SPINE KINEMATICS: A DIGITAL VIDEOFLUOROSCOPIC TECHNIQUE

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ABSTRACT

The scope for the clinical measurement of spine kinematics is not generally satisfied by the available technology. These studies were aimed at developing an image processing method for the measurement of intervertebral movement using videofluoroscopy. The technique is directed primarily at the assessment of patients with suspected mechanical dysfunction of the spine. The accuracy was established using a calibration model of spinal segments. The method was then applied to lumbar images obtained from motion x-rays of asymptomatic volunteers.

INTRODUCTION

Detailed analysis of the mechanical function of the spine depends upon the ability to measure motion between individual segments; motion across larger sections being non-diagnostic with respect to the site of the lesion. The preferred method of analysing images of these segments is a radiographic one. However, this has traditionally introduced problems of radiation dosage and the accuracy and laboriousness of handling data from anatomical landmarks. Nevertheless there is considerable potential for any method which overcomes these problems. Applications would include the assessment of stability following spinal injury, investigations of intervertebral disc derangement and kinematic changes related to conservative or surgical treatment.

A number of techniques are available for producing high-quality images of the spine, but even these are limited in their applications to motion and the handling of the geometric data necessary for analysing spine kinematics. Developments in image intensifier technology has created the opportunity to acquire traditional x-ray images but with the added advantages of motion and minimal radiation dosage. This feature, combined with the appearance, at relatively low cost, of a range of image processing techniques renders viable the on-line analysis of segmental motion. This paper describes studies aimed at developing a method of measurement incorporating these advances.

METHODOLOGY

Videofluoroscopic recordings were made of a calibration model using a Thompson CGR X-ray machine with image intensifier. The model was constructed from two lumbar vertebrae, hinged together by a universal joint. The segments could be set at known relative angles to produce images from which a range of motion could be calibrated. In addition, recordings were made of the lumbar spines of asymptomatic volunteer subjects. These displayed, over physiological ranges, the motions of the vertebrae in both the anterior-posterior and lateral projections.

Selected frames from the video sequences were digitised using a PDP11-based image processor. These images were first scaled to accommodate the rectangular arrangement of picture elements (pixels) inherent in the display. They were subsequently enhanced and two vertebral body corners labelled as a basis for tracking the motion. This was characterised in terms of angles and instantaneous centres of rotation (ICR).

RESULTS

Preliminary studies have shown that it is possible to measure flexion-extension and lateral bending movements with an accuracy of the order of 1° through 20° of movement using the calibration model as a standard. The accuracy of measurement is not reduced by a typical degree of soft tissue x-ray scatter or by the slight axial rotations which accompany these movements (figure 1). As a maximum, these axial rotations amount to 50% of that in the other plane. If, however, the orthogonal relationship between the bones and the primary x-ray beam is misaligned by more than 10° this accuracy is reduced.

A report of our preliminary studies [1] presented an encouraging level of inter- and intra-observer accuracy and repeatability in the placing of anatomical co-ordinates. For images obtained from volunteer subjects, the dispersion with respect to intraobserver recording of angular position was of the order of 0.5° (2SD). Moreover, throughout the full range of motion, these images were obtainable with less patient exposure to radiation than that usually associated with one x-ray plate of the same part.

The validation of the method for computing the locus of ICR's (Centrode) throughout the ranges of motion relied on the location of the universal joint which hinged the calibration model segments. This measurement has been used extensively in other studies defining spine kinematics [2]. We have calculated centrodes from the volunteer subjects and have found them to be consistant with known physiological ranges.

CONCLUSIONS

Our results suggest that it is now possible to create a rapid clinical method for accurately defining spine kinematics. This can be achieved with a level of x-ray dosage acceptable for screening and investigation in patients where conventional levels are unjustified by the severity of the disability. It is our intention now to automate the process of tracking anatomical landmarks to increase the efficiency of the analysis. We also intend to investigate the use of other kinematic indices, for example motion of the centre of mass.

REFERENCES

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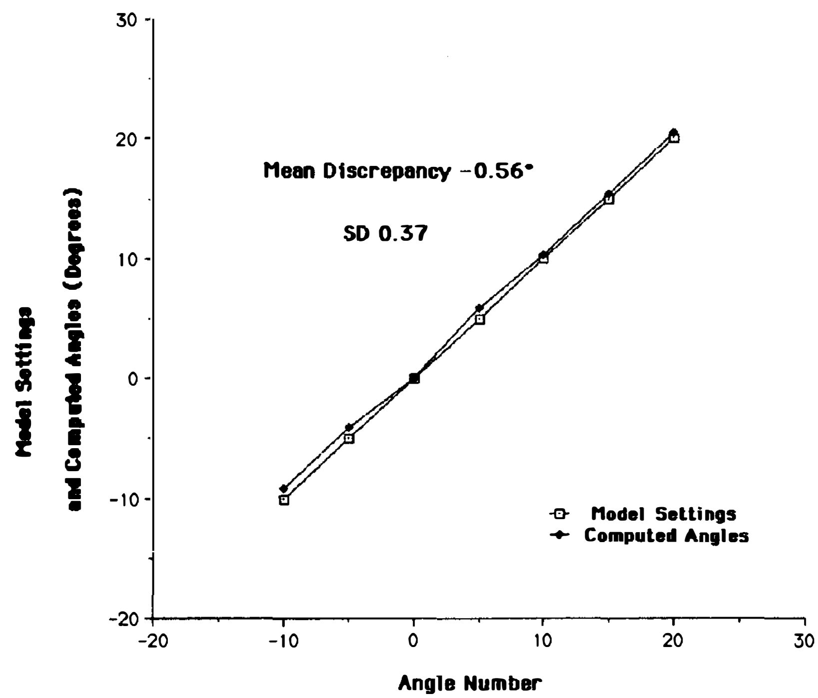

Figure 1. Calibration with X-ray Scatter and Model Rotation (Anterior-Posterior Projection)