Late-onset (adolescent) idiopathic scoliosis is the commonest spinal deformity seen in our clinics. Like many orthopaedic deformities the degree of the condition determines its importance. When schoolchildren are examined many small inconsequential curves may be seen since it is difficult to keep a straight spine in the face of three-dimensional growth for 20 years. The condition becomes progressively less prevalent when assessed by increasing magnitude of the curve. In order to separate potentially troublesome scoliosis from unimportant ‘schooliosis’, the Scoliosis Research Society suggested that in the former the Cobb angle should be more than 10°. To that definition must be added ‘concordant’ rotation in which the posterior elements are directed towards the concavity of the curve; otherwise there is no separation of structural from non-structural curves.

Most patients with late-onset idiopathic scoliosis require no treatment and suffer no functional limitations. In assessment of their management the advice given must be evidence-based. Personal experience is very valuable but it can also be inflexible.

Use of the Cobb angle in analysing scoliosis both epidemiologically and clinically has presented problems. The deformity of structural scoliosis is three-dimensional and as the lordotic apex twists so the frontal plane depicts the deformity less well. For example, the problems presented by a curve of 40° are much more than twice as great as in one of 20° and therefore, since the Cobb angle is not linearly proportional to the severity of the deformity, it cannot be handled by simple means and changes in percentage. Surgeons treating scoliosis can intuitively picture what a Cobb angle of, say, 45° represents and still tend to think in terms of this measurement. It can be argued that we should carry on using it since there is not a better means of assessment. However, having an intuitive feeling about the Cobb angle is not sufficient reason for using it as the critical variable in assessing the size of the curve in studies on the natural history or of response to treatment. The Cobb angle is a continuous variable but we tend to categorise it by grouping together, for example, curves of 11° to 15° in 5° batches. Now we have been invited, on the basis of the apparent ability of the Milwaukee brace to prevent progression of a Cobb angle of 6°, to endorse treatment with a brace and to resurrect screening in school.

What is ‘magic’ about 6° of progression? The answer is that this is probably the smallest difference in the Cobb angle that can be measured accurately, although reliable detection of this magnitude may not be possible. However, we are surely not saying that an increase in the Cobb angle from 40° to 46° is the same as from 10° to 16° or 100° to 106°! We cannot treat a continuous variable which is non-linear in a categorical fashion, particularly if this is of the same order of magnitude as the intrinsic error of the measurement. We cannot treat children with potentially serious spinal deformities on the basis of rough guides. Apart from the problems of measuring the severity of the curve, is there evidence to support the positivists in their enthusiasm for treatment with a brace? Is the evidence valid or should the negativists, as we have been gratuitously termed, fight back?

How it all started

The Milwaukee brace was developed in 1945 to provide “more efficient and comfortable passive correction and to aid fixation after operation” for scoliosis in association with poliomyelitis. It was not intended to be used as a non-operative treatment for any spinal deformity. The next decade saw the introduction of surgical instrumentation of the spine and the increasing success of operative treatment. Use of the Milwaukee brace after operation was phased out, but was reintroduced in 1954 for the conservative treatment of idiopathic scoliosis. There have been a number of suggestions as to its mode of action, including extension and three-point fixation, but the reason why the Cobb angle of a flexible thoracic curve is reduced while wearing the brace is because of the effect of flattening the lumbar lordosis.
The sagittal component of the three-dimensional deformity is crucial.\textsuperscript{5,11-15} This change in the lumbar lordosis induces active extension in the spine above and thus the deformity moves back towards the sagittal plane. It is like a forward bend test in reverse and will only occur in flexible curves; the smaller the curve, the more flexible it is. Thus, although the effect on the Cobb angle has been said to provide an index as to the likely success of treatment with a brace\textsuperscript{16} it is more accurate to state that it reflects the flexibility of the curve.

What is the brace actually doing? Even deformities of surgical magnitude are flexible, often surprisingly so. If the standing magnitude of the curve is \(x\) degrees and the supine or maximum traction or maximum side bending is \(y\) degrees, then the brace is holding the curve somewhere in between, at \(z\) degrees. While the brace may be preventing the curve from reaching \(x\) degrees, it also prevents it from reaching \(z\) degrees, which must happen thousands of times a day in the normal activities of daily living of a teenager. The unbraced individual is maintaining the flexibility of the curve while the brace is preventing this. Girls already have stiffer spines than boys\textsuperscript{17,18} which is one of the mechanical reasons favouring buckling of the spinal column,\textsuperscript{5} and treatment with a brace must increase that degree of rigidity. Is this really desirable or has it just been conveniently overlooked in favour of the dreaded Cobb angle?

There are three parts to the deformity of idiopathic scoliosis: a primary lordosis, a secondary lateral spinal curvature and rotation. If the effect of the brace is to reduce the lateral curvature, it is preventing the lordosis being expressed in the frontal plane. If the Cobb angle is reduced then the degree of lordosis must increase. That effect has already been noted in the statement that “in some patients with idiopathic scoliosis thoracic lordosis is the predominant component of the disease... the Milwaukee brace should be avoided,”\textsuperscript{19} although the authors did not appear to appreciate that all structural scolioses are lordotic.

However, if the effect of treatment is to reduce the secondary deformity it must enhance the primary lesion, with the result that the driving force for subsequent buckling after the end of the period of wearing the brace is all the greater. Just as the frontal film of a patient is an oblique view of the three-dimensional deformity so is the lateral view. The lateral deformity is not a kyphosis, as yet again erroneously described,\textsuperscript{5} but another oblique view of the same three-dimensional deformity. Derotated ‘plan d’élection’ views would reveal the true extent of the deformity.\textsuperscript{11,20} and these can easily be computer-generated from AP and lateral views\textsuperscript{21} without the need for further films. Other groups have also appreciated the difficulties of three-dimensional spinal measurement and contributed significantly.\textsuperscript{22-25}

The ‘results’ of brace treatment

When advocating the mechanism to underpin the need for treatment with a brace there is no mention of the nature of the three-dimensional deformity and what the brace may be doing to it. Rather the brace is applied empirically for as many hours as the patient can tolerate it, although this has only once been measured using hidden compliance meters.\textsuperscript{26} It was found that upper-middle-class school-children wore the brace for not much more than 10% of the prescribed time, despite what they and their family said to the surgeon involved. It was therefore concluded that data on the wearing of the brace by patients with idiopathic scoliosis may be extremely suspect.

Blount’s group\textsuperscript{17} looked at the papers on treatment with a brace most often quoted over the past 20 years and pointed out that “there have been no published data with regard to long-term end-results comparable to the available follow-up studies of untreated patients.” They went on to describe 47 patients out of 94 who had been out of their braces for more than five years. No data about the site of the curve or the gender were provided; the average Cobb angles were analysed before, during and after treatment. No statistical methods were applied to this retrospective study, but at face value it looked as though bracing could prevent progression in a group of patients aged almost 14 years at the beginning of treatment and with a mean Cobb angle of 44°. However, this is one of the better studies in terms of the length of follow-up. In the same year the Campbell Clinic\textsuperscript{57} published the results of the follow-up of 52 patients out of an original group of 125. Again, treatment with a brace started at the age of 14 years and went on to almost 17. The mean follow-up after completion of treatment was only 22 months, with a minimum of six months. There was an equal number of thoracic and lumbar curves. The mean Cobb angles were initially over 40° and improvement at this short follow-up was between 0% and 20%.

In 1980, the Minneapolis group reported their results in patients aged from 8 to 16 years.\textsuperscript{16} Of 133 braced patients, 74 were followed for five years or more after cessation of treatment. Of the original 133, 29 were treated surgically because of a poor response to the brace and 30 were lost to follow-up. Thus 59 (44%) have to be regarded as failures. No statistical methods were applied to the results but again this was the experience of one of the world’s leading scoliosis centres and guidance rather than numbers was deemed to be important. The mean final curve in the 74 patients (56%) who were followed up, was only a couple of degrees or so better than the original. It was suggested that smaller and more flexible curves responded better but of course they would also have a better natural history. The authors stated, quite rightly, that the role of the Milwaukee brace in the treatment of idiopathic scoliosis is still unclear and asked “what then is the proper role of the Milwaukee brace in scoliosis treatment?” They admitted that their study was an interim assessment and emphasised that further follow-up must be obtained on these patients. Who could disagree?

In 1984 came a report from the Gothenburg Scoliosis Databank.\textsuperscript{28} The authors wrote that “controlled studies to
examine whether braces alter the natural course have not been performed and the question of whether bracing alters natural history has become particularly germane with the advent of school screening.” Two groups were compared, 144 braced patients and 111 untreated. The analysis was based upon the mean Cobb angle and statistical methods were applied. The initial angle was not more than 30°. No significant differences were observed between the progression of the braced and observed patients. Nearly three-quarters of the untreated cases did not progress, suggesting that a similar proportion of the braced curves did not need bracing. The authors concluded by stating that “given the retrospective nature of our study and the questions raised by our results a controlled randomised prospective study of brace effectiveness seems warranted.”

In 1993 a paper was published jointly between Dublin and Boston comparing 32 adolescent girls braced in Boston with 32 matched untreated patients from Dublin. The data were analysed fairly rigorously and there was no statistically significant difference between the two groups. The authors stated that their observations “raise very seriously the question of whether bracing can be considered an effective way of altering the natural history in late-onset idiopathic scoliosis.” They pointed out that withholding conservative treatment would no longer be an ethical problem if a randomised prospective trial was carried out.

The following year, in 1994, without any further rigorous statistical comparison of bracing with observation, a review article was published to the effect that the pendulum had swung too far away from bracing for adolescent idiopathic scoliosis. Despite the absence of evidence, this article stated that “as high quality clinical research studies have been available in the late 1980s and early 1990s the proper place of brace treatment for adolescent idiopathic scoliosis has become apparent.” Extraordinarily, and rather sadly, it went on to liken treatment with a brace for scoliosis to penicillin for pneumococcal pneumonia, a condition with an abnormality of shape than others and there is therefore a wide range of Cobb angles which relate to the threshold of unacceptability. Moreover, with the passage of time surgeons can sway the opinion of the family and impose bias. The only indication for surgical intervention is concerned with surface shape and its perception by the patient and family, not on the opinion of the surgeon. Unfortunately, surgeons can sway the opinion of the family and impose bias. The only indication for surgical intervention is that the deformity is deemed unacceptable by the patient and family. Some individuals are much more sensitive to abnormality of shape than others and there is therefore a wide range of Cobb angles which relate to the threshold of unacceptability. Moreover, with the passage of time operation has been perceived as being more effective and safe. Consequently, surgery is more easily embarked upon.

In 1995 came a report of a prospective study by the Scoliosis Research Society on the effectiveness of treatment with a brace in girls with late-onset idiopathic scoliosis followed by a report of the prediction of the progression of curves from the same database. The introduction to the paper paraphrased all the unscientific aspirations of positivists about previous data, stating that “none of these studies met the stringent criteria for scientific evidence that must be used to prove the effectiveness of treatment.” This view had already been endorsed in the USA, Canada and the UK. It was pointed out that
“a well-designed study must include a large cohort of similar patients with similar patterns and sizes of deformity, that they should be randomised to different treatment methods and followed until at least skeletal maturity”. The spine continues to grow for several years after the attainment of appendicular skeletal maturity, often into the twenties, and therefore follow-up only to general skeletal maturity is insufficient for any reliable inferences to be made. Unfortunately, these ideals of a well-designed study could not be realised and the trial failed most of the Cochrane criteria for a sound investigation. Randomisation was not deemed feasible and the study therefore compared patients from centres where treatment was favoured with those managed by observation only. Using only girls removed one confounding variable. A number of different parameters were measured at follow-up, but failure remained defined as an increase in the Cobb angle by 6°. At maturity, 67 of the observed 129 patients (52%) had either failed or had been lost to follow-up, as had 29 of the 46 who had electrical stimulation (63%) and 40 of the 111 who had been braced (36%). These differences were statistically significant and indicated the need to perform a subsequent study when these patients reached the age of 18 years, at which time they would be closer to spinal maturity, although a further follow-up into their twenties was desirable.

In the subsequent paper on the prediction of progression there is clear evidence that thoracic curves have a much worse prognosis than thoracolumbar curves. Reviewing the paper on the non-randomised prospective trial, with particular reference to the site of the curve, we find that the more benign thoracolumbar curve is greatly over-represented in the braced group (32%) but is only present in 19% of those merely observed and in 11% of the group who received electrical stimulation. On the last page of the study it is stated that “It became apparent that use of a brace for a right thoracic curve of between 25° and 35° in girls was 40% more effective than treatment with observation alone or with surface electrical stimulation”, referring to Figure 1. However, this looks at all braced, observed and electrically-stimulated individuals and has nothing to do with the site of the curve. It does not, therefore, support the suggestion concerning the bracing of right thoracic curves. The follow-up is also unacceptably short.

Then in 1997 came a publication from the Iowa group who studied 102 of 111 patients treated with the Milwaukee brace for idiopathic scoliosis with a mean time from the cessation of bracing to follow-up of more than six years. They did not have a control group but their findings did not favour bracing, and they concluded that “it is currently impossible to state that bracing effectively alters the natural history of scoliosis in immature patients who are at high risk for progression.” This summarises the present position as regards treatment with a brace and defines patient management and the position of school screening.

This paper from Iowa was commented on by the Minneapolis group in the correspondence section of the American Volume of the Journal of Bone and Joint Surgery. They criticised the duration of treatment in the brace, although they conveniently reduced it to less than 50% of that stated, and also the “inadequate bibliography” since it did not cite what they regarded as “the superb study of Milwaukee bracing” by Salanova in 1986. However, the latter was not quoted in their own article in 1994! It is a short, non-peer-reviewed abstract which discusses the treatment of 63 patients with the Milwaukee brace; there is no control group. All had thoracic idiopathic scoliosis with a Cobb angle of more than 30°; the protocol required wearing the brace for 23 hours each day until the end of growth or fusion of the iliac apophyses (Risser V). No operations were required. For very immature spines the brace was said to be effective until puberty but not thereafter, which illustrates the autonomy of the quickly growing spine. In more mature patients the size of the curve at follow-up was greater than at the beginning. Interestingly, 60% felt that bracing had handicapped their life and 14% considered that it had left a psychological scar. The Minneapolis group seems to rely heavily on the international multicentre study by Nachemson and Peterson but incorrectly describes this as a randomised study.

Despite the lack of data in support of treatment with a brace, the positivists recently stated that “the truth is that an effective method of early non-surgical treatment is available. That method is bracing.”

Screening for scoliosis

The positivists used that statement to counter the publications of the 1993 United States Preventive Services Task Force which concluded that “there is no evidence that school screening for scoliosis is of any value”. They said that the report, which concluded that there was no method of early treatment which was of any value, was “an affront to those of us in the field of scoliosis treatment and management”. It is not just effective treatment that is important in terms of school screening. There are other considerations which influence the introduction of a screening programme. The paper by Whitby on the definitions and criteria in screening for disease provides a number of important references to the science of screening. It should be read by all interested in this. Their assessment was applied to screening for late-onset idiopathic scoliosis. The evidence was reviewed and a number of crucial questions asked. Was the condition an important health problem for the individual and the community? Progressive scoliosis is an important matter for the individual but late-onset idiopathic scoliosis, regardless of the size of the curve, does not affect organic health. Progressive early-onset deformities can lead to cardiopulmonary compromise in later life but late-onset idiopathic scoliosis does not. We have sympathy for our patients with deformities of the
torsio due to scoliosis. We are happy to treat them surgically to restore acceptability and to help to mitigate future social and psychological disadvantage, but we are not affecting organic health. There is little evidence to suggest that the untreated spine in scoliosis functions less well than a straight spine and there will be very little, if any, community effect in terms of public expenditure, social-security payments, loss of earnings, etc.

The Iowa group has recently analysed an ultra-long-term follow-up of the natural history of idiopathic scoliosis in 117 patients in the form of 50-year reviews of back pain and psychosocial characteristics. Although the patients with scoliosis reported more chronic back pain than the control group, their ability to work and perform everyday activities was similar to that of their peers. It was concluded that the natural history of late-onset idiopathic scoliosis did not necessarily include functional disability. No differences were found between the patients with scoliosis and the control group in any of the psychosocial characteristics measured except body image. Despite apparent deformities most showed no significant psychosocial difficulties and were well adjusted to their condition.

It is necessary to increase public awareness of the condition of late-onset scoliosis, to reassure patients that it is a matter of appearance and deformity only, to inform them that there are doctors in the vicinity who know about the condition, and that surgical treatment has a significantly favourable effect on shape with a very low rate of complications.

The abnormality being sought should be adequately defined. There are not many curves of more than 10° seen in schools and very few go on to significant progression. Before screening, the natural history of the condition should be adequately understood. Unfortunately, we know little about this except that progression tends to occur in girls who are slender, taller, stiffer and growing faster.

Then who should be screened? It has usually been 11- to 14-year-olds but would screening be justifiable in boys with a low rate of progression, and would it be better to screen nine and ten-year-olds since the earlier the onset the more likely it is to find children who go on to develop larger, more unacceptable deformities? There should be a satisfactory screening test. Non-invasive systems for measuring surface shape may be suitable but the equipment is expensive and salaries are required for those carrying out this work.

There should be facilities available for the diagnosis of patients by a screening programme which should be without risk to health. Such investigations generate too many radiographs on too many people. In addition to the health risk, there is the matter of cost. There should be an agreed policy on whom to treat. With the exception of the patient who finds their deformity unacceptable and wishes to have surgical correction, treatment is a very difficult matter as the earlier part of this article has addressed. As regards those with ‘schooliosis’ we need to know who will go on to unacceptability and to have a means of non-operative management which may prevent this. However, there is no evidence to suggest that bracing will achieve this end.

The cost of screening needs to be justified against existing costs of providing health care. Is it a good economic investment? In the light of the existing definitions and criteria it is inadvisable and indeed irresponsible to screen. Screening for a medical condition brings the diagnosis to an unsuspecting individual and is an important ethical issue. In screening for scoliosis we make a fundamental promise to the children, namely, that if we identify a spinal deformity we can reliably influence it favourably. With the uncertainty as to the efficacy of treatment with a brace, early detection breaks one of the pivotal promises and thus, currently, screening is unethical.

What next?

Although it should not be used for the purposes of health care ‘screening’ should be carried out as a basis for epidemiological surveys until we know much more about factors likely to determine the natural history of late-onset idiopathic scoliosis and the biological and biomechanical factors responsible for buckling of the spinal column.5 We need to look much more critically at the three-dimensional shape of the deformity of idiopathic scoliosis. The problem is not one of right/left deformity but of front/back asymmetry with relative anterior spinal overgrowth, as has been clearly demonstrated on many occasions during the century and a half before the work of the Leeds Scoliosis Study Group.42-45 If this lordotic configuration was not very unstable to rotation it would resemble the opposite of Scheuermann’s disease46-47 and would be much more user-friendly for analysis. We should study this complex three-dimensional deformity and model it to understand its geometry and behaviour as a matter of urgency, in order to learn more about patients who may need treatment and others whose deformity will not progress.

References


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