The reliability of quantitative analysis on digital images of the scoliotic spine

John Cheung
Dirk J. Wever
Albert G. Veldhuizen
Jean P. Klein
Bert Verdonck
Rutger Nijlunsing
Jan C. Cool
Jim R. Van Horn

Abstract Although analysis of scoliotic deformity is still studied extensively by means of conventional roentgenograms, computer-assisted digital analysis may allow a faster, more accurate and more complete evaluation of the scoliotic spine. In this study, a new computer-assisted measurement method was evaluated. This method uses digital reconstruction images for quantitative analysis of the scoliotic spine. The aim of the current study was to determine the reliability of the computer-assisted measuring method, which was done by establishing coefficients of repeatability for a variety of measurements. Measurements were carried out by five observers on 30 frontal and 10 lateral scoliotic digital reconstruction images. Each image was measured on three separate occasions by placing anatomical vertebral landmarks and drawing lines with a computer pointing device. The computer then calculated a number of geometrical shape parameters from scale calibration, landmarks and lines. The intra- and interobserver results were subjected to an analysis of variance to assess the level of agreement, and the means and standard deviations were calculated. The coefficient of repeatability (CR) was taken to be equal to two standard deviations. The mean intraobserver CR was found to be 3.1° for the Cobb angle on the frontal digital image and 3.3° for the kyphosis Cobb angle on the lateral overview. The mean difference in the intraobserver CR of the Cobb angle between measurements made by placing landmarks and those made by drawing lines was not statistically significant (P>0.05). The mean intraobserver CR for the other parameters can be summarized as follows: for lateral deviation it was 0.8 mm, for axial rotation 4.0° and for length of the spine 3.3 mm. The interobserver bias was negligible. It can be concluded that the reliability of our new method for quantifying geometrical variables on digital reconstruction images is better than measurements on conventional roentgenograms in previously published reports. The presented method is therefore considered to be more accurate for research of spinal deformities and more adequate for clinical management of scoliosis.

Keywords Spine · Scoliosis · Radiographs · Computer digital images · Intraobserver repeatability

Introduction

To understand the mechanisms of progression in scoliosis, radiographs should give adequate information about the deformity. For radiographic measurement, the Cobb angle is probably the most widely used parameter for quantifying the severity of scoliotic curvatures [6]. Although this angle can be obtained simply and quickly, several limitations have been reported [2, 7, 18, 25].
One of the major limitations is the representation of a complex three-dimensional (3D) deformity by a single two-dimensional (2D) measurement, which does not allow a complete and accurate description of the full extent of the scoliotic spine. Therefore, several investigators have proposed more accurate and technically complicated means of assessing spinal deformities that depend on methods of 3D curve analysis [2, 13, 15, 18].

In normal clinical work, it is difficult to obtain information pertaining to all three planes (frontal, sagittal and transverse) from the geometrical variables that can be measured on conventional film-based images. Nowadays, computer-assisted measurements made on digital radiographs offer the possibility of improving the interpretation of a complex 3D scoliotic spine deformity. Digital radiographs make it possible to perform increasingly accurate measurements that yield a better understanding of the process of deterioration of scoliotic curves.

Therefore, in the current study, a new method for the measurement of the scoliotic spine was introduced to obtain more information from all three planes. This method is based on the determination of anatomical vertebral landmarks on digital images. These digital images are reconstructed from a series of overlapping X-ray images acquired with a dedicated protocol. The successive images are matched and merged into a single overview image. These overview images have proven to show improved image quality for equivalent X-ray doses as compared to conventional film-based techniques [8, 9, 10]. The aim of this study was to assess the reliability of measurements on these new digital images.

**Materials and methods**

**Subjects**

Forty consecutive patients with scoliosis attending our orthopaedic outpatient department were examined. There were 32 girls (80%) and 8 boys (20%). The mean age of the patients was 15 years (range 11–21 years). Of the 40 patients, 24 had thoracic curve patterns and 16 had thoracolumbar curve patterns, with Cobb angles ranging between 10° and 60°.

**Radiographical measurements**

All radiographs of the scoliotic spine were obtained in a standing position. The postero-anterior projection was used in order to minimize the radiation dose to the breast [1]. All radiographs were made under identical conditions. First, a sequence of overlapping radiographs of the whole length of the spinal curvature from cranial to caudal was made by taking postero-anterior and lateral radiographs. These images were then combined into a single frontal and a single lateral overview image of the entire spine, using an algorithm. Next, anatomical vertebral landmarks were manually placed on the overview images on a 21-in. monitor by an observer using a pointer device (cursor). The contrast, brightness and zoom factor could be freely determined by the observer. Landmarks were placed on the corner points of each vertebra from T1 to L4. On the overview reconstruction image in the frontal plane, two additional landmarks were placed at the medial inner parts of both pedicle shadows (Fig. 1). The literature defines various parameters for evaluating the scoliotic spine [21]. The most significant parameters were selected and summarized as a set of numbers and charts [22]. The variables used in this study are shown in Fig. 2. The Cobb angle, with automatic determination of the apex and end vertebrae, the length of the spine [24], the axial rotation angle and the wedge angle of the apex were calculated with an algorithm using the vertebral landmarks. The axial rotation was determined using the method described by Stokes et al. [21]. The x co-ordinate of the apex vertebra in Fig. 2 represents the lateral deviation of the apex vertebra from a line through the midpoint of T1 and L4.

**Observers**

Five examiners (one orthopaedic surgeon, three orthopaedic residents, one radiologist) were familiarized with the computer programme and were taught how to place vertebral landmarks on the computer monitor. In order to assess the repeatability of results made using this measurement method, measurements were carried out three times on three different occasions by the same observer on 30 postero-anterior and 10 lateral digitized reconstruction images. The interval between measurements was at least 2 weeks. Each measurement on a frontal reconstruction image consisted of two consecutive phases. In the first phase, each observer placed landmarks on the reconstructed image with the cursor. The results of the measurements of the geometrical variables shown in Fig. 2 were analysed to determine the coefficient of repeatability of each