INTERVERTEBRAL DISTANCE MEASUREMENTS USING PERCUTANEOUS TRANSPEDICULAR EXTERNAL FIXATION PINS


Introduction

The transpedicular external fixation test has been described as a test to predict the outcome of spinal fusion. This test involves the percutaneous placement of Schanz screws in the pedicles. By rigidly connecting pins in adjacent vertebrae, load transfer between vertebrae is partially shifted to the external fixator thereby reducing intervertebral motion at a specific level in the spine. This test is used to identify patients likely to benefit from an internal spinal fusion. Prior to connecting the pins together, assuming minimal bone or pin deformation, pin motion should follow vertebral motion. Accurate measurements of vertebral motion would facilitate investigation of associations between pain and specific intervertebral motions. In this study, we describe a method by which vertebral motion can be determined by measuring the position of the exposed ends of the external fixation pins. The purpose of this study is to verify the accuracy of this technique using fresh cadaveric vertebral segments so that this protocol can be used to study intervertebral motion in the clinical setting.

Materials and Methods

Six fresh cadaveric spinal segments from L1 to L4 were separated from the intact spine by cutting through the body of L1 and L4. The vertebral bodies and posterior elements of L2 and L3 were left completely intact. Markers were placed in the vertebral bodies to serve as landmarks that could be consistently identified on CT reconstructions. Titanium Schanz screws (5mm, non-tapered) were placed bilaterally in the pedicles of L2 and L3 under fluoroscopic guidance in the standard surgical fashion. Plastic flags were rigidly attached to the tips of each Schanz screw. On the surface of each plastic flag, four spherically reflective markers 12 mm in diameter were evenly spaced approximately 20 mm apart, and fixed in position with cyano-acrylate.

The spinal segments were examined using computed tomography (CT) with contiguous 1mm slices. Three-dimensional (3D) reconstructions of the vertebra with Schantz screws, flags, and anatomical landmarks in place were created from the CT data. The 3D coordinates of the reflective markers and the anatomical landmarks were digitized from the CT based reconstructions using a virtual probe (AVS 5.0, Advanced Visual Systems, Waltham, MA). The proximal and distal ends of the segment were then rigidly fixed in a frame that could be positioned for static measurements as well as freely rotated for dynamic measurements. Using the frame, the spinal segments were fixed in neutral, flexion, extension, and lateral bending to the left and right. Once the specimen was positioned, the 3D position of the reflective markers on the end of the Schantz screws was measured using a non-contacting optical displacement measuring system (PCReflex, Qualysis Inc, Glastonbury, CT). The coordinates of the of the reflective markers on the Schanz screws at each position of the spinal segment were used to determine 3D transformations that described motion of the pin ends. Assuming that the vertebrae and pins did not deform, the calculated transformations were applied to the CT data. The transformed CT data for the anatomic landmarks were used to calculate distances between landmarks on adjacent vertebrae for each of the spinal positions. With the specimen fixed in each position (flexion, extension, etc.), a 3-D digitizing arm (Microscribe 3DX, Immersion Inc., CA), with a reported accuracy of 0.072 microns, was used to record the 3D coordinates of the anatomic landmarks. The distance between anatomic landmarks on adjacent vertebrae measured using the 3-D digitizing arm was used to assess the accuracy of the same distances as measured using the percutaneous measurement technique. To identify the sources of error in the measurements, the reproducibility of the CT, PCReflex, and Microscribe measurements of the distances between reflective markers on a particular plastic flag, or the distance between markers on and individual vertebra was calculated, since these intermarker distances would not be expected to change with motion between adjacent vertebrae.

Results

There was an excellent correlation (r² = 0.92) between the directly measured intervertebral motions and those that were non-invasively calculated from measurements of motion at the end of the Schanz screws (Figure 1). However, the mean absolute difference between pin end and direct measurements of intervertebral was 1.6±1.3mm. Sources of error in these intervertebral distances include the PC reflex camera system which was able to measure distances between reflective markers mounted to the same flag with a coefficient of variation (CV) of 0.41% (Std. Dev. 0.1mm). The CT measurements of these same intermarker distances differed from the PC Reflex measurements by 0.170± 0.0mm (CV 3%). The articulated arm measurements of distances between anatomic landmarks on a single vertebrae had a CV of 0.35% (Std. Dev. 0.34mm).

Discussion

Intervertebral motions measured by transforming CT data based on the motion of the ends of Schantz screws in the pedicles proved to be an excellent method for measuring variations in intervertebral distances. The absolute accuracy individual measurements was modest and appeared to reflect the individual errors of the three measurement techniques used to assess the measurements. Direct measurements of intervertebral distances were used to validate the pin end based measurements. Errors in the direct measurements of intervertebral distances contributed to the overall error, and this source of error would not be present in clinical applications. These results suggest that this method is applicable to clinical investigations of intervertebral motion. The results also indicated that the pin-bone interface remained a rigid mechanical link to the vertebra. Clinical applications of this method would allow real-time observation of intervertebral motion and investigation of the associations between pain and intervertebral motion. Errors greater than those reported would be expected in applications where the percutaneous pins or the vertebra undergo significant deformation. Externals cross-linking devices will have to be temporarily removed from spinal external fixators during clinical data collection to allow unrestricted movement of the patient’s vertebrae. Although a CT examination is required to determine the geometric relationship between the vertebrae and the reflective markers, intervertebral motion could be measured for a wide range of positions without additional radiation exposure. Using this method clinically to study dynamic interactions between vertebra might provide a better understanding of potential sources of pain such as foraminal stenosis, facet impingement, or intervertebral disk compression.