The Treatment of Scoliosis

A PRACTICAL APPROACH

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Continuous emphasis on the difficulties and complexity of the problem of the treatment of scoliosis has without justification created in the minds of most Orthopaedic Surgeons, confusion and an unwarranted desire to leave the treatment of such cases in the hands of those foolish enough to be interested in the problem. John Cobb has often stated that you do not have to be mad to treat scoliosis—but it helps.

The purpose of this paper is an attempt to straighten out our concepts.

The great revival of interest in Scoliosis in the past decade, has shown that correction and adequate posterior fusion, give gratifying results in those cases in which it is justified. Unfortunately, interest in the subject now seems to be waning. More surgeons and surgeons in training should treat scoliosis. It is rewarding work and the basic principles are easily learnt.

Etiological Considerations:

Theoretical dissentations as to the etiology, for example—is vertebral body rotation a primary or secondary phenomenon, should initially be avoided. Speculation as to which muscle is causing the deformity does not help the patient unless the surgeon can do something about it. For example, in paralytic scoliosis, factors such as:—

(1) Compensation.
(2) Imbalance of the extra-spinal muscles.
(3) Primary disturbance in vertebral growth.
(4) Secondary disturbance in vertebral growth.
(5) Imbalance of the deep spinal muscles.
(6) Fascial contracture may be involved.

These factors may interact and either re-inforce or counteract one another. The surgeon is now like Alice in Wonderland.

Paralytic Scoliosis:

Paralytic Scoliosis develops as a result of muscle imbalance. If recovery does not occur, the muscle imbalance becomes permanent, the growing spine is affected, the curvature can and often does increase. Secondary factors such as gravity, disparity of vertebral epiphyseal growth, etc., can make it worse. The age at onset and the degree of muscle imbalance are the decisive factors affecting the prognosis.

The conquest of Poliomyelitis will in five years, make this a rare condition and so eliminate 60% of all the Scoliosis cases requiring surgery. Paralytic curves are usually more flexible than idiopathic curves, but when severe, can be extremely rigid.

Idiopathic Scoliosis:

Idiopathic Scoliosis is a diverse group, probably due to a metabolic disturbance with hereditary factors. Onset is usually during adolescence but in a particularly maglignant group it starts shortly after birth. Progression of the curve is limited by the cessation of spinal growth. Deterioration if it occurs, is most rapid during the pubertal growth spurt. The curves are more rigid than paralytic curves.

Congenital Scoliosis:

Congenital Scoliosis is usually due to hemi vertebrae but can also be due to failure of differentiation of the posterior elements of the spine or due to congenital fusion of ribs. Deterioration is usually not significant except in those where the posterior elements have failed to differentiate and those associated with spina bifida occulta.

Neurogenic Scoliosis:

Neurogenic scoliosis is most often due to neurofibromatosis. It is characterised by the cafe au lait patch, the other stigmata of neurofibromatosis and a short sharp angular curve in which severe deterioration can occur. Spinal cord tumours occasionally present as scoliosis.

Thoracogenic Scoliosis:

Now that empyema, pulmonary fibrosis and thoracoplasty have become uncommon, is rarely seen.

ASSESMENT AND STUDY:

For the accurate assesment and study the physical examination must record data on posture, general physical development, musculature, shoulder level, scapular prominence, list, hip assymetry, leg length, cafe au lait marks, rib deformity, rotation, flexibility as well as the direction and extent of the major curve and the curve pattern.

X-rays taken of the spine should cover the 1st dorsal to iliac crest area on a 17 × 14 casette. A.P. erect, sitting and supine films should be done. Lateral bending films in the supine position are only necessary pre-operatively.

Vital capacity and pulmonary function studies are mandatory in paralytic cases. Equally important is a rough clinical assesment of the patients ability to cough.

It is essential to thoroughly understand the concept of a primary curve, a secondary curve, a structural curve, a functional curve and a combined structural-functional curve.

Ferguson defined a *primary curve* as one produced by a deforming factor or force.

A *secondary curve* is the result of the action of the law of balance. Muscles act involuntarily to bring the head erect over the centre of the pelvis with the body in balance, in the easiest possible way and to the extent that the muscles are able.

A *structural curve* is one with structural changes in bone, nerve, muscle or other tissue and is a curve which the patient cannot correct and maintain corrected when he is erect. Its cardinal roentgenographic signs are abnormal wedging, angulation, rotation and position of the vertebra in the curve. (Cobb).

A *functional curve* is one without structural changes that results from the normal available angulations between vertebrae. It is a curve which the patient can correct and maintain corrected when he is erect. (Cobb).

A *combined structural-functional curve* is one which has some structural and some functional characteristics which the patient can partly correct when erect. The curve with the most structural change is the major structural (primary) curve. Functional (secondary) and minor structural (combined structural-functional) curves are readily recognised.

The extent of the curve must be accurately determined by noting the maximally tilted end vertebrae. A curve extends from the top of the uppermost to the bottom of the lowermost vertebrae in the curve.

If in doubt, draw lines along the vertebral body margins in order to determine when these lines cease converging into the concavity of a curve and begin to diverge on the convex side of the adjacent curve. The maximally tilted end vertebra is usually common to adjacent curves unless unusual wedging is present.

After determining the extent and structural changes in a curve, it can be measured by either Cobb's or Ferguson's method.

By Cobb's method, the scoliotic angulation is the supplementary angle formed by the intersection of lines drawn perpendicular to the superior surface of the top vertebra and the inferior surface of the bottom vertebra.

Ferguson's method measures the supplementary angle formed by straight lines joining the central points of the apical and end vertebrae.

Both have a margin of error of approximately three degrees. No correlation exists between these two methods. A given curve will measure differently by these two methods.

Cobb's method consistently gives a higher measurement. Yet after correction, due to the fact that the end vertebrae of a curve usually corrects more than the apical vertebrae, it in 50% of cases, gives a lower measurement. Percentage of correction by Cobb's method, is therefore more favourable.

Cobb's method, because it tends to magnify the progression of a curve, is more useful in cases under observation. I have used Cobb's method exclusively. I believe it is more accurate, it can be applied segmentally in the localisation of pseudo-arthrosis and in measuring kyphosis. With Ferguson's method the centre point of the apical vertebrae is difficult to find in hemi vertebra, or where severe rotation is present.

Possibly both methods should be employed in assessing the degree of correction.

Concept of angular deviation of a curve: List

A curve convex to the right produces a left angular deviation and vice versa. Given a case with a triple curve pattern where the occiput is on the central spinal axis, i.e. no list, the angular deviation of the major curve is balanced or compensated by the sum total of the angular deviation in the opposite direction of the minor curves. In other words scoliosis is not just another crooked spine.

A patient with a major curve convex to the right without adequate minor curves, will list to the left. In this case the left angular deviation of the major curve is greater than the sum of the right angular deviations of the minor curves. It is uncompensated. Pelvic obliquity always creates difficulties. Apart from those cases of pelvic obliquity due to primary hip pathology or lower extremity inequality, which may often not have structural scoliosis, a deforming factor or force has incorporated the pelvis into and as part of a structural curve. The sacrum and its attached pelvic ring must be seen as the lowermost vertebra of this structural curve. Between the sacrum and the floor we must visualise a compensatory curve in the opposite direction.

When a structural curve extends down to or close to the lumbo-sacral junction and insufficient compensatory angular deviation is available in the spine above this curve, then the pelvis will tilt into this curve so as to create compensatory angulation below it.

Two examples:

(1) The severe C type dorso-lumbar paralytic curve.
(2) The triple curve with severe structural changes in all three curves in which the sum of the two minor curves is greater than the major curve.

Shoe raises to correct the pelvic obliquity obviously make it more difficult for these people to stand erect.

Secondary abduction or adduction hip contracture can develop in these cases. Their surgical correction will no alter the pelvic obliquity though it does make the correction of the scoliosis easier.

Pelvic obliquity can be or has to be maintained by the patient in the erect position by either going onto tip toe on one side or by flexing the knee on the other.

Curve patterns:

There are three flexible areas in the spine, cervical, dorsal and lumbar. The dorsal comprises nearly twice as many segments as each of the other. So lets say there are four regions by dividing the dorsal into two—an upper and a lower dorsal region.

A curve may have its apex at the junction between two of these regions. This allows for seven possible primary curves, i.e. cervical, cervico-dorsal, high dorsal, mid dorsal, low dorsal, dorso-lumbar and lumbar. The curve pattern which develops depends on the number of primary curves (one or two), the situation of the primary curve and the relative flexibility and length of spine above and below it and the etiology of the curvature.

C type, triple quadruple and double major quadruple curve patterns may emerge.

It is useful to recognise the following specifically.

(1) The high dorsal or cervico-dorasl paralytic curve because of its poor prognosis, cosmetic deformity and the difficulties encountered in correction.
(2) The long C type paralytic curve because it is very typical, fairly flexible, easy to correct and maintains correction best.
(3) The triple curve pattern of idiopathic scoliosis because strangely enough the major curve is to the right in over 80% of cases and it has a sex incidence of four girls to one boy.
The major curve is low dorsal. D6—D12 and D5—D11 are by far the most frequent.
(4) The double major curve pattern of idiopathic scolosis and occasionally paralytic scolosis because they balance each other so well that correction and fusion is not very often necessary but tiresome when it is necessary because of the double correction and length of fusion.
(5) The short sharp angular curve of Neurofibromatosis because of its poor prognosis.
(6) And lastly the curve of an intra spinal tumour with its increased interpedicular distance and scalloped body backs, because of its poor prognosis for both patient and surgeon if not recognised.

Necessity for treatment:

We must appreciate clearly that many curves do not get worse, some even improve, others resolve completely, others may stop progressing even before spinal maturity is reached. All idiopathic curves stop getting worse when spinal maturity is reached and the iliac epiphyses are completely formed and fused medially (Risser's sign). Approximately a third of children will reach spinal maturity at 14½, 15½, and 16½,

Unfortunately approximately 40% of scoliosis cases have a progressive structural curve threatening unsightly cosmetic deformity.

Observation and experience increase our selectivity as to time and degree of candidates for correction and fusion. A balance must be struck between Risser's enthusiasm and Cobb's conservatism. Fortunately in most cases, the decision is not in our hands for even in a conservative clinic, 61% of the idiopathic cases that come to correction and fusion, were of less than one year duration as far as is known. The curve average in their group analysed was 87%. "However, the emphasis must be on early detection. It must be realised that during the period of most rapid growth of the spine at and preceding puberty, some spinal curves may progress very markedly within a short time. Close and constant observation is required in this period so that measurements may be taken to arrest and correct the deformity before it is too late to achieve a satisfactory result." (de Forest Smith).

Poliomyelitic curves do not adhere strictly to Rissers rule of spinal maturity. Increase in the curvature though less rapid, can occur even after spinal maturity. In this respect Cobb's rule of keeping a paralytic curve under observation for ten years or until the age of 16 years, which ever is the longer is useful.

Progression of curvatures:

A curve may increase in its degree of angulation, its number of segments, its structural changes and its rigidity.

In approximately twenty per cent of progressive curves, additional segments are added to the major curve at the expense of the minor curves. One or every occasionally two vertebrae may be added to the major curve and usually from the non flexible minor curve. It appears that a curve does reach a point where the number of its component segments becomes constant and that further increase in the degree of curvature is accomodated by or the result of structural changes in the vertebral bodies. Most curves however, remain constant as regards to the number of their segments. But if fusion at an early age is contemplated, the possibility of the curve increasing in the number of it's segments, subsequent to the operation, makes an accurate selection of the fusion area, difficult.

Increase in the number of segments makes the Harrington factor less reliable. This factor is determined by dividing the number of degrees of the primary curve, as determined by the Cobb's method, by the number of vertebrae in the primary curve. For example, a typical idiopathic curve of

Figure I.
Post Poliomyelitis Scoliosis—Pre-operatively 30/1/57.

Figure II.
Post Poliomyelitis-Scoliosis—Pre-operatively 30/1/57.

60° extending from D6—D12 (i.e. 7 vertebrae) will have a Harrington factor of 8·5. Should this curve increase by 5° and absorb another vertebrae, the Harrington factor will decrease to 8·1 in spite of the fact that the curve has increased. Harrington states that if the factor is five or more, surgical treatment is usually indicated. In my opinion, a factor of seven or more in a growing child would be safer.

The increase in the number of vertebrae in a curve post-operatively, even in the presence of a good solid fusion, is one of the most potent causes for loss of correction in a growing spine. Significant progression of a structural curve deforms the thorax, diminishes vital capacity and pulmonary function and increases the likelihood of cardio-pulmonary effects. It increases fatigue and reduces exercise tolerance.

Three degress of severity are usually recognised:

Mild curves—less than 30°
Moderate curves—30°—60°
Severe curves—60°

Conservative Treatment:

"It must be remembered that many spine curves are mild and few need any treatment." (Cobb).

Severe curvature with a well established cosmetic deformity in a child over the age of twelve is best dealt with by correction and fusion. Less severe curvatures should initially be treated conservatively. Relentless deterioration in spite of adequate conservative treatment is an indication for correction and fusion in a child over the age of 8 years.

Regular observation:

At four monthly intervals with a clinical examination and measurement of the curvature on an erect, sitting and supine X-ray film, insures effective control. Plotting the curvature on a graph with degrees of curvature on the abscissa against time on the ordinate gives the best idea of progress and a trend to deteriorate is soon discovered. Adequate justification for treatment conservative or otherwise, can only be based, in mild cases, on factual evidence of deterioration.

During this period of observation the parents frequently require reassurance. Confidence is gained when they realise that the child's problem is being studied scientifically. They accept correction and fusion and all that it implies more readily, should deterioration make it necessary.

Physiotherapy:

Physiotherapy will never correct a structural curve.

Functional curves and posture may be improved by it. It helps maintain the flexibility of the primary and secondary curves. Breathing and coughing exercises are useful in cases with reduced pulmonary function. Swimming is excellent exercise. Money should not unnecessarily be wasted in the vain hope of a cure. Bed exercises, tendo-achilles and sole-structure stretching is important during long periods of recumbency.

Shoe raises:

A temporary shoe raise which improves a low curve problem has some limited value. Radiological confirmation of the improvement is necessary before it is prescribed.

Leg length inequality if it does exist and is not merely apparent because of a high hip resulting from trunk shift, should be corrected.

Buttock pads:

I have found a small pad slipped into a pocket inside the pants, very useful in improving the sitting posture of a

Figure III.
Fusion D9—L3. 30/4/57.

Figure IV.
Post-operative-Fusion D9—43. 10/11/58.

child with a wasted buttock. These low lumbar curves frequently develop structural changes.

Recumbency:

Keeping a child supine for up to 16 hours a day has some value in slowing down the rate of deterioration but is difficult to enforce. Adolescents do not take easily to it. I have just about given up.

Braces:

Many braces have been invented for the treatment of scoliosis.

I have used the Milwaukee brace extensively. As far as I am concerned it is the only brace that is of any value in the treatment of scoliosis.
It is indicated in five instances:

(1) Rapidly progressive structural curves in young children. It slows down progression and gains time.
(2) Collapsing spines in paralytic cases. It provides stability and improves breathing until it can be replaced by long and adequate fusion.
(3) A mild or moderate idiopathic curve which is showing rapid progression near the end of the growth period can be held until growth is completed.
(4) Cervico-dorsal curves prior to fusion.
(5) After soft tissue release procedures to correct pelvic obliquity.

Many curves continue deteriorating in spite of a well fitting Milwaukee brace. These curves probably require fusion. My cases do not sleep in the brace. The best way to assess the effectiveness of the brace is an X-ray erect with and without the brace. If the pelvic piece does not fit snugly or is loosely fastened, all the corrective effect is lost. Orthodontic supervision is necessary.

Enthusiasm for the Milwaukee brace should be carefully controlled and its limitations understood. There are few better methods of achieving pre-operative correction, unless of course one is keen on fusing mild flexible curves.

Plaster Casts:

My enthusiasm for procrastination jackets either the turnbuckle or localiser cast, is waning. I am of the opinion that if a Milwaukee brace is not holding the curvature it should be fused. The Murk Jansen plaster bed has very limited value.

Operative Treatment:

Every now and then we hear of a new method of treating scoliosis which will do the job better and quicker. They all have a catch-word and a gimmick and our language is enriched by it. Terms like "localiser cast," "springplasty," "muscle arthroplasty," "instrumentation." come to mind. A healthy degree of scepticism develops with experience. Carefully documented end result studies have been published —Mac, Risser, Gucker, Irwin, Roux. Any new method advocated can no longer get by without two year percentage correction maintained figures. One or two photographs of a good result no longer suffice. Classification of results as better, same or worse when better implies:—"if the curve was decreased; if progression of the curve in a child was arrested; if function was improved; if fatigue, pain and respiratory distress were reduced; and if the psychosocial effects of the deformity were reduced," does not suffice. Clearly the results may be interpreted as proportional to the

enthusiasm of patient and surgeon for the method of treatment.

I have adhered to and advise others starting to treat scoliosis to adhere to a method proved over 40 years. Cast correction plus an adequate, mature posterior spine arthrodesis of the whole extent of the curvature.

Indication:

The prime indications for correction and fusion are:—

(1) To correct unsightly cosmetic deformity.
(2) Stabilisation of a weak collapsing spine.
(3) Prevention of further deformity.

Note the omission of pulmonary function. Cast correction and fusion does not improve vital capacity and pulmonary function, it may reduce it.

Other indications:

(1) Curves over 60° usually require correction and fusion.
(2) High paralytic curves.
(3) Progressive uncontrolable structural scoliosis in a young child.
(4) Curves due to Neurofibromatosis.
(5) Adults with painful structural curves.

Correction:

Three types of casts should be used.

The turnbuckle cast of Risser as modified by Cobb, has stood the test of time. It achieves correction if the hinges are properly placed eccentric to the apex of the curve by a combination of lateralbending, three point pressure and traction.

It will correct severe rigid curves better than any other type of jacket. In no single instance have I found its leniency to exaggerate the secondary curves a practical disadvantage. It must be applied snugly and properly. The head piece is always necessary except in low lumbar curves when plaster shoulder straps suffice. The thigh on the side of the convexity is incorporated, the arms are free. Full correction can be achieved in less than six weeks.

Milder more flexible curves can be corrected with the Risser localiser cast.

The Stagnora distraction jacket is the most effective cast for the high dorsal and cervico-dorsal curve.

Check X-rays taken through the plaster at regular intervals determine the correction achieved.

Theoretically, permissable correction in a triple curve pattern is the sum of the residual angulation of the minor curves when the patient attempts to correct them by lateral flexion. Sufficient angulation must remain in the major curve after correction and fusion, to balance the residual angulation in the minor curves.

In practise, over-correction and maintenance of over-correction is rarely encountered.

It is always wise to assess the ability of the lateral trunk flexors to maintain the correction of the lumbar minor curve

The greater the degree of correction obtained in a rigid curve, the more solid the fusion will have to be to maintain it. I do not subscribe to the defeatist attitude of limiting correction to avoid subsequent loss.

Our efforts should rather aim at achieving a massive fusion and a more careful post-operative programme.

Pressure sores are occasionally encountered but can largely be avoided if frequent changes of position are encouraged and if the child is given full permission to unscrew the turnbuckle, should she become unbearably uncomfortable. Correction of rigid curves should proceed slowly.

Flexible curves can be corrected rapidly.

Peripheral nerve lesions are occasionally encountered during correction. The ulnar nerve is most commonly affected. Weakness and numbness in the ulnar distribution is usually transient but can be permanent. At first, like others I ascribed it to damage to the roots either by stretching or pinching. Now I am of the opinion that it is due to repetitive trauma to the nerve in the groove behind the medial epicondyle from continually resting on the elbow. This area should be protected and if the paralysis becomes permanent an anterior transposition of the nerve must be performed. Other potential sites of nerve pressure are the posterior triangle of the neck and the upper arm on the edge of the plaster.

Selection of the Fusion area:

One of the arguments in favour of postponing fusion until spinal maturity is reached, is that it simplifies the selection of the fusion area and reduces the incidence of short fusions. In a mature spine, fuse the whole extent of an idiopathic primary curve and to one vertebra above and two below a paralytic primary curve. Leave at least two mobile levels below the fusion unless the low nature of the primary curve or trunk muscle weakness requires the fusion to extend down to the sacrum.

The rule in an immature spine is to fuse to one vertebra above and one vertebra below an idiopathic primary curve. In a paralytic curve the fusion should extend to at least two vertebra above and two below. If the fusion area, so calculated, extends to or above the 5th dorsal vertebra, it must be extended up to dorsal one.

Operative Technique:

It was my privilege to spend a year with John Cobb and Phillip Wilson Jnr. at the Hospital for Special Surgery. John Cobb is a meticulous master of the art of posterior spinal fusion.

His modification of the Hibb's technique, I will attempt to describe.

Marker X-rays are taken before the operation. A methylene blue skin tatoo mark and metal X-ray marker technique are used.

The operation is performed under general anaesthesia through a window in the turnbuckle jacket. After toweling a straight scratch in the skin in the line of the proposed incision, the whole length of the incision is infiltrated intradermally with a ¼% procaine solution to reduce haemorrhage from skin vessels. Through a small incision the spinous process of both marker vertebrae are nicked for subsequent identification. The incision is then made in short easy stages to reduce blood loss.

Skin drapes are applied. The surgeon now removes the outer of the two pairs of gloves he has on. The subcutaneous areal or tissue is scratched apart. The midline decussation of the fascia covering the paravertebral muscles is exposed. The cartilage cap of each spinous process to be exposed is split exactly in the midline and broken off to each side. Cobb's periosteal elevator can now be slipped between the periosteum and the spinous process. Both sides are plugged and the next spine is exposed. When all the spines have been exposed the interspinous ligaments are split exactly in the midline.

Perfect subperiosteal dissection can now be achieved. The lamina are exposed as far as the base of the transverse processes. The spinous processes and laminae are meticulously cleared of all attached soft tissue sparing only the yellow fibres of the flavum. This clearing is done methodically from top to bottom, at no time should more than two vertebrae be exposed to the air. The rest of the wound is packed off. If haemorrhage is encountered it is packed off, the next vertebra is dealt with and later you return to the troublesome area which by now is dry. This discipline saves time. In three-quarters of an hour up to twelve vertebrae can be stripped and cleared and looking as if the job has been done by army ants. It looks slow but is really very much faster than any other method.

Diathermy is hardly used.

After a check count of the vertebra in the fusion area, broad decortication of the exposed bone surfaces is done by raising curls of living bone.

Start in the deepest part of the wound and work progressively upwards. In the dorsal area, a short laminar chip based laterally is raised from the middle of the lamina on each side. Four long curls are then raised utilising the whole of the spinous process and extending far out onto the lamina—two on each side. One will be bent upwards to bridge the inter-laminar space and lock in under the laminar chip of the vertebra above and the other will be folded down to lock in under the laminar chip of the next caudal

vertebra. In the lumbar area an additional curl is raised from each superior articular process.

In this way broad decortication is achieved and living curls of bone interdigitate across the interlaminar spaces, forming a broad fusion bed. Small juicy pieces of cancellous homogeneous bank bone are tucked into all the crevices under these bone curls. And later when the fusion bed is complete a large quantity of cancellous matchstick strips of bone are packed longitudinally over the whole fusion area. Sufficient homogeneous bone should be added so that it is just difficult to close the paravertebral muscles over the fusion. A cushing clip is left at the upper and lower limit of the fusion as an X-ray guide. The bone graft is now encircled by an intact periosteal tube. Dusting with penicillin and streptomycin powder and post-operative antibiotic cover, has enabled this series to be accomplished without a single case of significant sepsis.

The wound is closed in layers without drainage. The window in the plaster is packed with wool and covered with elastoplast, to be filled in with plaster after the removal of the sutures.

The whole dorsal spine can be fused in two hours. Blood loss is approximately two pints and must be replaced. I always have three pints on hand. When the fusion extends into the lumbar spine the rate of progress is slower.

The operation can be done in two or three stages at fortnightly intervals depending on the pre-operative condition of the patient and his condition during the operation. Particular attention must then be given to junctional areas. If the fusion is to extend into the lumbar region for three vertebra or more, it is better to do it in two stages.

Tracheotomy and mechanical respirators may be employed if required.

I do not fuse the articular facets.

Facet fusion is widely advocated and in Mac's series articular facet fusion reduced the pseudo-arthrosis incidence from 65% to 30% in paralytic cases and from 56% to 15% in idiopathic cases. These figures may appear to be very significant but many factors are involved. In the Cobb series that I analysed the incidence of pseudo-arthrosis was 20% in idiopathic cases. He does not do a facet fusion. His argument which seems valid is that destruction of the facets increases the intersegmental mobility of the spine. The incidence of pseudo-arthrosis is always higher in paralytic cases than in idiopathic cases. Surely the greater flexibility of the paralytic curve must be a potent factor. I like to see the facets locked tightly by the corrective force which has been applied.

Autogneous bone is probably better than homogeneous bone. Tibial grafts are in my opinion criminal and it is difficult to get sufficient autogneous iliac crest bone in children. I am quite happy with homogeneous bone either from the bank or a willing relative.

Post-operative management:

After the lost blood has been replaced, an intravenous infusion is maintained until the patient passes flatus. Early in the series I lost one case on the third post-operative day from acute dilitation of the stomach. These children are prone to develop dilitation and a gastric suction tube must be passed if nausea and vomiting persist longer than the 1st post-operative day.

Coughing and breathing exercises are very important. A dorsal fusion makes coughing painful and atelectasis is a real danger.

After wrapping in of the window the patient remains recumbent for six months in the turnbuckle jacket. The cast is then removed and X-rays are taken and a snug holding jacket applied, with shoulder straps.

After a further four months in bed, the plaster is removed, X-rays are taken and if satisfactory, the patient is allowed up in a full steel spinal brace. The fusion is protected in this brace for three to six months.

It is virtually impossible to recognise a pseudo-arthrosis on the oblique X-ray taken six months after operation, as the fusion mass is still in a conglomerate state. After 10 months the mass is more uniform and a pseudo-arthrosis can be seen on the oblique X-ray. Its immediate correction is mandatory. Shorter periods of recumbency can by all means be tried. Experience will teach that they lead to greater loss of correction and a higher pseudo-arthrosis incidence.

Within a month or two the list resulting from the accentuated minor curves corrects. The flat chest as a result of rib pressure fills out. Correction of extremity deformities may be undertaken during the holding jacket period.

Check X-rays are taken at three monthly intervals and any pseudo-arthrosis that appears must be dealt with. Undue loss of correction is a good indication of the presence of a pseudo-arthrosis. Two years post-operatively when the fusion is really solid, any unsightly rib hump can be improved by rib resection. This is usually a two stage procedure to avoid mediastinal flutter. It reduces the vital capacity only slightly. It is only tolerated when pulmonary function is reasonable and should be left to a thoracic surgeon.

In cervico-dorsal curves, the unsightly prominence of the trapezius can be vastly improved by resection of the 1st and 2nd ribs.

Bone Growth after Spinal Fusion:

I quote from Johnson and Southwick. "It was concluded from these cases that when a spine fusion is questionably solid and fairly massive, there is little increase in length of the fused area." The study of Hallock, Francis, and Jones conveys an inaccurate and perhaps unintentional impression that considerable growth occurs in a solidly fused spine segment. It does however, indicate from the practical clinical point of view what will happen to the average child after an average fusion in early childhood.

Pseudo-arthrosis in spine fusions in children are more common than generally suggested, they may be gross or microscopic, but if the fusion is massive, the less chance there will be that it will break down under the stress of growth and motion.

This has been my experience in two cases fused at age 6 to 8 years respectively. Very little growth has occurred. The fusions are massive and solid. The slight increase in length of the fused area can be explained by increasing radiological magnification as the patient gets bigger.

Average age at fusion.	Average degree of curvature prior to fusion.	Average correction obtained.	Average correction maintained for 2 years.	Average Length of post-operative followup.
13½	77% (in 28 cases where known)	89% (in 25 cases where it is recorded) If 6 added as zero correction drops to 72%.	47% (in 27 cases where it is recorded) If 4 cases with incomplete records added as zero, then it is 40%	3·4 years

Pseudo-arthrosis rate:—25% (8 cases). Recorrection and fusion required in three cases.
Short fusions:—Three cases, ages 12 years, 11 years, 12 years.

The indication for fusion in these two children were clear cut and demanding and their restriction of spinal growth will stunt them less than the eventual scoliosis would have.

Loss of Correction:

Most of the loss of correction occurred during the 1st year after the operation and specifically between the 6th and 12th post-operative month. Loss of correction occurred in same case, up to 16 months after the operation.

Cutting the window in the turnbuckle jacket causes an immediate loss of correction of from 5° to 10°.

Inadequate fusions, short fusion and pseudo-arthrosis are the most potent causes of loss of correction.

RESULTS.

Total 67 cases corrected and fused. 32 cases with two years follow up. One double major excluded—31 cases.

25 Post-Polio	80%
1 Neurofibromatosis	4%
5 Idiopathic	16%

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