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Use of the smartphone for end vertebra selection in scoliosis

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ABSTRACT

Objectives: The aim of our study was to develop a smartphone-aided end vertebra selection method and to investigate its effectiveness in Cobb angle measurement.

Methods: Twenty-nine adolescent idiopathic scoliosis patients' pre-operative posteroanterior scoliosis radiographs were used for end vertebra selection and Cobb angle measurement by standard method and smartphone-aided method. Measurements were performed by 7 examiners. The intraclass correlation coefficient was used to analyze selection and measurement reliability. Summary statistics of variance calculations were used to provide 95% prediction limits for the error in Cobb angle measurements. A paired 2-tailed t test was used to analyze end vertebra selection differences.

Results: Mean absolute Cobb angle difference was 3.6° for the manual method and 1.9° for the smartphone-aided method. Both intraobserver and interobserver reliability were found excellent in manual and smartphone set for Cobb angle measurement. Both intraobserver and interobserver reliability were found excellent in manual and smartphone set for end vertebra selection. But reliability values of manual set were lower than smartphone. Two observers selected significantly different end vertebra in their repeated selections for manual method.

Conclusion: Smartphone-aided method for end vertebra selection and Cobb angle measurement showed excellent reliability. We can expect a reduction in measurement error rates with the widespread use of this method in clinical practice.

Level of evidence: Level III, Diagnostic study

Introduction

The Cobb technique is still the most important method for assessment of spinal deformity severity, progression risk and treatment plan.[1,2] Especially, it is the gold standard measurement method in the diagnosis and monitoring of scoliosis patients. It is usually measured by using a protractor and pencil or picture archiving and communication systems (PACS) or smartphone applications on standing posteroanterior radiographs.[3,4] Smartphone applications have become popular in orthopedic clinics parallel to the widespread use.[5] Cobb angle measurement with smartphone-aided method has become feasible because of its simple, fast and portable applicability.[6] Although many measurement techniques are defined, intra- and interobserver reliability is still controversial.[6–8] End vertebra selection, the deviation of the endplate lines and the use of different measuring instruments are among the reasons for differences in measurement.[9] It is known that end vertebra determination is the main source of measurement error.[8] Surgeons usually prefer visual selection to define the end vertebra on printed or digital radiographs. Zhang et al[9] developed a computer-aided system for end vertebra selection by using Fussy Hough transform technique.[10,11] They reported excellent intra- and interobserver reliability but this technique require software installation and can not be used on printed radiographs.

The purpose of this study was to develop a smartphone-aided end vertebra selection method to reduce the variability of Cobb angle measurement and investigate if this method is user friendly and sensitive.

Patients and methods

Twenty-nine posteroanterior radiographs of adolescent idiopathic scoliosis (AIS) patients were randomly selected from our

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hospital spinal deformity archive. Selection criteria required that patients were between 10 and 18 years of age, Cobb angle at least 20° degrees, and had no other neuromusculoskeletal disorders or surgery. Images area ranged from occiput to the hip joints. Damaged or unclear images were excluded. Each radiograph was printed onto A3 sized paper with multiple copies and all identifying information was masked by plaster and numbered to avoid remembering radiographs by the examiners. Measurements were performed by using smartphone and traditional manual method with 7 examiners (2 spinal surgeons, 3 orthopedist and 2 senior residents in orthopedic surgery) who are interested in scoliosis. Surgeons had no training period for the manual set because they had familiar measurement method. For the manual set, examiners selected upper and lower end vertebra visually and measured Cobb angle with the same narrow-lead (0.5 mm) pencil and the same protractor.

All smartphone measurements were performed using an Apple iPhone 5 (Apple incorporation, Cupertino, USA) running the iSetSquare application. For the smartphone set, examiners received a training period with 5 radiographs (not used in statistical analyze). In the smartphone-aided end vertebra selection technique, at first apical vertebra of spinal curve is detected. And then smartphone is placed horizontal on apical vertebral endplate and application indicator reset the angle to zero by pressing center of the screen of smartphone (Fig. 1B). Afterwards, smartphone is moved through next proximal vertebral endplates and the software automatically displays the angle (Fig. 1B–E). Phone is moved next upper vertebra endplate again and this is continued until the detect vertebra that highest angle is measured with smartphone and is determined upper most tilted vertebra (Fig. 1F). The same procedure is applied for the detection of lower most tilted vertebra. After upper and lower end vertebrae were determined, smartphone aligned to the both endplates sequentially and Cobb angle is calculated automatically.

For both methods, examiners measured the printed radiographs to put on the table. All examiners carried out the measurements independently for two times in each setting (manual and smartphone sets), with one week interval between each session. All data were recorded bye one blinded researcher.

We analyzed intraobserver and interobserver reliability in end vertebra selection and Cobb angle for both measurement methods. Intra- and interobserver reliability were calculated by intraclass correlation coefficient (ICC, 2-way mixed model on absolute agreement). ICC values may vary between 0 and 1, higher values indicate better reliability. The Fleiss criteria[12] for ICC values were adopted: 0.75 to 1.00: excellent reliability, 0.60 to 0.74: good reliability, 0.40 to 0.59: fair reliability, <0.40: poor reliability. We used ICC method because it provides more truly estimate reliability by giving high degree only when variance between trials for a special subject is small.[13,14] However, it doesn't distinguish different means between groups so we used paired 2-tailed Student *t* test to confirm if there is significant intraobserver differences in magnitude with a positivity threshold of $p < 0.05$. In addition, we calculated Cobb angle variability for each methods using to provide 95% prediction limits for the error in measurements. Statistical analyses were performed using SPSS 20.0 software (SPSS Inc., Chicago, IL).

Results

The study group includes 22 females and 7 males had a diagnosis of AIS. The mean age of the patients was 12.76 ± 2.8 years (range: 10–17). Eight of the major curves were thoracic and twenty-one were thoracolumbar.

The mean Cobb angle was 42.2° (range, 20°–81°) in the manual method and 45.5° (range, 23°–82°) in the smartphone-aided method. The 95% prediction limit of the Cobb angle variability was 3.6° (range, 2.6–4.9°) in the manual set and 1.9° (range, 1.1–2.4°) in the smartphone set.

The overall intraobserver ICC was 0.946 and interobserver ICC was 0.910 for the manual set, whereas the intraobserver ICC was 0.985 and interobserver ICC was 0.967 for the smartphone set (Table 1). Both intraobserver and interobserver ICCs were excellent in 2 methods but values of ICC were better in the smartphone set than manual set.

While the overall intraobserver ICC of upper end vertebra selection was 0.982 in the manual method, 0.991 in smartphone technique and overall interobserver ICC of upper end vertebra selection was 0.956 in the manual method, 0.966 in smartphone technique. Intraobserver ICC of lower end vertebra selection in the manual method was 0.973, in smartphone technique was 0.987 and interobserver ICC of lower end vertebra selection in the manual method was 0.914, in smartphone technique was 0.967 (Table 2). Both method provide excellent reliability in upper and lower end vertebra selection, however, smartphone set was better than manual set in all trials. When we analyze if there is significant intraexaminer end vertebra selection differences between sets, 2 of 5 observers selected significant different end vertebra between their first and second sets in manual method ($p < 0,05$, paired t-

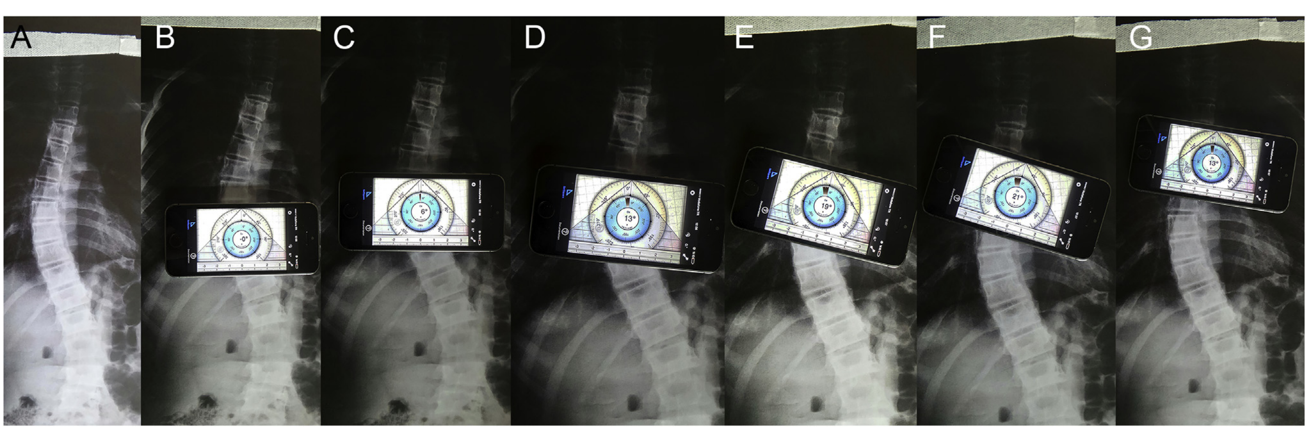

Fig. 1. Upper end vertebra selection technique by smartphone application. 1A shows posteroanterior scoliosis radiograph. 1B (0°): Smartphone is placed on apical vertebral endplate and angle is reset by pressing the center of screen. 1C (6°), 1D (13°), 1E (19°): Application automatically displays the angle while smartphone is placed on vertebral endplates proximally. 1F (21°): Upper end vertebra is defined when highest angle is derived. 1G (13°): Note that if procedure continues after end vertebra is found, angle start to decrease.

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