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COSTODESIS AND CONTRALATERAL RIB RELEASE IN THE MANAGEMENT OF PROGRESSIVE SCOLIOSIS

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This paper reports on 41 immature patients whose scoliosis was treated by fixation of ribs on the convexity. All had progressive scoliosis, the curve deteriorating at more than 10° p.a., or the rib-vertebra angle difference being greater than 20°. Of the 24 with infantile idiopathic scoliosis examined 5 years after operation, 10 maintained the improvement obtained at operation and in a further 19 the rate of deterioration had been slowed.

Factors leading to a favourable outcome included: 1) An initial rib-vertebra angle difference of less than 30°. 2) Success in achieving convex rib fusion. 3) The use of the operation in patients with infantile idiopathic scoliosis. There was a less favourable outcome in congenital and adolescent scoliosis. Spirometric volumes were diminished immediately after operation. Costodesis is therefore contraindicated in patients with precarious respiratory function.

Key words: ribs; scoliosis; scoliosis surgery; spine; thoracic vertebrae; thorax surgery

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There is general agreement regarding the treatment of progressive adolescent scoliosis. Severe curves are corrected and a rod or plate is inserted to maintain the correction during the period needed for maturation or appropriately placed bone graft. However, infantile and juvenile scoliosis is less amenable to treatment by fusion. Less bone is available in the donor sites, and rapid spinal growth may result in microfractures in the grafted bone, and loss of correction. The vertebrae are softer and do not tolerate a metal insert as well as those of an adolescent.

An alternative approach is to attempt to prevent growth on the convex side of the spine, and this may be achieved by unilateral curettage of the apical growth plates (Roaf 1970). An early review of patients so treated showed that in some 50% the scoliosis did not progress. Diminution of the curve was observed in patients with residual growth potential in whom a bony bar developed on the convexity following operation. Similarly Loynes (1972) demonstrated that intertransverse fusion prevented the otherwise inevitable development of lateral spinal curvature after thoracoplasty. Operative convex rib fixation was therefore undertaken as a primary procedure in an attempt to prevent further deterioration of progressive curves. The preliminary results were encouraging and the present study reports a prospective study of convex costodesis with a 5-year follow-up.

PATIENTS AND METHODS

All 58 patients who had a costodesis in the Royal Liverpool Children's Hospital between January 1971 and March 1974 were examined for inclusion in this study. The scoliosis was considered to be progressive if

there was a rib-vertebra angle difference of greater than 20° (R.V.A.D., Mehta 1972) or an annual deterioration in the curve of more than 10°. One child was excluded due to loss of radiographs or inadequate follow-up. Forty-one patients were then available for study. Of these, four had prior surgery (curettage of the apical vertebral body epiphyses on the convex side).

Clinical and laboratory investigation

Clinical examination was supplemented by anthropometric measurements and radiography, which included erect A.P. and lateral X-rays, and flexion view of the spine. Therapeutic flexion using a mechanical mobiliser was also used to improve spinal mobility prior to operation.

Respiratory function studies

The forced vital capacity (FVC) and the forced expiratory volume in 1 second (FEV 1.0) were measured using a Vitalograph, and the volumes corrected to body temperature and standard pressure (Vitalograph 1977). Predicted normal spirometric volumes were calculated using the height correction of Bjure et al. (1968) and the formulae of Polger & Promadhat (1971). Measured volumes were expressed as a percentage of normal values.

Costodesis

The operation was undertaken using general anaesthesia without hypotension. With the patient prone, the pelvis and chest were supported on pillows. The incision was vertical, the latissimus dorsi and posterior spinal muscles being elevated. The periosteum was incised and reflected from six to eight ribs. The posterior ends of two ribs at the apex of the curve were excised, the adjacent ribs being then tied together with nylon tape, at the angle (wire, used in a preliminary study, cut through the ribs). Other ribs attaching at the extremities of the curve were then divided at the angle, and the medial portions were tied together, overlapping the first group posteriorly. Depressing the ribs near the apex towards the pleura resulted in some derotation of the scoliotic curve. Bone from excised ribs was laid down on the laminae and transverse processes to effect a posterior fusion in five patients.

A release was undertaken on the concave side in all but four patients. Through a separate incision the muscles were erased from the spinous processes and laminae. The transverse processes were freed of all ligaments, and in some patients, excised. The capsules of the costotransverse joints were removed. A variable number of ribs at the apex were divided, or their medial ends excised.

The wounds were closed with suction drainage, and the patients nursed in plaster of Paris beds until skin healing occurred. They were subsequently placed in a plaster jacket, and the jacket wedged to correct the curve. They remained recumbent for 3 months and were then allowed to walk in the cast. A Milwaukee Brace was provided 6 months from operation, and removed only for bathing.

Radiographs of the corrected spine were taken after wedging of the P.O.P. jacket. Subsequent films were at 6-monthly intervals. Curvature was measured by the Cobb method (Cobb 1948), rotation estimated as described by Mehta (1973). The angular deformity after surgery was subtracted from that present prior to surgery to give the correction. The patient stood for all but the first post-operative radiograph, which was taken supine.

Mean increase in curvature

Estimation of the mean annual increase in Cobb angle prior to surgery relied on two radiographs taken at an interval of greater than 1 year. Where these were not available the period in years from conception to surgery was used as the denominator.

Fourteen of our patients had further surgery during the period of review. Theirs were the more severe curves and omission of their data from the overall mean Cobb angles for 4 and 5 years after operation would lead improperly to an apparent mean angular improvement in the mean data for their group. For such patients we have used the greatest Cobb angle prior to the second operation in the mean figures calculated thereafter.

RESULTS

Of the 41 patients, four had adolescent scoliosis (one male and three females). Thirteen had congenital scoliosis, neurological disorders or Marfans syndrome (four males and nine females). For 24 patients there was no known aetiological factor (21 infantile and three juvenile idiopathic scoliotics, being four males and nine females).

The greater part of the major curve was thoracic, but in eight patients lumbar vertebrae formed part of the curve. No patient had clinical thoracic lordosis. The 24 idiopathic scoliotics had a mean age at diagnosis of 1.6 years, and at operation of 4.5 years, these figures for those 13 of known aetiology being 2.5 years and 5.8 years respectively (Table 1). The four adolescents were diagnosed at a mean age of 12.3 years and had their operation at 13 years.

Table 1. Showing the changes in the mean angle of the thoracic curve after operation

		No. of patients	Mean age in years: At diagnosis	Mean age in years: At operation	Mean angle of curvature: Prior to operation	Mean angle of curvature: After operation	Years: 1	2	3	4	5	Mean annual increase in curve in degrees: Prior to operation	Mean annual increase in curve in degrees: After operation
Infantile and juvenile idiopathic	Improved	10	2.4	4.4	52	26	32	34	33	32	35	16	2
	Worse	14	1.0	4.5	52	22	50	54	55	56	60	12	8
	Total	24	1.6	4.5	52	24	43	46	45	46	50	14	5
Infantile and juvenile known aetiology		13	2.5	5.8	64	37	57	63	64	66	72	11	7
Adolescent	Total	4	12.3	13.0	52	36	57	58	67	69	69	17	7

The first two lines compare patients with I.I.S. who showed an improvement at 5 years with those whose curve had deteriorated.

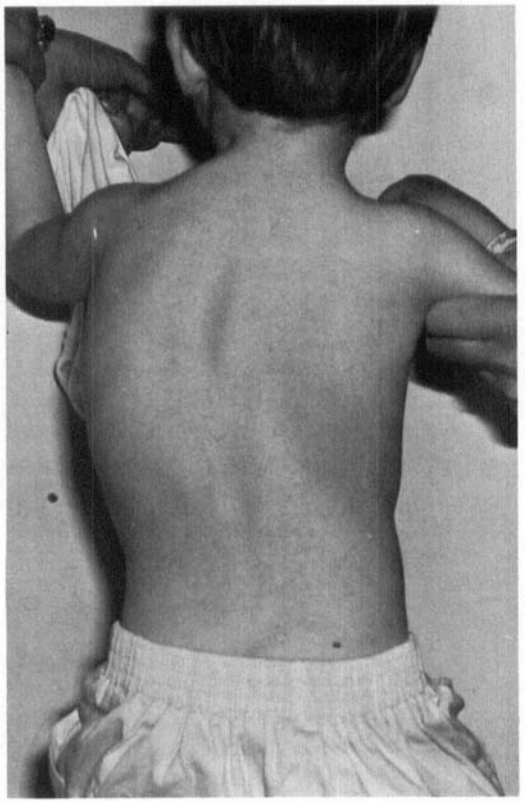
Complications

The operation was without untoward incident in all patients, but pneumothorax was diagnosed and treated in two patients in the recovery room, and haemothorax in another. Three patients had post-operative pulmonary consolidation and another patient had respiratory insufficiency requiring oxygenation for 3 days. Two had post-operative abdominal distension.

Following removal of the cast four patients noted dyspnoea on effort. This resolved after a few weeks, except in patient No. 41 in whom it persisted for 2 years. One patient (No. 23) defaulted from the clinic and returned after a year with a kyphoscoliosis and incipient paraplegia requiring decompression.

Table 2. Showing the number of patients requiring additional treatment at the time of review

	Treated	No. with 5 year curve better than pre-op. curve	Decreased curve progression	Those having late spinal fusion	Of remainder: Those in brace	Of remainder: Out of brace
Infantile idiopathic	24	10	19	7	14	3
Infantile known aetiology	13	3	10	7	7	0
Adolescent	4	1	3	1	0	3
Total	41	14	32	15	21	6



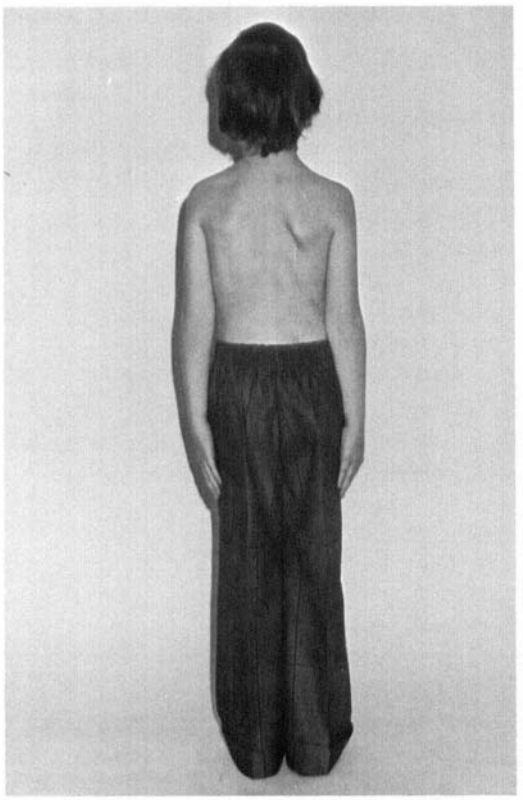


Figure 1. a, Patient No. 1 aged 2.5 years, prior to surgery with a 77° curve. b, Patient No. 1 aged 8 years. At 5 years after surgery he maintained a 57% correction of his angular deformity at 47°.

Curve progression (Table 2)

In 14 patients (34%) the angular deformity at 5 years was better than that immediately prior to operation. In 32 (78%) the mean rate of curve progression was decreased after operation.

Increasing curvature necessitated instrumentation and fusion in seven (29%) of the infantile idiopathic scoliotics, seven (54%) of the miscellaneous group and one (25%) of the adolescents. Only six patients were free of their braces at 5 years.

Infantile and juvenile idiopathic group (Table 2)

The cosmetic result was satisfactory in the majority of patients (Figure 1a and b). However, one patient required subsequent removal of protruberant rib ends.

The mean pre-operative curvature of 52° and the mean age at diagnosis of 18 months, lead us to believe that these infants had an unfavourable prognosis (Thompson & Bentley 1980).

The mean angle of curvature reduced to 24°

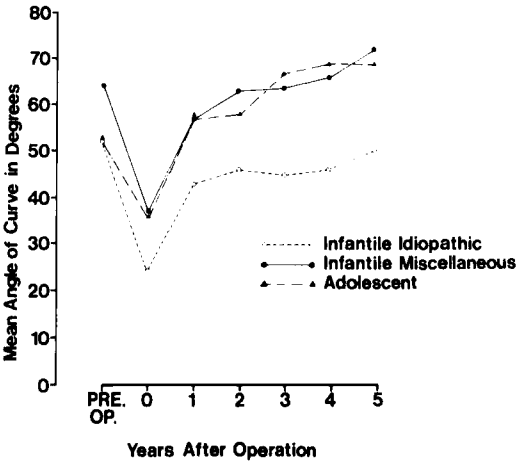


Figure 2. A graph to show progress of the angular deformity as measured by the mean Cobb angle. The figure at 0 years represents the curvature in the corrective cast.

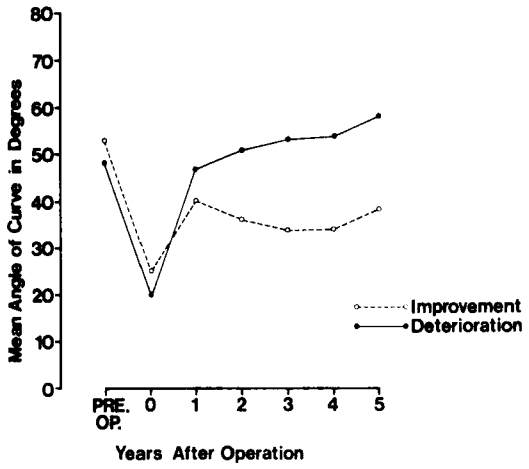


Figure 3. The mean Cobb angle for infantile idiopathic scoliosis, subdivided into those who at 5 years had improved and those who had worsened. The trend is established by the second post-operative year.

(54% correction) in the plaster cast. After 5 years the mean angle was 50° (3% correction). (Table 1 and Figure 2). Prior to operation the mean annual increase in curvature was 14°, but this was reduced to 5° in the 5 post-operative years. This was the only group to retain an overall improvement over the 5 years. Of 10 patients with maintained improvement, seven had had an R.V. A.D. prior to operation of less than 30°. Of 14 who had a deterioration, nine had an R.V. A.D. of greater than 30°.

The patients improved after 5 years have been compared with those no better or who had worsened (Table 1 and Figure 3). Those who improved were diagnosed at a later age than those who worsened. The correction in plaster was similar in the two groups (26°, 54% compared with 22°, 57%). However, at 1 year the former retained 38% correction, the latter only 3%. It appears that maintenance of correction 6 months after cast removal correlates with prognosis. Ro-

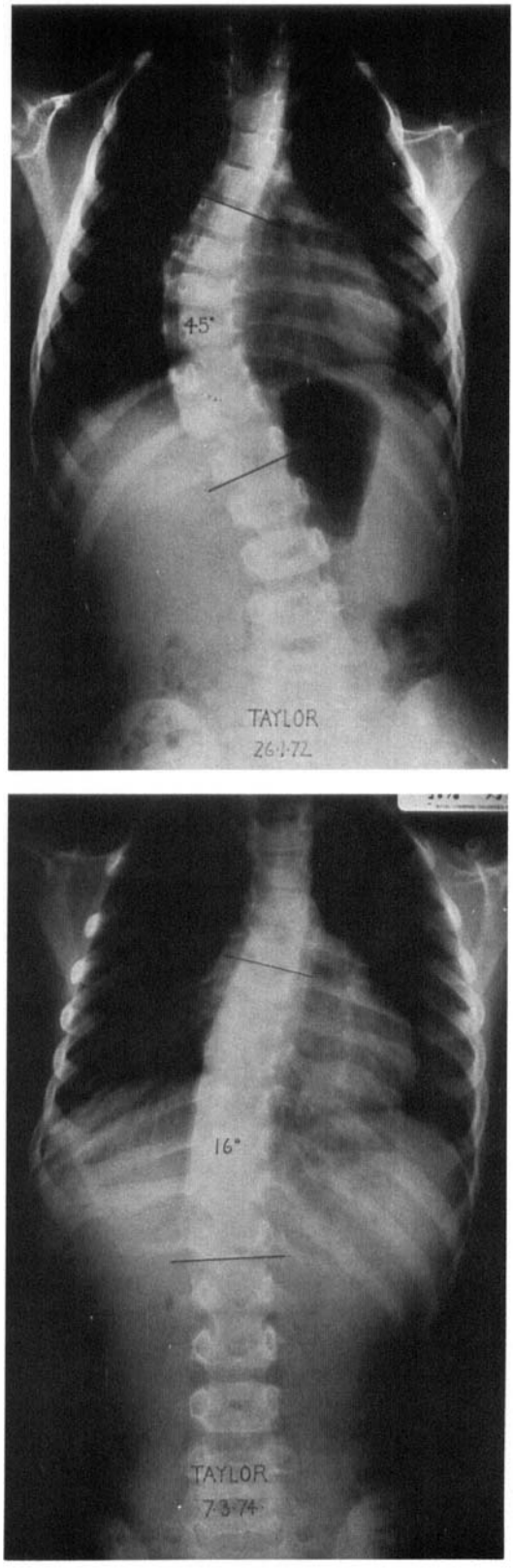


Figure 4. a, The pre-operative radiograph of patient No. 14 with infantile idiopathic scoliosis, a thoracic curve of 45° and a lumbar curve of 15°. b, The same patient 2 years after surgery. The thoracic curve is now 16° with fusion between five ribs. There is also resolution of the lumbar curve, though this did not always occur.

tation did not improve in this group or either of the other groups.

Fusion of the tied ribs on the convexity correlated with maintenance of correction (Figures 4a and b). This was clearly seen in the third post-operative year. Fifteen of 16 patients showing improvement had fusion between four or more ribs on the convexity. This compared with four of nine patients whose curves had deteriorated (chi-square, $P < 0.05$). Inter-rib fusion followed concave release in 24 of 38 patients.

Infantile and juvenile of known aetiology (Table 2)

In this group the scoliosis was congenital (7), neurogenic (4) or secondary to arachnodactyly (2).

The mean angle of curvature prior to operation was 64°. The correction in plaster was to 37° (42%). Deterioration occurred over the 5 years and by the fifth, the mean Cobb angle was 72° (–12.5% correction). The structural changes were greater in this group, but flexibility of the curve as measured by lateral bending showed no statistical correlation with the result at 5 years. The percentage correction was lower than in the idiopathic group, but the mean annual increase in curvature diminished from 11° to 7° after operation.

Adolescent scoliosis

The cosmetic result was satisfactory in these four patients. From a pre-operative mean angulation of 52°, plaster correction led to a mean curvature of 36°, a 31% correction. However, at 1 year the mean angle was 57°, deteriorating to 69° (–31% improvement) at 5 years. Nevertheless, progression of the curves had been slowed from a mean figure of 17° pre-operatively to 7° after operation.

Respiratory function

Thirty four patients were studied, 29 infants or juveniles and five adolescents. Three patients had post-operative signs of respiratory insufficiency, two with dyspnoea on effort and one with liability to cough.

Infantile idiopathic scoliosis. Consecutive yearly spirometric measurements were not available for each child. Pre-operative readings were only available for four children. The mean pre-operative F.V. C. was 1.3 litres (range 0.7–1.8), that is 75% of predicted normal. Their mean F.E.V. 1.0 was 1.2 litres (range 0.66–1.7) which is 77% of predicted normal (Tables 3 and 4).

One year after operation the mean F.V.C. was 62% of predicted normal (Figure 5). Thereafter, the F.V.C. improved to 81% at 7 years and 87% at 8 years. The F.E.V. 1.0 progressively decreased to 63% at 4 years, and then improved to 75% at 5 years and 88% at 8 years (Figure 6 and Table 4).

Infantile curves of known aetiology. Pre-operative readings were available for six patients. Mean F.V.C. 1.2 litres (range 0.5–2.4) 69% predicted normal. In the postoperative period it diminished to 45% at 3 years. The reading of 43% at 7 years was based on a single patient. The mean F.E.V. 1.1 litres (range 0.5–2.1) 67%. This decreased to 47% at 3 years, and at 4 years it was 57%.

Adolescent scoliosis. We studied five patients whose mean pre-operative F.V. C. was 1.8 litres

Table 3. F.V.C. mean figures expressed as a percentage of predicted normal

	Pre-op. F.V.C.	Post-op. F.V.C., years 1	2	3	4	5	6	7
Infantile idiopathic	75	62	62	63	67	73	80	81
Infantile miscellaneous	69	46	59	45	57	–	–	43
Total infantile	72	51	61	54	63	73	80	71
Adolescent	80	45*	55	53	–	–	72	–

* Based on only one reading from a patient with pre-operative evidence of airway obstruction.

Table 4. F.E.V. 1.0: Mean figures expressed as a percentage of predicted normal

	No. with F.E.V./F.V.C. ratio less than 70%	No. with post-op. respiratory symptoms	Pre-op. F.E.V. 1.0	Post-op. F.E.V., years							
				1	2	3	4	5	6	7	8
Infantile idiopathic	1	2	77	65	63	64	63	75	80	75	88
Infantile miscellaneous	0	1	67	37	61	47	57	–	–	38	–
Total infantile	1	3	71	47	61	56	60	75	81	70	88
Adolescents	1	3	73	34*	49	48	–	–	66	–	–

* Based on a reading from one patient with pre-operative evidence of airway obstruction.

(range 1.1–2.6), 80%. Their F.E.V. was 1.6 litres (range 1.1–2.3) 73% of normal. At 1 year after operation there was a diminution of lung volumes in the only patient studied, (F.V.C. 1.3 litres, F.E.V. 0.9 litres) and thereafter improvement to 6 years (2.1 litres 72% and 1.9 litres, 66% respectively) (Figure 7).

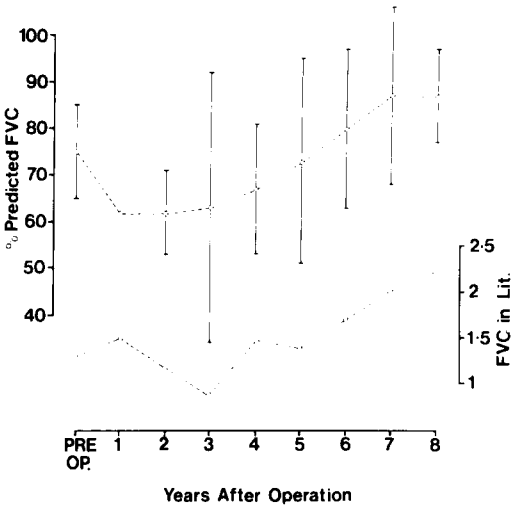


Figure 5. The mean FVC of all those with infantile idiopathic scoliosis expressed in the upper graph as a percentage of the predicted FVC. The total height of each vertical line represents 2 S.D. The lower graph is of the same results expressed as litres at B.T.P.S.

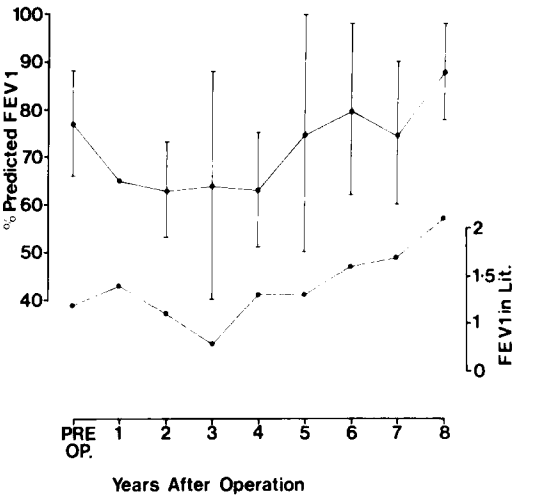


Figure 6. The FEV 1.0 of those with infantile idiopathic scoliosis recorded in a similar manner to Figure 1.

DISCUSSION

This paper describes the results of costodesis; an operation in which ribs on the convexity of a scoliotic curve are approximated and fixed together. Of the 41 patients studied, all were placed in a corrective plaster cast, and all but four had an operative release procedure on the concavity with excision of transverse processes or ribs. The results show that new bone subsequently linked regenerating ribs on the concavity, producing a

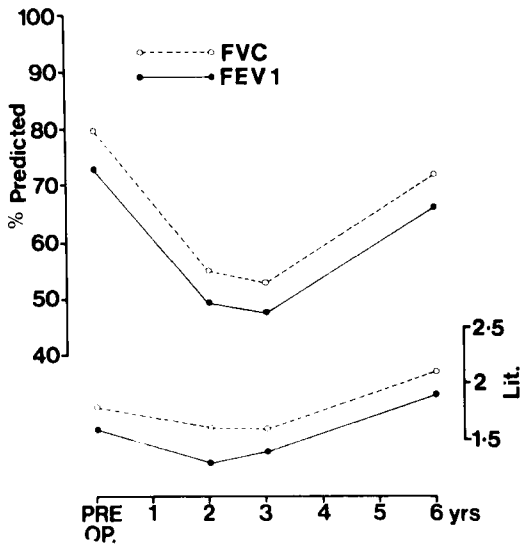


Figure 7. The F.V.C. and F.E.V. of those with adolescent scoliosis.

tether. We have subsequently abandoned concave release.

Five years after operation 42% of those with idiopathic infantile or juvenile scoliosis maintained their improvement, and in 79% the rate of progression was diminished. The operation was therefore of value in the management of these infants. However, six patients had post-operative respiratory complications during the first 48 hours, and one of our 2-year-old patients (not included in this series) died of respiratory failure after an extensive costodesis. Others have had a variable but temporary decrease in respiratory function. Moreover post-operative intercostal scarring is an impediment to any subsequent transthoracic approach to the vertebral bodies. The value of costodesis has therefore to be evaluated having considered these potentially damaging side effects.

Infantile idiopathic scoliosis

Whilst some improvement in the curvature was noted at operation, much of the correction seen on the post-operative X-ray is lost at 1 year. This is evidence of continued resilience in the spine, the correction remaining being dependent on the intercostal ties. The slow deterioration between 1 year and 3 years may represent loosening of the ties, or stretching of fibrous tissue between ribs. This concept is supported by the results after artificial grouping of patients into those with a final overall improvement (successes) and those with a loss (failures) (Figure 2). Selection of patients is clearly important in determining success or failure, the majority of successes having initial curves of less than 40°, and an R.V.A.D. of less than 30°. They also usually had radiological evidence of convex inter-rib fusion. Ten of 24 patients were improved at the end of the 5-year, period suggesting that growth potential was retained on the concavity, but inhibited on the convex side by the inter-rib fusion. Their deterioration in the 12 months after removal of the cast was slight. We now believe that identification of this group 2 years after surgery should render prolonged bracing unnecessary.

On removal of the cast following convex costodesis (and in a majority, concave release) the mean angular curvature was 25°, a 52% improvement. This is greater than the 44% improvement reported in 1975 by James for cast correction alone. However, more recently from the same centre McMaster & McNicol (1979) report a mean improvement from 62° to 29° (52%) using conservative management in a Risser turnbuckle jacket. The mean angular curvature in our series was moderately severe prior to operation (mean 52°, range 33°–77°). Nevertheless, it is less than that recorded in the patients of Barnes (1979), who used rib resection on the concave side followed by a localiser jacket for 2 months. On removal of the cast he achieved a mean correction of from 80° to 50° (38%). In the present series there was substantial loss of correction in many on removal of the cast, such that by 2 years the mean angular deformity was 46°, only 6° better than the pre-operative measurement. Pigott (1971) recorded a similar slight improvement 2 years after concave release and excision of rib heads, with no cast correction.

At 5 years the mean angular curvature was 50°, a 3% correction. However, McMaster & McNicol had an 11% improvement 6 years after correction in turnbuckle jacket and subsequent management in a brace. Their method of selection

was similar to our own, but their brace relies on distraction to maintain the curve. It appears from the figures quoted after turnbuckle cast and at the end of treatment that their brace regimen was more effective than ours, though at the expense of significant orthodontic moulding in 36%. We believe that disturbance of dental occlusion by excessive distraction outweighs the minor additional correction gained. Moreover, all of the Edinburgh patients required spinal fusion, and after that procedure the post-operative mean Cobb angle was 42°, a final correction of 53%. However, of our 24 patients, seven had curves of less than 40° at final review and remain with mobile spines. Three had already been told to discard their braces. Nevertheless, we believe that parents must be warned that costodesis and brace treatment may represent a holding procedure, as seven of our patients required spinal fusion during the period under review.

The exact role of concave release in this study is not yet clear, but in 22 patients it was followed by concave inter-rib fusion which might be expected to have a detrimental effect on the scoliosis. Though Pigott reported an improvement at 2 years after a concave release, Barnes (1979) examined 48 children at a mean follow-up time of 6 years after concave release alone and reported a mean deterioration of 8°. Not all of his children had progressive scoliosis at the time of operation, but cast correction was undertaken as in our series. We believe, therefore, that costodesis should not be combined with a "concave release".

Infantile scoliosis of known aetiology

The decrease in the mean annual rate of progression (from 11° p.a. to 7° p.a.) demonstrates some value of costodesis in this group of patients. Moreover, though there was a substantial loss of correction in the first 3 years, the mean figures suggest that stability was achieved thereafter. Formal simultaneous spinal fusion was only undertaken in three of our patients. However, we would now recommend that in congenital scoliosis with localised areas of instability, concomitant short segment fusion be undertaken.

Adolescent scoliosis

Though based on only four patients, our results show that over the quinquennium the adolescents progressed from a mean curvature of 52° to 69°. In view of the excellent reported results of Harrington Rod fixation (Harrington & Dickson 1973) and spinal fusion, we feel that costodesis has no place as a procedure aimed at correcting the adolescent spinal curve.

Respiratory function

In comparison with other procedures costodesis produces adverse effects during the 4 years after operation. Thus Gazioglu et al. (1968) found a 17% improvement in spirometric values 1 year after spinal fusion, and Lindh & Bjure (1975) noted an improvement of 10% at 18 months. Zorab et al. (1979) found little measurable increase in lung volumes after corrective spinal surgery, and Westgate & Moe (1969) reported a decrease of 6% of vital capacity during the first and second years after instrumentation for kyphoscoliosis. Nevertheless, such deterioration is greatly exceeded by the immediate fall in the percentage of normal F.V. C. reported here (13% infants, 35% adolescents).

The majority of patients had pre-operative diminution of vital capacity in the absence of airway obstruction, similar to that reported in other studies (Cook et al. 1960), This evidence of restrictive lung disease (Levine 1979) was more apparent after operation. Surgical fusion of the ribs may be responsible for this adverse effect. However, the improvement in lung volumes 4–5 years after operation at a time when the ribs remain fused, leads us to believe that cast immobilisation may contribute to the post-operative deficit in pulmonary function. An additional factor may be the instability of the infant airway, Mansell et al. (1972) having shown that closing volumes exceed the functional residual capacity in the infant. For this reason the small child with scoliosis may have precarious respiratory function which requires careful assessment prior to surgery.

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