NEURAL-NETWORK DETECTION OF THORACIC CURVE SEVERITY IN SCOLIOSIS

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INTRODUCTION

Torso deformity is often the primary complaint of a patient with scoliosis. Non-invasive detection of progression of the underlying scoliosis from torso deformity would reduce the cancer risk associated with spinal X-rays (Levy et al., 1996) and may define the 3-D scoliosis deformity more completely and with greater sensitivity to patient concerns than simply measuring the Cobb angle on a plain X-ray. While studies to date have shown only moderate torso-spine correlations (Stokes & Moreland, 1989), in a recent study using an artificial neural network (ANN) to analyze 3D full-torso surface topographic data in 65 scoliotic patients we were able to predict the maximal spinal Cobb angle within 6.5° in 63% of patients (Jaremko et al., 2001). A clinical test should be both sensitive (few false negative results) and specific (few false positive results). Here, we measured the ability of the torso-scanner/ANN system to distinguish between thoracic spinal curves of varying severity by determining the sensitivity and specificity of ANN predictions of the thoracic Cobb angle.

METHODS

Imaging: For each patient, 3D torso surface coordinates were acquired by four laser cameras, and two spinal X-rays at 20° to each other were generated (Figure 1a) (Poncet et al., 2000). A 3-D torso surface model was generated by a custom algorithm. Anatomic landmarks from the two X-rays were digitized to create a 3-D reconstruction of the spine and rib cage (Poncet et al., 2000) (Figure 1b).

Figure 1: (a) Laser camera (cam 0-3) and X-ray layout for concurrent surface & spine imaging. (b) Resulting superimposed 3D torso and spine models.
Patient Database: The study had appropriate ethics approval. During five data collections in 30 months, 122 scan/X-ray data sets were acquired from 46 consenting patients aged 8 to 18 (36 female; 39 idiopathic and 7 congenital scoliosis), with a mean thoracic Cobb angle of 28.7° (range: 0-71°). One-quarter of the data set (n = 31) was randomly selected to form a "test set", whose indices did not differ significantly from those in the remaining "training set" (n = 91, p > 0.05).

Indices: The magnitude of the Cobb angle of each thoracic spinal curve (apex T6-T11) was recorded. Cross-sections were cut through the torso surface model at approximate vertebral levels (Figure 2a). The angle of rotation of the principal axes of each cross-section from a reference axis joining posterior superior iliac spine (PSIS) skin markers was computed (Figure 2b). The maximal value and range (max. – min.) of cross-sectional rotations in the thoracic region (T6-L1) and in the entire torso below the arms (T4-L5) were recorded. From the line joining cross-section centroids (Figure 2c), the torso-Cobb angle (analogous to the Cobb angle) was computed for thoracic torso curves (T6-L1), and maximal lateral deviations of this line were computed between T6-L1 and between T4-L5. The patient's age, sex (0 for female, 1 for male) and T1-L5 torso height (from skin markers) were also recorded.

Evaluation: A three-layer back-propagation ANN was trained to estimate the thoracic Cobb angle in the training set from 12 input torso geometric and clinical indices (torso-Cobb angle, centroid-line lateral deviations, torso rotations, torso height, patient age and sex), then used to estimate the thoracic Cobb angle in the test set. Sensitivity (SN), specificity (SP), and positive and negative predictive values (PPV, NPV) were computed for an hypothetical clinical test where a test-positive result was an ANN prediction of a thoracic Cobb angle greater than a specified threshold, and a true-positive result was a thoracic Cobb angle greater than that threshold.
RESULTS & DISCUSSION

Most (60%) of our clinic patients had thoracic curves from 10-50°. The ANN was most sensitive and specific when predicting thoracic Cobb angles between 25-40° (Figure 3), particularly at 30° (prevalence = 0.52, SN = 0.94, SP = 0.87, PPV = 0.88, NPV = 0.93). Thus, an ANN prediction that the thoracic Cobb angle was >30° was correct 88% of the time, while a prediction of an angle < 30° was correct 93% of the time.

The ANN best recognized the patterns that were most common in our data set (thoracic curves from 25° to 40°). Likely because we had few patients with mild curves <20° in our data set of clinic patients, the ANN trained here had low SN and SP for curves <20° and was not yet suitable for initial screening. However, the highly sensitive and specific ANN predictions of the thoracic Cobb angle near 30° could be clinically useful. For example, a patient diagnosed with a thoracic scoliosis of 15° could be re-assessed by laser scan/ANN (without X-ray) every few months until the ANN estimated that the curve had progressed beyond 25°, at which time a confirmatory X-ray could be taken and decisions made regarding bracing treatment. This procedure could reduce both X-ray irradiation and costs compared to current practice.

CONCLUSION

Neural-network analysis of full-torso scan imaging was able to distinguish accurately between clinic patients with mild and severe thoracic curves, showing promise for future detection of curve progression without use of X-rays. We are collecting data for a longitudinal study of curve progression using this laser scanner / neural-network system.

REFERENCES


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