AI-based Automatic Measurement of Cobb Angles in Lumbar MRI for Degenerative Scoliosis

Jasper W. van der Graaf[1,2], Miranda L. van Hooff[2, 3], Bram van Ginneken[1], Merel Huisman[4], Matthieu Rutten[1,5], Dominique Lamers[2], Nikolas Lessmann[1], Marinus de Kleuver[2]

[1]Diagnostic Image Analysis Group, Radboud University Medical Center Nijmegen, The Netherlands; [2]Department of Orthopedics, Radboud University Medical Center Nijmegen, The Netherlands; [3]Department of Research, Sint Maartenskliniek, Nijmegen, The Netherlands; [4]Department of Medical Imaging, Radboud University Medical Center Nijmegen, The Netherlands; [5]Department of Radiology, Jeroen Bosch Hospital, 's-Hertogenbosch, the Netherlands; Jasper.vandergraaf@radboudumc.nl

Disclosures: Bram van Ginneken: 3A; Thirona. Nikolas Lessmann: 3A; Stryker. Marinus de Kleuver: 3C; Medtronic.

INTRODUCTION: Adult spinal deformity (ASD) is a growing problem in an aging society. Degenerative scoliosis, a common form of ASD, has an estimated prevalence of 36% in the age group of 60 and higher. The severity and progression is monitored with the Cobb angle, traditionally measured on conventional AP radiographs. MR images are often also available for these patients and measuring the Cobb angle on these images can be useful, and possibly makes the use of radiograph images redundant. An automatic method for performing this measurement could reduce workload and subjectivity. The purpose of this study was to evaluate a novel automatic method that measures Cobb angles on lumbar MR images in patients with degenerative scoliosis.

METHODS: We retrospectively included high-resolution sagittal lumbar MR scans (voxel size 0.9x0.47x0.47mm) of 50 patients with degenerative scoliosis. Vertebrae and intervertebral discs (IVD) were automatically segmented using a 3D AI algorithm. 3D planes were fitted through the upper and lower half of each IVD, which is roughly parallel to the vertebral endplates. The angles between all endplates were computed and the largest angle was used as an estimate of the Cobb angle. Automatically measured Cobb angles were compared to manual measurements of two musculoskeletal radiologists and one spinal surgeon. Manual Cobb angle measurements were performed on a merged AP view of the vertebrae segmentation, mimicking a conventional AP radiograph. An example case with an automatic manual measurement is shown in Figure 1. The degree of agreement was assessed by calculating the mean absolute difference (MAD), the intraclass correlation coefficient (ICC; < 0.5 = poor reliability, 0.5 - 0.75 = moderate reliability, 0.75 - 0.9 = good reliability, > 0.9 = excellent reliability), and by making Bland-Altman plots and reporting the limits of agreement.

RESULTS SECTION: The mean manually measured Cobb angle across all three readers was 14.8° (SD 8.2°). The (MAD) between manual measurements of all three readers was 2.7° (SD 1.7°) with ICCs ranging from 0.90 (95% CI 0.83-0.94) to 0.93 (95% CI 0.88-0.96). When taking the maximum angle per scan, the automatic measurements found a mean Cobb angle of 18.0° (SD 7.7°). The MAD and the ICC, compared to the average manually measured Cobb angles, were 3.6° (SD 3.1°) and 0.83 (95% CI 0.71-0.90). The upper and lower limits of agreement of the Bland-Altman plot were 10.9° and -4.6° respectively (Figure 2A). In measuring the Cobb angle all three readers chose the same top vertebral level in 42% (21 out of 50) of the cases. The agreement on the bottom vertebral level was 32% (16 out of 50) and in 18% (9 out of 50) of the cases, all three readers performed the exact same measurements with the same top and bottom vertebral level. The algorithm was also used to extract the angles at the exact chosen vertebral levels of the three readers. The MAD was 2.0° (SD 1.3°) and the ICCs were 0.93 (95% CI 0.88-0.96), 0.97 (95% CI 0.94-0.98), and 0.92 (95% CI 0.87-0.96). The upper and lower limits of agreement of the Bland-Altman plot were 5.3° and -5.7° respectively (Figure 2B).

DISCUSSION: When the algorithm extracts the largest possible Cobb angle, it overestimates the measurement compared to the readers. However, the readers often disagree on the chosen vertebral level at which the measurements are performed. When the algorithm extracts the Cobb angle at the specified level chosen by the readers there is an excellent agreement with ICCs ranging between 0.92 and 0.97, which is higher than the ICC's between readers (ranging from 0.90 to 0.93). The presented AI driven algorithm can automatically measure the Cobb angle in lumbar MRI with similar accuracy as human readers. Moreover, it ensures that always the maximum angle is reliably measured.

SIGNIFICANCE/CLINICAL RELEVANCE: The use of such a reliable automatic Cobb angle measurement tool will improve the accuracy of Cobb angle measurements and gives you standardized extra information on top of spine MRI. Also the use of MRI could make radiographic imaging, with its related radiation dose, more redundant.

ACKNOWLEDGEMENTS: This study was funded by Radboud AI for Health (ICAI)

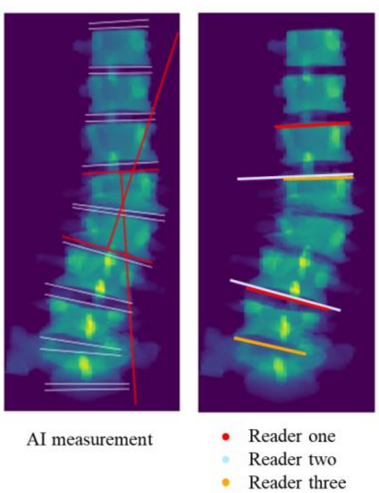

Figure 1: Example of an AI measurement and the corresponding manual measurements

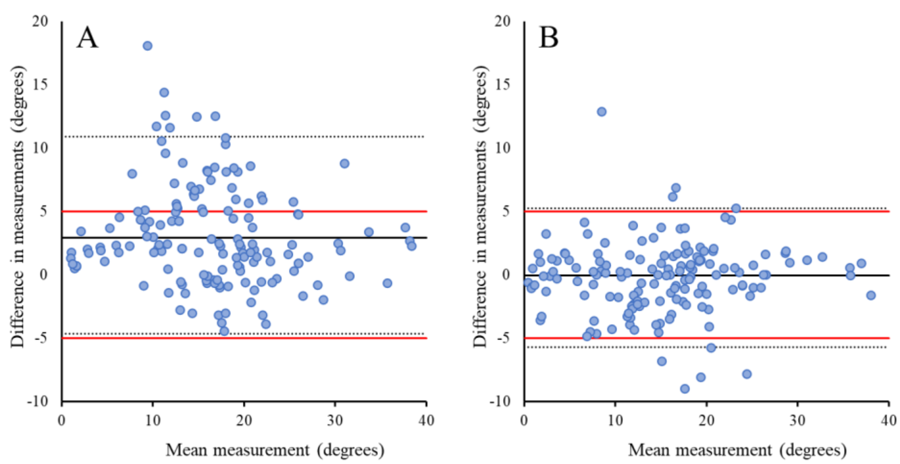

Figure 2: Bland-Altman plots of all manual measurements of the three readers compared to the largest automatic measurement (A), and at the exact same chosen vertebral levels as the manual measurements (B). The red lines represent the clinically accepted measurement error of 5°. The black line represents the measurement bias, and the dotted lines represent the upper and lower limits of agreement.