The natural history of post-tubercular kyphosis in children

RADIOLOGICAL SIGNS WHICH PREDICT LATE INCREASE IN DEFORMITY

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The progression of post-tubercular kyphosis in 61 children who received ambulatory chemotherapy was studied prospectively. The angles of deformity and kyphosis were measured for each patient at diagnosis, 3, 6, 9, 12 and 18 months later and every year thereafter for 15 years. During the course of the disease signs of instability appeared on the radiographs of some of the children. These were dislocation of the facets, posterior retropulsion of the diseased fragments, lateral translation of the vertebrae in the anteroposterior view and toppling of the superior vertebra. Each sign was allocated one point to create a spinal instability score. The influence on the progression of the deformity of the level of the lesion, the vertebral body loss, the number of segments involved, the angle of deformity before treatment and the spinal instability score was analysed.

The mean angle of deformity at the start of treatment was 35°. This increased to 41° at 15 years. Progression occurred during the active phase of the disease and again after cure when variations in progression were observed. Type-I progression showed an increase in deformity until growth had ceased. This could occur either continuously (type Ia) or after a lag period of three to five years (type Ib). Type-II progression showed decrease in deformity with growth. This could occur immediately after the active phase (type IIa) or after a lag period of three to five years (type IIb). Type-III progression showed minimal change during either the active or healed phases and was seen only in those with limited disease.

Multiple regression analysis showed that a spinal instability score of more than 2 was a reliable

predictor of patients with an increase of more than 30° in deformity and a final deformity of over 60°. Since signs of radiological instability appear early in the disease, they can be reliably used to identify children whose spine is at risk for late progressive collapse. Surgery is advised in these cases.

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Over 30 million people worldwide suffer from overt tuberculosis and more than two million have the active, spinal form.¹ The disease can be successfully treated by anti-tuberculous drugs²⁻⁴ and attention has now turned to the management of residual deformity.⁵⁻⁷ In the developing world spinal tuberculosis is the main cause of kyphosis; 15% of patients treated conservatively have a considerable increase in kyphotic deformity, which in 3% to 5% is more than 60°. ⁵⁻⁷ A severe kyphosis is a major cosmetic and psychological disturbance in a growing child and can result in secondary cardiorespiratory problems and late-onset paraplegia. Correction of an established deformity is both difficult and hazardous with a high rate of complications, even in experienced hands.⁸ Prevention of deformity must be a priority in the treatment of spinal tuberculosis.

Children under the age of ten years at the time of infection are at serious risk of developing severe deformity.^{5-7,9} The natural history of spinal tuberculosis in children after infection, however, is not clear since most reports have either drawn conclusions at a single point in time^{2-4,10} or have considered the mean angle of deformity for all children in the study group.^{2-4,11,12} Both can cause errors. Deformity may improve or deteriorate at various times and a single study will overlook this (Fig. 1). Deterioration also varies between children. The mean angle of deformity will not show the severe increase in deformity which may occur in a few children or the improvement in others. There has been no previous description of the natural history of post-tubercular kyphosis in children which specifically documents the progression of the deformity in each child at yearly intervals until growth is complete. This study reports a follow-up of 61 children (63 lesions) over a period of 15 years.

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Fig. 1

Graph showing the progression of deformity in a four-year-old child over 15 years. Post-tubercular kyphosis is a 'deformity in continuum'. A study performed at three years would indicate progression of deformity with growth; at five years it would show no change with growth and at 15 years improvement with growth.

Patients and Methods

These children formed part of a prospective, multicentre, controlled clinical trial of 304 patients with tuberculosis involving the thoracic or lumbar spine to investigate the efficacy of a short course of ambulatory chemotherapy as compared with a short-course of chemotherapy combined with modified Hong Kong surgery, in the management of spinal tuberculosis.¹³ Patients were included if they had clinical and radiological evidence of active spinal tuberculosis involving any vertebral body from T1 to S1 inclusive, and if they were available for follow-up for at least five years. They were excluded if they had a neurological deficit, significant extraspinal disease which could affect the management or response to treatment, a history of previous antituberculous therapy for 12 months or more or previous major surgery for spinal tuberculosis.

Of the ambulatory group, 61 patients with 63 lesions were aged 15 years or younger at the time of diagnosis and were selected for this study. There were 26 boys and 35 girls with a mean age at the start of treatment of 6 years and 11 months (2 to 14). Twenty-eight patients (29 lesions) were below the age of five years, 20 (21 lesions) were between six and ten years old and 13 (13 lesions) between 11 and 15 years. Twelve children who had involvement of the T1 to T10 vertebrae were considered to have thoracic lesions, 31 with involvement of T11 to L2 to have thoracolumbar lesions and 18 with lesions below L2 to have lumbar lesions. There were 154 vertebral bodies involved, 38 thoracic, 75 thoracolumbar and 41 lumbar. The mean number of vertebral bodies involved per patient was 2.7 for thoracic lesions, 2.4 for thoracolumbar lesions and 2.2 for lumbar lesions.

For each patient, the angles of kyphosis and deformity were measured at diagnosis and on follow-up radiographs at 1, 3, 6, 9, 12 and 18 months and every year thereafter for 15 years (Fig. 2). In lower lumbar lesions, where L5 was affected, the angle of kyphosis was measured by drawing lines along the posterior border of the first normal upper vertebra and the posterior margin of S1. Intra- and inter-observer variation in these measurements was analysed in a

pilot study in which three observers measured 15 radiographs and repeated the assessment six weeks later. The mean difference was 2.2° and 96% of the differences were less than 5°. Using the statistical method of confidence limits¹⁴ it was determined that if a measured difference was more than 4°, there was 95% level of confidence that this represented a true change.

The vertebral body loss (VBL) at the start of treatment was measured by carefully studying the anteroposterior and lateral radiographs of each patient and dividing each vertebral body into ten equal parts. The amount of destruction in each vertebral body was assessed and then added up to give the total vertebral body loss. At the start of treatment the mean vertebral body loss was 1.6; for thoracic lesions it was 1.8, for thoracolumbar lesions 1.5 and for lumbar lesions 1.4. For patients less than five years of age the vertebral body loss was 1.8; for those aged six to ten years it was 1.7 and for those over 11 years 1.1.

Fig. 2

Diagram showing that the angle of the deformity (D) is measured by drawing two lines, one on the superior surface of the uppermost involved vertebra and the other through the inferior surface of the lowermost involved vertebra. The angle of the kyphosis (G) is measured by drawing a line on the upper surface of the first normal vertebra above the lesion and one through the lower surface of the first normal vertebra below the lesion.

Fig. 3

Diagram of the radiological signs for the 'spine at risk'. Figure 3a – *Separation of the facet joint*. The facet joint dislocates at the level of the apex of the curve, causing instability and loss of alignment. In severe cases the separation can occur at two levels. Figure 3b – *Posterior retropulsion*. This is identified by drawing two lines along the posterior surface of the first upper and lower normal vertebrae. The diseased segments are found to be posterior to the intersection of the lines. Figure 3c – *Lateral translation*. This is confirmed when a vertical line drawn through the middle of the pedicle of the first lower normal vertebra does not touch the pedicle of the first upper normal vertebra. Figure 3d – *Toppling sign*. In the initial stages of collapse, a line drawn along the anterior surface of the first lower normal vertebra intersects the inferior surface of the first upper normal vertebra. 'Tilt' or 'toppling' occurs when the line intersects higher than the middle of the anterior surface of the first normal upper vertebra.

The progression of the angles of deformity and kyphosis was plotted graphically for each patient, which made it possible to view clearly the progression over 15 years and the changes at times of rapid growth. Changes which occurred during the active phase of the disease and after complete cure were documented.

Radiological signs of 'spine at risk'. During the course of the disease, as the severity of collapse increased, the posterior arch became disrupted by dislocation of the facet joints in some children. In severe anterior destruction, facet dislocation led to spinal instability with various radiological features as shown in Figure 3.

Separation of the facet joints. With progressive kyphosis the facet joint at the apex of the curve was subluxed followed by frank dislocation. In patients with severe involvement, there was separation at more than one level with wide distraction of the spinous processes at the corresponding levels.

Posterior retropulsion of the diseased vertebral segments. With progressive destruction, the remnants of the destroyed vertebral bodies were retropulsed. This was assessed by drawing two lines along the posterior surface of the normal vertebra above and below the level of the lesion. Retropulsion was confirmed when bone at the involved level was seen to lie posterior to the drawn lines.

Lateral translation of the vertebral column. Translation was confirmed when the line drawn from the centre of a pedicle of the lower vertebra did not intersect the pedicle of the upper vertebra in an anteroposterior radiograph.

Toppling sign. The separation of the facet joint allowed the superior normal vertebral segment to tilt or topple, so that the anterior surface of the vertebra came into contact with the superior surface of the vertebra below the level of the lesion. A line drawn along the anterior surface of the

inferior vertebra will intersect the superior first normal vertebra above the middle of its anterior surface.

A radiological spinal instability score was developed. Each radiological sign was allocated one point, with a maximum possible score of four. The outcome measures of the severity of progress of the deformity and the angles of deformity and of kyphosis at 15 years were then correlated with the pretreatment angle of deformity, the pretreatment vertebral body loss, the number of vertebral bodies involved, the level of the lesion and the spinal instability score. A step-wise multiple linear regression analysis was undertaken using SPSS software (SPSS Inc, Chicago, Illinois) to establish the effect of these variables on the angles of deformity and kyphosis.

Results

The mean angle of deformity at the start of treatment was 35°. This increased by 6° over 15 years to 41°. The progression of deformity occurred in two distinct phases, an active phase and a healed or growth phase (Fig. 4).

Active phase. Changes which occurred until complete clearance of the disease were included in this phase. There was a mean increase in the deformity of 12° (3 to 29) with all patients being affected. The severity of collapse during the active phase was influenced by the severity of destruction, the level of the lesion and the age of the patient. The angle of the deformity at the end of this phase correlated well ($r = 0.83$) with the severity of destruction of the vertebral bodies as assessed by vertebral body loss. Healing in spinal tuberculosis involves collapse until the healthy vertebrae make contact, and the deformity therefore increases in proportion to the severity of vertebral body loss. The increase in deformity depended on the level of the lesion.

Fig. 4

Graph showing that the progression of the angles of deformity and kyphosis occurred in two phases. During the 'active phase' the progression was identical in both. During the 'healed phase' the angle of deformity improved gradually while the angle of kyphosis increased after 60 months. This increase may represent a change in the angle of kyphosis caused by retardation of growth occurring at normal segments above and below the level of the lesion.

Fig. 5

Lateral radiographs of the lumbar spine of a four-year-old child with severe destruction of L2 and L3 at the start of treatment. Follow-up shows excellent improvement with growth at 60 months, 120 months and 180 months. The fusion mass of L2 and L3 begins to show increased anterior growth. By 15 years the fusion mass almost resembles a normal vertebra except for the attachments of the pedicles at two levels.

Lumbar lesions deformed less (6°) than either thoracic (11°) or thoracolumbar (15°) lesions ($p < 0.01$). Deformities in children aged over ten years progressed less (4°) than in those under five years of age (10°) or between six and ten years (14°) ($p < 0.01$).

Healed or growth phase. Clinical and radiological cure was seen consistently by 18 months, and changes thereafter were considered to be due to growth. There was a gradual decrease by 6° in the mean angle of deformity during the following 162 months. Thoracolumbar lesions showed less tendency for improvement during the healed phase (2°) compared with thoracic (10°) and lumbar lesions (9°) ($p < 0.001$). There was no statistical difference in the changes between children under five years of age (2°), those aged between six and ten years (3°) and those 11 years and older (3°).

While all children showed progression of deformity during the active phase, there were wide individual variations during the healed phase (Figs 5 and 6). This was evident

only when the progression was plotted graphically (Figs 7 to 9). There were three patterns of progression.

Type I. There were 25 children (39%) in this group. Their deformity progressed until completion of growth (Fig. 7). The speed of progression varied, but was maximal during peak growth. In 19 children the progression was continuous without any lag period between the active and healed phases (type Ia). In the remaining six (9%) there was a lag of from three to six years after the active phase when the deformity remained static which was then followed by a sudden and severe deterioration (Type Ib).

In those with type-Ia progression, the mean increase during the active phase was 15° with a further increase by 9° during the healed phase. In those with type-Ib progression, the mean increase during the active phase was 11° , and 47° during the healed phase (Table I). Type-Ib progression was more ominous because of its severity and the lag period of several years when the child could have been discharged from follow-up.

Fig. 6a

Fig. 6b

Radiographs showing extensive thoracic lesions in a three-year-old girl with a deformity of 40° (a) at the three-year follow-up. This progressed to 115° at 15 years (b).

Fig. 7

Graph showing that type-I progression showed deterioration in the deformity even after healing of the disease. In type-Ia this deterioration continued throughout growth whereas in type-Ib progression there was a lag period of a few years before the deterioration started. The progression was more severe in type-Ib.

Fig. 8

Graph showing that type-II progression had a decrease in deformity during the healed phase. In type-IIa the improvement started soon after healing of the disease and in type-IIb after a lag period of a few years.

Fig. 9

Graph showing that type-III progression had only a minimal increase in deformity during the active phase and little change during the healed phase. This was found in children with only minimal structural involvement.

Type II. There were 27 children in this group who improved with growth during the healed phase (Fig. 8). Improvement immediately followed the active phase (type IIa) in nine children and after a lag period of a few years in 18 children (type IIb). Those with type-IIa progression had a smaller increase during the active phase (8°) compared with those with type-IIb progression (9°) but had a greater improvement during the healed phase (type-IIa, 26° ; type-IIb, 15°). By the time of the 15-year review, children with type-IIa progression had a mean improvement of 18° compared with 6° in those with type-IIb progression (Table I).

Type III. There were 11 children (17%) in this group who showed no significant change in the deformity during the entire period (Fig. 9). These patients had only minimal disease without gross destruction of the vertebral bodies or alteration in growth. There was a mean increase in deformity of 4° during the active phase, but a decrease of 5° during the healed phase.

The severity and course of the deformity were deter-

mined by the changes during growth rather than by those occurring during the active phase of the disease.

The influence of various parameters such as age, the level of the lesion and the severity of deformity before treatment on the changes associated with growth was then analysed. Of the 29 children who were younger than five years when treatment started 12 (41%) had an unfavourable influence, 15 (52%) had a favourable influence and two (7%) had no change during growth. Although thoracic lesions showed the greatest tendency to deform at the start of treatment they also showed the most improvement with growth.

The difference in the number of patients with type-I progression and a vertebral body loss <1.0 (3/20; 15%) and those with a vertebral body loss >2.0 (7/8; 88%) was significant ($p < 0.01$). Five of 21 patients (24%) with a pretreatment deformity of less than 30° had unfavourable progression compared with 24 of 42 (57%) with a pretreatment deformity of greater than 30° ($p > 0.001$).

Outcome based on the spinal instability score. Thirty-three patients had an instability score of 0, one a score of 1,

Table I. The changes in the mean angle of deformity (degrees) during the active and healed phases in children with different patterns of progression

Type of progression	Changes in deformity in the active phase	Changes in deformity in the healed phase	Total changes over 15 years
Type Ia (n = 19)	15	9	24
Type Ib (n = 6)	11	47	58
Type IIa (n = 9)	8	-26	-18
Type IIb (n = 18)	9	-15	-6
Type III (n = 11)	4	-5	-1

Table II. The outcome as determined by the increase in deformity based on the spinal instability score, by number and percentage

Spinal instability score	Number of patients having a decrease in deformity	Increase of		
		<10	11 to 30	>31
Score of 2 and less (n = 37)	34 (92)	3 (8)	0	0
Score of 3 and more (n = 26)	6 (23)	0	13 (50)	7 (27)

three a score of 2, 12 a score of 3 and 14 a score of 4; thus 37 patients had an instability score ≤ 2 of whom 34 (92%) had a decrease in deformity (Table II). Only three (8%) had an increase of less than 10° and no patient had an increase of more than 10° . However, for the 26 patients with an instability score ≥ 3 only six (23%) had a decrease in deformity; 13 (50%) had an increase of less than 30° and 7 (27%) of more than 30° (Table II). The difference in outcome between those with an instability score < 2 and those with a score of ≥ 3 was highly significant ($p < 0.0001$).

At the 15-year follow-up, 33 of 37 patients (89%) with an instability score of ≤ 2 had an angle of deformity less than 30° . No patient had a deformity greater than 60° . In comparison, only three of 26 (11%) patients with an instability score ≥ 3 had an angle of deformity of less than 30° while 23 (89%) had a deformity of more than 30° ($p < 0.0001$). In 18 (69%) the deformity was over 60° .

It was clear that the instability score influenced the deformity and its final angle at 15 years irrespective of the level of the lesion or the age of the child at presentation. The score had an over-riding influence on the prognosis. Children with a score > 2 are at serious risk of a gross increase in deformity.

Progression of the angle of kyphosis. The mean angle of kyphosis at the start of treatment for all children was 25%. This increased by 11% during the active phase of the disease. The pattern of progression during the active phase was similar to the progression of the angle of deformity although the values were lower, mainly because of the expansion of the disc spaces above and below the lesion. During the healed phase, progression again paralleled that of the angle of deformity for the first 60 months when there was a decrease of 2° . Subsequently, unlike the angle of deformity, the angle of kyphosis showed a gradual increase. This was due to secondary changes in the vertebral bodies, above and below the lesion, which allowed further collapse of the two aspects of the deformity with an increase in the angle of kyphosis.

Stepwise multiple linear regression analysis was performed with the angle of deformity at 180 months as the dependent variable. The level of the lesion, the age at the start of treatment, the number of vertebral bodies involved, the pretreatment vertebral body loss, the pretreatment angle of deformity and the instability score were independent variables. The instability score, the pretreatment angle of deformity and the level of the lesion significantly affected the angle of deformity at 180 months ($r^2 = 0.78$). The instability score was the most significant accounting for 69% of the variables. A multiple regression analysis was then performed using the same variables and taking the angle of kyphosis at 180 months as the dependent variable. It was found that the instability score, the pretreatment angle of kyphosis, the level of the lesion and the vertebral loss at presentation were the significant predictors ($r^2 = 80\%$).

Discussion

Potent antituberculous drugs have made uncomplicated spinal tuberculosis curable and the emphasis has now shifted to the problem of deformity and methods of preventing it.^{5-7,9} Severe kyphosis can be a major disability^{7,9,15} for which surgical treatment is difficult and associated with a high rate of complications.⁸ Special attention must be given to patients who are at high risk of progression.

Severe kyphosis is more often a complication of childhood spinal tuberculosis than of adult disease. Those under the age of ten years at the time of vertebral involvement are at serious risk of an increase in deformity.^{4,6,9,16-19} In a controlled trial of young Korean patients who received ambulatory chemotherapy, there was a higher incidence of severe lesions in children than in adults.²⁰ Rajasekaran et al¹⁹ found that vertebral body loss at the start of treatment in children under 15 years of age was 1.9 compared with only 0.96 in adults ($p < 0.01$). In this study, pretreatment vertebral body loss was 1.74 for those under five years of age, 1.70 for those between six and ten years and 1.0 in those over ten years ($p < 0.05$). This suggests that children under ten years of age have more severe involvement and destruction than older children. The immature spine is also more flexible and susceptible to collapse.²¹ In a 15-year follow-up of lumbar lesions, the degree of collapse which occurred in the first 18 months per vertebral body loss in patients under ten years of age was nearly twice that seen in adults.¹⁹

The natural history of other spinal deformities such as idiopathic scoliosis, congenital scoliosis and congenital kyphosis has been well documented.²²⁻²⁷ There has been no such information for the progression of deformity during growth for healed spinal tuberculosis in children. The findings of this study clearly show that, unlike adults, in whom the deformity is static after cure of the disease,¹⁸ post-tuberculous kyphosis in children is a dynamic deformity with variable progression throughout growth. Progression over 15 years occurred in two phases. First, there was an initial collapse within the first 18 months during the active phase of the disease when all children had a variable increase in deformity. Healing involved collapse with contact of healthy vertebral bodies leading to fusion. It is natural that the extent of the collapse corresponded to the severity of destruction. It was also significantly influenced by the level of the lesion but not by the age of the child.

Secondly, important changes occurred after cure of the disease, which was usually achieved by 18 months. The changes during the healed phase determined the progression of deformity. Five varieties of progression were noted. Earlier reports concluded that growth had either a deleterious or insignificant effect on healed tubercular kyphosis,^{4,8,9,28} but the findings of this study have shown that in post-tubercular kyphosis there was improvement during growth in 44% of children. This is unique to post-tubercular kyphosis since growth is usually associated with

deterioration in other spinal deformities.²²⁻²⁷ There was no change in deformity in 17% of patients and a deterioration in 39%.

Regeneration of partially destroyed vertebral bodies during growth has not previously been clearly documented. Dickson,¹⁷ in a review of ambulant chemotherapy in Nigerian children, observed a favourable response in a few due to growth of the anterior part of the vertebral body. Cleveland et al²⁹ followed 18 patients for 21 years and found that growth of the fusion mass occurred in both the sagittal and coronal planes. Rajasekaran,¹⁸ describing 28 children under the age of 15 years at the start of ambulant chemotherapy, noted anterior growth and a decrease in the angle of deformity in ten. It was concluded that the severity of the initial deformity was important in determining the response with growth. Decrease in deformity was by preferential growth of the anterior parts of the fusion mass and occurred in children of all ages, irrespective of the level of the lesion.

The age of the child at the start of treatment did not influence the pattern of progression. The mean age at the onset of the disease was seven years for those with type-Ia progression, six years for type-Ib, five years for type-IIa and five years for type-IIb. There was no significant age difference in these types. The mean age of patients with type-III progression was higher at 10.5 years. This suggests that children over ten years of age have less destruction and an adult type of progression.

The level of the lesion had a significant effect on the extent of deformity at presentation, the severity of collapse during the active phase and the decrease during the healed phase. The mean deformity at the start of treatment for the thoracic (50°) and thoracolumbar levels (40°) was higher than that for lumbar levels (20°, $p < 0.01$). Thoracic lesions had the greatest mean deformity at presentation, but this could have been due to the additive affect of the normal kyphosis. The normal range of maximum kyphosis is 30° to 50° with a mean of 37°.³⁰ Although thoracic lesions have a greater angle of deformity because of the pre-existent kyphosis, surprisingly they showed the greatest degree of improvement, 10° during the healed phase. This reduced tendency to collapse during the healed phase was probably due to protection by the rib cage against instability of the spine.

Thoracolumbar lesions had the worst prognosis with the greatest deterioration during the active phase and the least improvement during the healed phase. The mean increase during the active phase was 15° compared with 11° in the thoracic and only 7° in the lumbar regions. The mean decrease during the healed phase was only 2° compared with 10° in the thoracic region ($p < 0.01$) and 8.5° in the lumbar region ($p < 0.01$).

Lumbar lesions were associated with the least pretreatment deformity, less deterioration during the active phase and a substantial decrease during the healed phase. Stagnara et al³⁰ found that the range of lumbar lordosis is 33° to

79°, measured from the top of L1 to the sacrum. The lordosis is highly protective against kyphotic collapse, and severe destruction, involving more than two vertebral bodies, must occur before the lordosis can straighten and collapse into kyphosis.¹⁹ The reduced tendency for progression in the lumbar region and the increased tendency in the thoracic and thoracolumbar regions have already been reported by other authors.^{6,18,29,31} Progression during growth was also influenced by the severity of the pretreatment angle of deformity, the extent of the initial vertebral loss and, importantly, by an instability score of more than 2. While the pretreatment angle of deformity and vertebral loss indicated the severity of involvement, the instability score influenced the changes associated with growth and the final outcome.

The four radiological features which have been described (Fig. 3) each indicate disruption of the posterior arch. With considerable destruction of the anterior elements disruption of the posterior arch leads to instability. In the normal spine, 80% of the mechanical forces are borne by the anterior column. When this is destroyed by disease, those borne by the posterior column lead to subluxation and dislocation of the facet joints. In children with extensive destruction more than one facet joint was found to dislocate sequentially before the healthy vertebral bodies came into contact with each other. This leads to loss of integrity of both the anterior and posterior columns. For those with an intact posterior arch, after cure of the disease, the undestroyed growth plates of the involved vertebrae regenerated. With resumption in growth of the anterior aspect of the fusion mass there was a progressive improvement in deformity. This study clearly shows that the capacity for such anterior growth depends on the integrity of the posterior arch, as indicated by a lack of radiological evidence of instability. The instability score can accurately predict an increase in the angles of deformity and kyphosis of more than 30° and a final deformity of more than 60°. The radiological signs of instability are useful clinically as they appear early in the disease and are a guide to prognosis. In current clinical practice it is customary for the child to be discharged from follow-up a few years after cure of the disease. However, this study clearly shows that a deformity can progress. In children with type-Ib progression the deformity will become more severe, and the child may develop an unacceptable deformity without supervision. It would be useful to identify such children early in the course of the disease since surgery during the active stage is easier and safer.⁸ The radiological signs of instability are therefore useful for identifying the course of the disease.

Although a score has been developed it is not incremental. Radiological signs are absent until the posterior arch is disrupted. Once dislocation of the facets has occurred the signs appear quickly. Of the 63 lesions, 33 had a score of 0 and 26 a score of more than 3. Only one lesion had a score of 1 and three had a score of 2, showing that dislocation of the facets rapidly led to instability. In a few

patients, lateral translation was visible in the antero-posterior radiographs initially but was not seen subsequently. This could have been because the two aspects of the deformity became translated, one behind the other, as a result of the available freedom of movement. The results show that children with a score of more than 2 should be advised to have surgery to prevent collapse. The procedure must be tailored to the child according to the level of the lesion, the severity of the destruction and the extent of the instability.

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