The value of radiographs obtained during forced traction under general anaesthesia in predicting flexibility in idiopathic scoliosis with Cobb angles exceeding 60°

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Our aim in this prospective radiological study was to determine whether the flexibility rate calculated from radiographs obtained during forced traction under general anaesthesia, was better than that of fulcrum-bending radiographs before corrective surgery in predicting the extent of the available correction in patients with idiopathic scoliosis. We evaluated 33 patients with a Cobb angle > 60° on a standing posteroanterior radiograph, who had been treated by posterior correction. Pre-operative standing fulcrum-bending radiographs and those with forced-traction under general anaesthesia were obtained. Post-operative standing radiographs were taken after surgical correction.

The mean forced-traction flexibility rate was 55% (SD 11.3) which was significantly higher than the mean fulcrum-bending flexibility rate of 32% (SD 16.1) ($p < 0.001$). We found no correlation between either the forced-traction or fulcrum-bending flexibility rates and the correction rate post-operatively ($p = 0.24$ and $p = 0.44$, respectively).

Radiographs obtained during forced traction under general anaesthesia were better at predicting the flexibility of the curve than fulcrum-bending radiographs in curves with a Cobb angle > 60° in the standing position and may identify those patients for whom supplementary anterior surgery can be avoided.

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Predicting the flexibility of the curve is important in the performance and correction of scoliosis. Various methods such as side-bending, fulcrum-bending, push-prone and traction radiography have been described to predict flexibility and to determine whether corrective surgery can be achieved through a posterior approach alone or whether an anterior release is also required.[1-3]

A considerable limitation in obtaining side-bending radiographs is the compliance of the patient, which affects the reliability of this method. Fulcrum-bending radiography which was popularised by Cheung and Luk[2] has become the standard reference method for predicting the flexibility of the major curve. These radiographs are uncomfortable to obtain and cause muscle spasm which affects the reproducibility of this method,[4] and the difficulty in positioning the bolster at the apex of the curve has made the method less popular. Push-prone and traction radiography has been used in the past on the conscious patient, but discomfort to the patient and the requirement of expert radiological skills to obtain the images have made this technique unpopular.[5,6] More recently, forced traction under general anaesthesia has been shown to achieve a better prediction of flexibility than side-bending radiography.[7]

Hamzaoglu et al[4] compared radiographs obtained using the fulcrum-bending method with those using forced traction under general anaesthesia and found no difference between the two methods in predicting flexibility in curves with a Cobb angle < 60°.

Our aim in this prospective radiological study was to evaluate whether the estimation of the correctability with forced traction under anaesthesia was better than that of fulcrum-bending radiography for deformities with a Cobb angle > 60°.

Patients and Methods

We treated 33 patients with idiopathic scoliosis by posterior instrumented fusion over a period of two years. There were 28 females and five males with a mean age of 18 years (9 to 41) at the time of surgery. All had pre-operative standing posteroanterior (PA) and fulcrum-bending radiographs for the major curve with side-bending radiographs for the compensatory curve taken in a standardised manner before surgery. Surgical planning and informed consent of the patient or their guardian were based on the above radiographs. The patients

Fig. 1

Photograph showing the method of obtaining radiographs with forced traction under general anaesthesia.

then had a posterior instrumented fusion with or without an anterior release according to the findings of the intra-operative radiographs.

All the patients underwent further radiological studies using forced traction under general anaesthesia pre-operatively on the day of surgery. The technique involved positioning the patient supine under general anaesthesia with one member of the surgical team applying traction by holding the patient's ankles and another assistant, often the anaesthetist or operating department assistant, applying counter-traction holding the patient under the axillae. The chief surgeon, using a lead glove, applied force at the apex of the convexity of the curve thereby obtaining manual correction (Fig. 1). A standard anteroposterior radiograph was then obtained.

The major Cobb angle on the forced-traction radiograph was measured, the neutral and stable vertebrae were identified and the levels of fusion were planned. We chose to apply a Cobb angle of 40° as our threshold for selecting one or either form of surgery. If the major Cobb angle was < 40° on the forced-traction radiograph, then only a posterior correction was performed, but where the Cobb angle was > 40° anterior releases were carried out in addition to the posterior instrumentation. The error of measurement for the radiographs was assumed to be SD 5°. The final decision to proceed with a posterior instrumented fusion with or without an anterior release and the number of levels incorporated in the fusion was delayed until the forced-traction radiographs were available, which inevitably extended the duration of the procedure so that only one case was booked on the operating list.

Posterior instrumentation was undertaken in every patient, in 22 using all pedicle screw instrumentation and in 14 using both hybrid-pedicle and laminar-hook implants. Three patients required anterior release in addition to posterior correction since the Cobb angle was more than 40° on the forced-traction radiograph.

Full-length standing PA and lateral post-operative radiographs were taken to assess the correction and the integrity of the stabilising instrumentation.

All the radiographs were measured for their major structural curve angle using the Cobb method[8] and apical vertebral rotation was measured using the Perdriolle technique.[9] Idiopathic curves were classified according to the classification of Lenke et al[10] and Lenke, Edwards and Bridwell.[11]

We used the following parameters as devised by Luk et al.[3] The correction rate is an expression of the percentage of the difference between the pre- and post-operative measurement of the Cobb angle divided by the pre-operative Cobb angle, all obtained from the standing PA views. However, several factors influenced the outcome of correction including the surgery and more importantly the inherent flexibility of the curve. In order to recognise the contribution of the flexibility of the curve, the flexibility rate was expressed as a percentage by subtracting the Cobb angles measured on forced-traction or fulcrum-bending from the pre-operative radiographs and dividing the result by the pre-operative Cobb angle measured on the standing PA radiographs.

Statistical analysis. This was performed using STATA 9.2 (STATA Corporation, College Station, Texas). A power calculation was undertaken and 16 patients per group were required for a significant difference of 10% to be observed between the forced-traction and fulcrum-bending flexibility rate ($\alpha = 0.05$ and $\beta = 0.2$). Data were initially plotted to test for normality. The difference between the forced-traction and fulcrum-bending flexibility rate was evaluated using the Wilcoxon rank test. Spearman's correlation coefficient was used for correlations between forced-traction and fulcrum-bending flexibility rates and the correction rate. Linear regression was applied to transformed data to assess the influence of age on the forced-traction flexibility rate.

We performed *ad hoc* Kruskall-Wallis tests to investigate differences between the flexibility rate of different Cobb angles within the group. Statistical significance was set at a p-value ≤ 0.05.

Results

The mean pre-operative Cobb angle of the major structural curve was 74° (SD 9.1) and the mean apex rotation was 26° (SD 10.7) on the standing radiographs for the whole group. The curves were corrected to a mean major Cobb angle of 33.7° (SD 10.0) and apex rotation of 23° (SD 10.1) with forced-traction under general anaesthesia and a mean major Cobb angle of 51° (SD 15.2) and apex rotation of 25° (SD 6.5) with fulcrum bending.

The mean post-operative Cobb angle of the major structural curve was 25.5° (SD 10.8) and the mean apex rotation was 20° (SD 7.9) on the standing radiographs for the whole patient group.

The forced-traction flexibility rate was significantly higher than that with fulcrum-bending (Wilcoxon rank test, $p < 0.001$). The mean forced-traction flexibility rate was 55% (SD 11.3) whereas the mean with fulcrum-bending was 32% (SD 16.1). The difference between the forced-traction and fulcrum-bending flexibility rate was 23% (SD 15.4).

Linear regression showed no statistical relationship between the forced-traction flexibility rate and age as a continuous variable (p = 0.218, coefficient: -28%, 95% confidence interval (CI) -73 to +17). Therefore the patients were analysed as a single group because of the lack of the relationship between the forced-traction flexibility rate and age.

Spearman correlation analysis showed that there was no significant relationship between the forced-traction flexibility rate and the correction rate (r = 0.21, p = 0.24) or between the fulcrum-bending flexibility rate and the correction rate (r = 0.14, p = 0.44).

The number of patients indicated for anterior release in addition to posterior instrumentation on fulcrum-bending radiographs according to the criteria of Cheung and Luk[2] would have been 22, whereas in our study only three patients with a major Cobb angle > 40° on forced-traction radiographs had an anterior release. The forced-traction flexibility rate in these three patients was higher than the fulcrum-bending flexibility rate.

The patients were subsequently divided into groups according to the Cobb angle of their pre-operative standing radiographs. Group 1 consisted of ten patients with a Cobb angle of between 60° and 69°, group 2 of 13 patients with a Cobb angle of between 70° and 79° and group 3 of ten patients with an angle > 80°. An *ad hoc* Kruskall-Wallis test showed no significant difference between the three groups with regard to their forced traction (p = 0.50) and fulcrum bending flexibility rates (p = 0.19).

Discussion

The flexibility of the scoliosis curve has been the major predictor of the correction achieved at surgery[1-3] with modern instrumentation such as pedicle screw constructs.[12] The pre-operative assessment of flexibility is used as a main component of surgical decision-making and is important for predicting post-operative correction and determining the need for concomitant anterior release. Most surgeons aim to achieve correction through a posterior approach with no additional procedures.[13] Various radiological techniques are used to evaluate the pre-operative flexibility. Side-bending radiographs are the most popular method and are generally assumed to be better than traction radiographs.[14,15] Only when the Cobb angle is > 60° has the corrective ability of radiographs obtained during traction without anaesthesia been better.[1,6] Vedantam et al[5] compared push-prone and side-bending radiographs and found that the application of pressure to the apex of the convexity with the push-prone method gave a better prediction of flexibility and correction, but with the disadvantages of practicality and patient compliance. Fulcrum-bending radiographs have recently been popularised by Cheung and Luk[2] and are the reference method for assessing flexibility. Davis et al[7] compared traction under anaesthesia with side-bending radiography in patients with a mean major Cobb angle of more than 60° and showed the superiority of the former. This has been confirmed by Hamzaoglu et al[4] who compared traction under anaesthesia with fulcrum-bending radiography and found no difference between the two methods for Cobb angles < 60°. The traction method used in their study was different from that described by Davis et al.[7] They applied traction to the cervical spine without any additional apical corrective force. We used the same technique as that described by Davis et al[7] with forced traction under general anaesthesia and an additional force applied to the apex of the curve allowing further correction to the curve, and better assessment of flexibility.

Our results have shown that the corrective ability of forced traction under general anaesthesia is better than that of fulcrum-bending radiography in patients with a Cobb angle of more than 60° in the standing position. We found that the forced-traction flexibility rate was significantly higher than that with fulcrum-bending. However, we found no difference in the forced-traction flexibility rate within our group of patients with increasing Cobb angles. No relationship was found between the forced-traction and fulcrum-bending flexibility rate and correction rate. Watanabe et al[14] found that other variables such as the patient's age, the level of the apex, and the number of involved vertebrae, in addition to a Cobb angle ≥ 60°, influenced the corrective ability of traction radiographs and were superior to side-bending radiographs.

Our study has certain limitations. Because of the small number of patients we were unable to investigate other variables such as age and the number of involved vertebrae in the corrective ability of forced traction under general anaesthesia and fulcrum-bending radiographs. Deviren et al[16] noted that the curve became more stiff with increasing age. They showed that for every increase in age of ten years, structural flexibility decreased by 5% because of degenerative changes in soft connective tissues, facet joints or intervertebral discs. It is difficult to standardise the patient's effort in fulcrum-bending radiographs. Reproducibility of the radiographs obtained with forced traction under general anaesthesia is uncertain since whether the same amount of traction is applied to each patient is not known.

The indications for an anterior release vary among surgeons and institutions. We chose a Cobb angle of 40° as the threshold for performing an anterior release. This was based on the study by Cheung and Luk[2] who performed an anterior release in patients when the residual curve was more than 40°. The advantage of our technique was that we were able to avoid 19 anterior releases when compared to the criteria of Cheung and Luk,[2] but the threshold Cobb angle for an anterior release may vary with dissimilar radiological assessments. Whether the determination of a threshold Cobb angle measured from radiographs obtained during forced traction under general anaesthesia is a guide to the surgeon as to the need for an anterior release needs further investigation.

Our study did not specifically compare whether the forced-traction and fulcrum-bending radiographs suggested different levels of fusion. However, neither the forced-traction nor fulcrum-bending flexibility rate correlated with the post-operative correction rate which implied that the flexibility of the curve was only one factor involved in obtaining correction of the scoliosis.

We recommend that all patients undergoing surgical correction for Cobb angles > 60° measured from standing PA radiographs should have radiographs obtained during forced traction under general anaesthesia because they are better than fulcrum-bending radiographs in estimating the flexibility of the curve. Further studies are required to investigate whether other variables such as age and the number of involved vertebrae influence the corrective estimation obtained from forced-traction radiographs under general anaesthesia.

Supplementary Material

ë A table showing the details of the Cobb angles and Lenke classification for each patient is available with the electronic version of this article on our website at www.jbjs.org.uk

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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