# Automatic motion analysis of the wrist using dynamic CT imaging to diagnose scapholunate ligament injuries

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INTRODUCTION: Wrist arthroscopy is currently the golden standard for diagnosing scapholunate interosseous ligament (SLIL) injuries. However, this technique is invasive, costly, and operator-dependent. Four-dimensional Computed Tomography (4DCT) is an emerging imaging modality that enables non-invasive analysis of wrist motion. While the potential of 4DCT for diagnosing SLIL injuries has been demonstrated, image analysis and clinical implementation are hindered by the substantial volume of generated data (usually between 100-200 dynamic CT scans per wrist). Therefore, the aim of this study is to develop a fully automated motion analysis to quantify wrist kinematics using 4DCT scans.
METHODS: This study was approved by an Ethics Committee. Healthy wrists of volunteers (unilateral) and both wrists of patients suspected of SLIL injury received a 4DCT scan. In patients, the final diagnosis was determined through arthroscopy using the Geissler grading system. The 4DCT imaging protocol included a static CT scan of the forearm and wrist followed by two dynamic imaging sequences involving wrist radial to ulnar deviation (RUD) and wrist flexion to extension (FE). Scans were reconstructed at a 10 Hz sampling rate, yielding 140 to 190 dynamic CT scans per wrist. Post-processing included carpal bone segmentation through a previously-developed AI algorithm and registration of static bone meshes onto corresponding dynamic positions. Using the registered meshes of the scaphoid and lunate, the scapholunate distance (SLD) and the sagittal scapholunate angle (SLA) were automatically computed in each wrist position, which was defined as the radiocapitate angle in the sagittal (during FE) and coronal plane (during RUD). All data were linearly interpolated based on this angle. Median and maximum values of the SLD and SLA were calculated during both wrist movements. A Mann-Whitney U test was employed to compare both groups and a p-value < 0.05 was considered statistically significant. Results are presented as medians and the interquartile range (IQR).
RESULT: 49 scanned wrists from 44 participants (23 men) were included. In this preliminary analysis, only wrists with a Geissler grade 4 injury were included. This resulted in a dataset of 41 healthy wrists and 8 wrists with grade 4 SLIL injury. Due to technical errors two imaging runs from healthy wrists were excluded, resulting in a final analysis of 40 healthy wrists for both RUD and FE. As shown in Table 1, both the average and maximum SLD were significantly larger in the injured group compared to the healthy group during RUD (respectively 2.49 mm vs 0.86 mm; 3.25 mm vs 1.06 mm) and during FE (respectively 1.99 mm vs 0.92 mm; 2.88 mm vs 1.34 mm). The average and maximum SLA were also significantly higher in the injured group during RUD (respectively 93.0º vs 69.2º; 101.8º vs 74.0º) and during FE (respectively 92.3º vs 71.9º; 107.5º vs 91.5º). Figure 1 displays the course of the SLD and SLA for both groups during both wrist movements.
DISCUSSION: In this study, we have developed a fully automated motion analysis of 4DCT scans of the wrist. This analysis was applied to healthy wrists and wrists with arthroscopically-confirmed grade 4 SLIL injury and allowed for continuous measurements of the SLD and SLA throughout wrist motion. Consistent with existing literature, both SLD and SLA were found to be significantly larger in the injured group. To determine the sensitivity and specificity of these parameters, future analysis should include more injured wrists with different Geissler grades. The presented fully automated motion analysis can enhance the user-friendliness and interpretation of 4DCT by providing a quantitative assessment of dynamic wrist scans.
SIGNIFICANCE/CLINICAL RELEVANCE: This study is the first to compute a fully automatic analysis of wrist kinematics using 4DCT scans. Implementation of the proposed analysis into the diagnostic workflow could enhance the value of 4DCT for early diagnosis of SLIL injuries.

**Table 1.** Median and maximum values of the scapholunate distance (SLD, in mm) and scapholunate angle (SLA, in degrees) during RUD and FE.

| Parameter | Wrist motion / Metric | Radial – Ulnar deviation | | | Flexion - Extension | | |
|---|---|---|---|---|---|---|---|
| | | Healthy (n=40) | SL grade 4 (n=8) | P-value | Healthy (n=40) | SL grade 4 (n=8) | P-value |
| SLD (mm) | Median | 0.86 [0.64 – 1.06] | 2.49 [1.36 – 3.40] | 0.00* | 0.92 [0.71 – 1.17] | 1.99 [1.31 – 3.23] | 0.00* |
| | Maximum | 1.06 [0.93 – 1.28] | 3.25 [1.72 – 5.10] | 0.00* | 1.34 [1.04 – 1.61] | 2.88 [2.80 – 4.98] | 0.00* |
| SLA (degrees) | Median | 69.2 [62.3 – 74.1] | 93.0 [83.8 – 103.0] | 0.00* | 71.9 [57.0 – 85.2] | 92.3 [66.6 - 102.3] | 0.00* |
| | Maximum | 74.0 [67.8 – 80.5] | 101.8 [87.8 – 107.2] | 0.00* | 91.5 [81.2 – 97.3] | 107.5 [99.8 – 114.6] | 0.00* |

**Figure 1.** Wrist kinematics of the healthy and injured group during both wrist movements. **A, B)** Median and IQR of the scapholunate distance (mm) **C, D)** Median and IQR of the scapholunate angle (degrees). The radiocapitate angle was used to define the wrist position.