation was 16.3 years (13 to 22). There were 25 male and 13 female patients. The minimum follow-up was 3 years with a mean of 5 years (3 to 11). The main indications for surgery were an age of 13 years or older and a thoracic kyphosis of more than 50°. The main complaint was the deformity, but 18 patients had pain in the kyphotic region and this was the main reason for operation in three.

The aim of surgery was to correct the deformity, relieve or reduce the pain and prevent an increase in the kyphotic angle and resultant complications. The most important radiological factors were a Cobb angle of more than 45°, a wedge deformity of more than 5° in one or more vertebrae, irregular end-plates with a certain degree of sclerosis, narrowing of disc spaces and, sometimes, the presence of Schmorl's nodes and lengthening of the vertebral bodies.

We considered that an angle of 45° indicated the max-

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Fig. 1a

Fig. 1b

Fig. 1c

Radiograph and photograph of a 16-year-old boy with Scheuermann's kyphosis of 100° (a). He was operated on with two 4.5 mm rods using butterfly fixation and cross half-laminar fixation (b). The kyphosis was reduced to 62° (32% of correction) after surgery and improved to 54° (46% of correction) after four years, showing a dynamic action of 8° (c).

imum limit of physiological kyphosis (Bradford et al 1975; Winter and Hall 1978; Montgomery and Erwin 1981; Stagnara et al 1982; Voutsinas and MacEwen 1986). Each of the three authors independently measured the angles and wedge ratio and we used the mean values.

Lateral radiographs were not used routinely to test reduction in hyperextension. None of the patients had had any previous treatment. Thirteen had thoracic scoliosis to the right of more than 5° and seven of these had a Cobb angle from 12° to 48°.

The mean duration of the operation was 180 minutes and the mean intraoperative blood loss was 1000 ml. Hypotensive anaesthesia was not used. For patients with severe kyphosis the 'wake-up test' was used to detect neurological impairment after reduction, but this test was negative for all patients.

The fusion area should at least include the two end-vertebrae and wider fusion has provided better results. Until 1979, patients were immobilised in a Risser cast and were kept in bed for four to six months. From 1980 we used a plaster jacket in hyperextension with the neck included, and patients began to walk within the first two weeks. The mean time of immobilisation was 9 months (8 to 14).

Operative technique. The technique and instrumentation have already been described (Resina and Ferreira-Alves 1977, 1985; Waldemar Link 1989). Special stainless spring-steel rods (Waldemar Link, Hamburg, Germany) are fixed by staples or wires. The latter may be double, each of 0.9 mm diameter or single of 1.2 mm in diameter. The rods

are 4 to 4.5 mm in diameter and provide the reduction force for the correction of the kyphotic curve.

The position of the patient is the same as for scoliosis surgery, and proximal supports are placed so as to make correction of the kyphosis easier. We use a standard subperiosteal posterior approach, including one or more vertebrae above and below the defined fusion area to widen the operating field. The articular facets are excised to facilitate reduction and fusion of the curve.

The length and thickness of the rods are determined by several factors: the patient's age, the severity, extension and flexibility of the curve, and the quality of the bone. One or two rods may be used, but two 4.5 mm rods seem to give good reduction (Fig. 1).

Before placing the rod on the laminae, drill holes are made so that the wires can be fixed along several segments either to the base of the spinous processes or by 'half-laminar' fixation (Fig. 2). In the former (Fig. 2, top left), bone-perforating forceps are used to penetrate the laminae on each side of the process. A right-angle awl may be useful. With this type of fixation, the wire can be replaced by a staple, which is easier to use and more rapidly adjusted.

When the bone is not hard enough and a firm grip cannot be achieved, we prefer to use half-laminar fixation. One end of the bone-perforating forceps is placed on the posterior surface of the lamina near the centre and the base of the spinous process; the other penetrates under the border of the opposite lamina (Fig. 2, top right and bottom). When the forceps is closed, the hole is made outside the dural sac

Fig. 2

Holes made at the base of the spinous process (top left) and for half-laminar perforation (other drawings). The sites of penetration of the perforating forceps (A and B) are shown.

and at the level of the ligamentum flavum. This is a safe manoeuvre since at this level the anterior surface of the spinous process is concave for the insertion of the ligamentum flavum (Verbiest 1979; Wenger, Carollo and Wilkerson 1982) (Fig. 3).

Fig. 3

Medial sagittal sections of a vertebra. The vertebral canal is wider in the sagittal plane at the level of the insertion of the ligamentum flavum. This leaves the way free for the perforating forceps and the half-laminar wire to pass safely. The site of the hole for the wire is shown (arrows).

From 1969 to 1980 stabilisation of the end-vertebrae was carried out with sublaminar wires, which is undoubtedly safer. Although there were no neurological complications, this type of fixation was abandoned and 'butterfly fixation' to the transverse processes was adopted (Figs 1 and 4).

Fig. 4a

Fig. 4b

Fig. 4c

Radiographs of a 17-year-old boy with Scheuermann's kyphosis of 80° (a). Cross half-laminar fixation and reinforcement of the ends with butterfly fixation were performed (b). There was a reduction to 40° (50%) at five-year follow-up (c).

Table I. Results of surgical treatment of 38 patients with Scheuermann's kyphosis

Mean age in years (range)	16.3 (13 to 22)
Male:female	25:13
Mean angle of kyphosis (degrees $\pm$ SD; range)	
Preop	67.66 $\pm$ 1.96 (50 to 100)
Postop	39.29 $\pm$ 1.41 (20 to 62)
Final	43.21 $\pm$ 1.67 (22 to 65)
Correction (degrees $\pm$ SD; per cent)	
Postop	28.27 $\pm$ 1.72 (41.3 $\pm$ 1.9)
Final	24.45 $\pm$ 1.98 (35.3 $\pm$ 2.3)
Effective correction (equal or less than 45°)	57.9%

Using the thinnest Cobb elevator and a bone-perforating forceps a double 0.9 mm wire of 15 to 20 cm in length is passed under the transverse process on each side of the end-vertebra. The ends of the wires are held with forceps. If necessary, this type of fixation may be performed at two levels. If this method is too difficult at the lumbar vertebral level a transverse hole can be made through the articular processes. After the holes are made, 1.2 mm wires of 15 to 20 cm in length are passed into the bone and their ends are held with forceps.

Wiring starts at the proximal vertebra and follows a caudal progression to the convexity of the kyphosis. In the case of half-laminar fixation each wire will encircle both rods. If extra reinforcement is required, wiring is performed in the opposite direction (cross half-laminar fixation) (Figs 1 and 4). Once the wire has reached the maximum convexity of the kyphosis the proximal 'butterfly' is anchored by the opposite rod. With the compressor-guide, the rod is pushed until it is in contact with the spinous process of the distal vertebra where it is fixed with the rod-holding forceps. All the wires or staples are tightened and adjusted and the ends cut and bent distally. The bottom butterfly fixation or any other type of reinforcement is completed.

To achieve a more accurate position of the implant, the rods may be connected by three or four transverse wires,

inserted at different levels.

Fusion is performed by meticulous decortication and the use of large autologous iliac grafts with cancellous bone. Special care must be taken with the insertion of grafts into the decorticated beds of the articular facets and at the ends of the rods. Intermittent suction drainage is maintained for 24 to 48 hours and prophylactic antibiotics are given.

RESULTS

Details of the results are given in Tables I and II. Effective correction is defined as the percentage of patients who achieved a final angle less than or equal to 45°, which is considered to be the threshold of normal kyphosis.

In our series 22 patients had curves of less than 70° with a mean initial angle of 59.27 $\pm$ 1.31° and a mean final angle of 40.55 $\pm$ 2.07° (effective correction in 15 patients (68.2%)). The other 16 had curves of 70° or more with a mean initial angle of 79.18 $\pm$ 1.98° and a mean final angle of 46.88 $\pm$ 2.55° (effective correction in 7 patients (43.8%)). Included in this group were two patients with severe curves which were reduced by 14° and 22°, respectively.

Of the patients aged 16 years or under, seven had an initial angle ranging from 70° to 85°. Nevertheless, it was in this group that the best results were obtained, with a mean final angle of 36.94 $\pm$ 1.67° (effective correction in 15 patients (88.2%)). Worse results were seen in the patients who were 16 years or older; the mean initial angle was 68.95 $\pm$ 2.73° and the final angle 48.29 $\pm$ 2.15° (effective correction in 7 patients (33.3%)).

Figure 5 shows plots of the postoperative and final angles against the initial angle according to age. There are no cases above the dashed lines, which means that all cases had at least a slight correction and 22 patients (57.9%) had an effective correction. In spite of great variability there is a general trend towards dependence on the initial angle and age. A multiple linear regression model, with independent

Table II. Results in ten patients with Scheuermann's kyphosis of 80° or more

Case	Age (yr)	Follow-up (yr)	Kyphosis (degrees)			Correction (degrees/per cent)			
			Preop	Postop	Final	Postop	Final	Loss	Gain
5	13	10	85	29	30	56/66	55/65		
7	15	6	80	40	43	40/50	37/46	3	
10	15	8	84	43	34	41/49	50/59.5		9
13	16	6	86	56	52	30/35	34/39.5		4
15	18	6	82	42	36	40/49	46/56		6
17	20	9	91	45	52	46/50.5	39/43	7	
18	16	4	100	62	54	38/38	46/46		8
19	17	5	80	45	40	35/44	40/50		5
26	14	4	80	48	34	32/40	46/57.5		14
28	21	5	93	40	55	53/57	38/41	15	
Mean	16.5	6	86	45	43	41/48	43/50	8	7.7

Fig. 5a

Relationship of the postoperative (a) and final (b) angles to the initial angle according to age. Cases below the dashed line improved with surgery. Those below the dotted line achieved normality.

Fig. 5b

variables initial angle (x_1) and age (x_2), was fitted to the data by the method of least squares. For the postoperative angle (y_p) the regression equation is:

$$y_p = 14.0 + 0.374x_1 \quad (1)$$

The p value for the F -test is 0.001 (age was removed from the complete model because its coefficient was not significant, $p = 0.225$). For the final angle (y_f) the corresponding regression equation is:

$$y_f = 13.0 + 0.325x_1 + 2.1x_2 \quad (2)$$

with $p = 0.007$, and 0.001, respectively, for the x_1 coefficient (initial angle), and the x_2 coefficient (age). In both cases the usual assumptions underlying the linear regression model, normality of the residuals and homoeasticity, were checked and considered adequate.

The results show that the age of the patient is not important for the postoperative result but plays a significant role in the final result: the older the patient, the worse the

result. This is thought to be closely related to wedge remodelling.

The effective correction, expressed as a percentage, is dependent on age (chi-squared test, $p = 0.0007$). Gender has no significant effect.

As far as loss of correction is concerned, there was a mean loss of $3.74 \pm 1.21^\circ$ observed only in 25 patients. In five there was no loss and in eight there was an improvement in the correction (dynamic action). Most losses occurred in patients with curves of less than 70° , with the most serious in boys over 16 years old with severe kyphosis. Minor losses occurred in patients under 16 years old. As expected from equations (1) and (2), the loss (1) had a significant linear regression with age, $\hat{l} = -26.8 + 1.78x_2$ (F -test, $p = 0.001$) where negative values mean improvement.

The number of wedged vertebrae was 4.13 ± 1.0 (2 to 6). There was no evidence of differences among the groups.

The ring apophyses were open in 20 patients and closed in 18. Of 17 patients under 16 years of age, 15 had an open

ring apophysis. This is directly related to age (chi-squared test, $p = 0.0002$).

As far as the Risser sign is concerned information is incomplete but of 22 patients seven were between 17 and 22 years of age and Risser-5. The remaining 15 were between 15 and 18 years of age and were Risser-4. In all Risser-5 patients the ring apophyses were closed but in the Risser-4 patients they were closed in nine and open in six.

In order to make a more accurate study of the initial and final wedge deformity the wedge ratio was determined. This is the quotient of the anterior and posterior heights of the vertebral bodies with wedge deformity, measured on lateral radiographs and expressed as a percentage (Nordwall 1973). An average of 5° to 8° corresponds to a mean wedge ratio of 87.5% to 82.5%. The sum of all the wedged vertebral angles was measured in addition to the apical vertebral angle. From a practical point of view, the calculation of the wedge ratio is thought to be more accurate than the measurement of the wedge angle. As in scoliosis (Nordwall 1973), there is a good correlation between wedge angle and wedge ratio ($r = 0.837$, $p < 0.001$).

The overall results indicate a mean initial wedging of $11.54 \pm 2.30^\circ$ and of $7.64 \pm 2.16^\circ$ at follow-up. The initial wedge ratio was $71.81 \pm 6.22\%$ and $83.34 \pm 5.91\%$ at follow-up. The wedge remodelling was thus 3.90° or 33.8% and the change in ratio was 11.53%.

Remodelling was always significantly different from zero (t -test, $p < 0.001$). It was worse in patients with severe kyphosis (3.61° , 12.17%) and more successful in patients under 16 years of age (4.69° , 12.09%) but a significant relationship between remodelling and age or the initial kyphosis could not be established. There were no significant differences in relation to gender. Remodelling, even in young patients in their twenties, is a decisive factor for improvement, and suggests an osteogenic potentiality in the vertebral bodies, even in patients who have already reached maturity in the other parts of the skeleton. This is consistent with the findings of Calvo (1957), Tupman (1962), Collis and Ponseti (1969), Dickson and Deacon (1987) and others.

Finally, despite the restricted number of patients, these results show clearly that age is important for a successful operation: the younger the patient, the better. Gender is unimportant and the 'preoperative angle' of kyphosis plays only a small role.

In 17 patients there was an associated scoliosis. Ten had scoliosis of 12° or less (5° to 12°), which was totally corrected by instrumentation. In the remainder the scoliosis ranged from 17° to 48° . In four it was of 48° , 43° , 38° and 32° and was corrected to 17° (64.6%), 25° (41.8%), 15° (60.5%) and 10° (68.7%), respectively.

Complications. Previous reports of posterior instrumentation for the correction of Scheuermann's kyphosis have described a number of complications, some of which were serious (Bradford et al 1975; Taylor et al 1979; Speck and

Chopin 1986; Lowe 1987; Otsuka, Hall and Mah 1987). Although our technique was developed during the period from 1969 to 1979, medical complications have been few and not serious. There were no cases of infection, pneumothorax, deep-vein thrombosis, haematoma or gastrointestinal, urinary, psychiatric or neurological disorders. Three patients had loss of reduction of 14° , 18° and 22° respectively and one had rod fracture with pseudarthrosis.

DISCUSSION

During adolescence Scheuermann's kyphosis of less than 60° can be treated by a modified Milwaukee brace (Bradford et al 1974; Montgomery and Erwin 1981; Sachs et al 1987; Gutowski and Renshaw 1988) but this requires a strict treatment plan, and is slow and difficult.

Sachs et al (1987) reviewed 247 patients with Scheuermann's kyphosis of whom only 120 had completed a five-year follow-up. Ten of these used the brace inconsistently. Of the remaining 110, 76 (63%) showed an improvement of at least 3° in their kyphosis, 10 were unchanged and 24 became worse. Several of these patients underwent surgery. Only in 34 patients (31%) was the kyphosis reduced to less than 45° and 15 of these were in the group with an initial kyphosis of 45° to 54° .

Murray et al (1993) studied the natural history of 67 patients chosen from a group of 118, diagnosed between 1920 and 1986. The mean angle was 71° after follow-up of 32 years.

We consider that the natural evolution of the disease should no longer be accepted and we question the cost-effectiveness and the results of non-operative treatment. We therefore believe that it is necessary to rethink the question of operative treatment, using simple, less invasive and less damaging techniques in relation to the spinal cord and nerves.

We have made a comparative study of the results of surgery (Table III), and feel that it is unwise to perform a combined anterior and posterior arthrodesis on an adolescent or an adult in the early twenties to achieve only 3° or 4° of improvement. It is also incorrect that an adolescent with a Risser-5 test and fusion of the ring apophyses has no osteogenic capacity to remodel the vertebral bodies (Fig. 6)

We found our technique easy to perform with uniformly successful results and no major complications. The rods, because of their flexibility and elasticity, provide a progressive (dynamic) reduction which ends only with fusion. Segmental fixation spreads the force along the spine. The biomechanics are logical, do not cause any compression or distraction and do not hinder spinal growth (Resina and Ferreira-Alves 1977, 1985).

In a standing patient with kyphosis, the more severe the deformity, the greater the compression moment (White, Panjabi and Thomas 1977; Wenger et al 1982; Dunn 1985; Ogilvie 1987). With our technique, the flexibility of the

Fig. 6a

Fig. 6b

Radiographs of a 21-year-old boy with Scheuermann's kyphosis of 93° which was reduced to 55° by the age of 25 years. In four years the mean wedging was reduced from 12.4° to 8° and the wedge ratio improved from 76% to 87.5%. He had a Risser-5 sign and closed ring apophysis. The combined fixation with wires and staples is also shown.

Table III. A comparative study of the surgical treatment of Scheuermann's kyphosis reported in the literature. The numbers in parentheses are the ranges

Authors	No. of patients	Age (yr)	Kyphosis (degrees)			Correction (degrees)			Follow-up (mth)	Instrumentation
			Preop	Postop	Final	Postop	Final	Loss		
Bradford et al (1975)*	22	17	72.3 (50 to 128)	31	47	41.3 (57%)	25.3 (35%)	16	35 (5 to 92)	Harrington compression rods
Taylor et al (1979)*	27	16.7	72 (55 to 93)	40.4	46	31.6 (44%)	25.9 (36%)	5.7	28 (6.72)	Harrington compression rods
Speck and Chopin (1986)*	53	17.5	77.5 (60 to 107)	38	42	39.5 (51%)	35.5 (46%)	5.5	57 (12 to 68)	Harrington compression rods
Ferreira-Alves et al (1995)*	38	16.4	67.6 (50 to 100)	39	43	28.3 (42%)	24.5 (36%)	3.7	72 (36 to 132)	Resina segmental flexible rods
Bradford et al (1980)†	24	21	77 (50 to 110)	41	47	36 (46.7%)	30 (39%)	6.0	47 (30 to 67)	Harrington compression rods
Herndon et al (1981)†	13	19	78 (61 to 95)	37.7	45	40 (51.3%)	33 (42.3%)	7.6	29 (12 to 66)	Harrington compression rods
Lowe (1987)†	24	21.5	84.6 (72 to 105)	44.2	49.8	40.4 (47%)	38 (43%)	5	32.5 (19 to 46)	Luque double L-rods

* posterior spine arthrodesis

† combined anterior and posterior arthrodesis

rods facilitates the action of the extensors and increases the posterior tension forces, which tend to reduce deformity. The surgery straightens the kyphosis and may keep it within physiological limits, while the instrumentation, fusion and external immobilisation stabilise the curve and improve or restore the natural balance of the spine.

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