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Evaluation of Dorsal Scaphoid Displacement Using Posterior Radioscaphoid Angle in Patients With Suspected Scapholunate Instability: A Preliminary Study

Lionel Athlani, MD,*† Jonathan Granero, MD,* Kamel Rouizi, MD,‡ Gabriela Hossu, PhD,† Alain Blum, MD, PhD,‡ Gilles Dautel, MD, PhD,* Pedro Augusto Gondim Teixeira, MD, PhD†‡

Purpose To assess the validity and reliability of the posterior radioscaphoid angle (PRSA), an indicator of dorsal displacement of the scaphoid, in distinguishing wrists with and without chronic scapholunate instability (SLI).

Methods We prospectively evaluated 40 patients (22 men and 18 women; mean age, 46 ± 13 years) with suspected SLI with radiographs and computed tomography arthrography. Based on these data, 3 groups were defined: positive SLI ($n = 16$), negative SLI ($n = 19$), and questionable SLI ($n = 5$). An independent reader measured the PRSA on sagittal computed tomography images using the same procedure.

Results The PRSA median values were significantly lower in the negative SLI group (98°) compared with the positive SLI (110°) and questionable SLI (111°) groups. The difference between the positive SLI and questionable SLI groups was not significant. The best differentiation between patients with and without SLI was obtained with a PRSA threshold value of 103° (specificity of 86% and sensitivity of 79%).

Conclusions In this preliminary study, PRSA analysis offers a quantitative tool for the evaluation of dorsal scaphoid displacement in cases of SLI, including for patients presenting with questionable initial radiography findings. (*J Hand Surg Am.* 2021;46(1):10–16. Copyright © 2021 by the American Society for Surgery of the Hand. All rights reserved.)

Type of study/level of evidence Diagnostic II.

Key words Carpal instability, computed tomography arthrogram, scaphoid dorsal displacement, scapholunate ligament, wrist injury.

*From the Department of Hand Surgery, Plastic and Reconstructive Surgery, Centre Chirurgicale Emile Gallé, Nancy University Hospital; and the †IADI Laboratory, INSERM U1254, University of Lorraine; and the ‡Guilloz Imaging Department, Central Hospital, Nancy University Hospital, Nancy, France.

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Corresponding author: Lionel Athlani, MD, Department of Hand Surgery, Plastic and Reconstructive Surgery, Centre Chirurgicale Emile Gallé, Nancy University Hospital, Lorraine 54000, France; e-mail: lionel.athlani@gmail.com.

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SCAPHOLUNATE INSTABILITY (SLI) is the most common dissociative carpal instability.^{1,2} It is the most frequent cause of scapholunate advanced collapse (SLAC) wrist.³ Damage to the scapholunate interosseous ligament (SLL) is the main factor in the development of SLI; however, the extrinsic, palmar, and dorsal ligaments of the carpus are also important. Indeed, static SLI can appear only in the event of an associated injury of the SLL and extrinsic ligaments.^{4,5}

Scapholunate instability may be challenging to diagnose. In static SLI, the diagnosis is obvious when a careful radiographic analysis is performed showing a fixed pattern of carpal collapse. In the predynamic and dynamic SLI stages, the diagnosis is harder to make based solely on standard radiographs. Dorsal displacement of the scaphoid is an important diagnostic factor, but its assessment is difficult on plain radiographs.⁶ Bone superimposition and patient positioning issues can influence the relative projection of the scaphoid and the radius on a lateral view.⁷ In addition to radiographs, computed tomography (CT) arthrogram or magnetic resonance (MR) arthrogram studies are frequently used to evaluate SLL tears and associated osteoarthritis.^{1,2} Meister et al⁸ evaluated the diagnostic utility of scaphoid dorsal subluxation on MR imaging as a predictor of SLL tears. With a sensitivity of 72% and a specificity of 100%, the authors concluded that the presence of as little as 10% dorsal subluxation of scaphoid predicts SLL tear.

Recently, Gondim Teixeira et al⁹ described the posterior radioscaploid angle (PRSA) on sagittal CT images. They concluded that this angle is a quantitative and reproducible predictor of SLAC wrist in patients with SLL lesion. We believe it could be also an indicator of the dorsal displacement of the scaphoid in patients with chronic SLI. The aim of this study was to assess the validity and reliability of the PRSA in distinguishing wrists with and without chronic SLI.

MATERIALS AND METHODS

Study sample

This prospective study was approved by our institutional review board. All patients provided written informed consent. Between January 2015 and December 2018, 40 consecutive patients aged greater than 18 years, who presented with chronic, post-traumatic wrist pain (more than 6-week history) and tenderness to palpation over the scapholunate joint, were referred by the same surgical team for complete imaging workup because of suspected SLI. We excluded any patient with major joint stiffness, history of wrist surgery, fracture fixation, or arthroplasty implants in the wrist, or congenital wrist deformity. An independent examiner (a hand surgeon with 9 years of clinical experience) reviewed all medical records to confirm that patients met inclusion criteria. Each patient underwent an imaging evaluation consisting of radiographs and CT arthrogram of the painful wrist.

Radiographic evaluation

All patients underwent standard posteroanterior (PA) and lateral radiographs along with dynamic posteroanterior views in a clenched fist position. The images were analyzed on an OsiriX workstation (Pixmeo 2016, Geneva, Switzerland). Measurements were performed independently by 2 readers (reader 1 was a surgeon with 5 years' clinical experience and reader 2 was a radiologist with 5 years' musculoskeletal imaging experience). Static and dynamic scapholunate gap (SLG) (in millimeters) and scapholunate angle (SLA) (in degrees) were calculated (with 0.1 mm accuracy for gaps and 1° for angles), in which SLGs greater than 3 mm and SLAs greater than 70° were considered pathological.¹⁰

Computed tomography arthrogram

All patients underwent a CT arthrogram using the same protocol. Images were acquired with a 320-detector row CT scanner (Aquilion ONE, Canon Medical Systems, Otawara, Japan).

All acquisitions were performed using the continuous volumetric mode (no table feed) with an 8 to 10 cm field of view, a 512 × 512 matrix, and a 0.5-mm slice thickness. The tube rotation time and interval were 0.5 seconds. The tube output was 100 kVp and 50 mAs. Images were reconstructed with bone kernel. The z axis coverage was 8 cm.

The contrast agent was injected into the joint under strict aseptic conditions using fluoroscopy control by a musculoskeletal radiologist, with opacification of the midcarpal and radiocarpal compartments. The contrast agent was specific to arthrography (non-diluted iodixanol). An independent examiner who was a radiologist with 12 years' experience in musculoskeletal imaging analyzed the 3 portions of the SLL (dorsal, volar, and proximal) on axial, sagittal, and coronal reformatted images. The SLL ruptures were characterized by a clear loss in continuity of the dorsal or ventral portion of the ligament. Based on the ligament's appearance, patients were divided into 2 groups: no tear or isolated tear of proximal portion only (normal SLL), and partial tear (PT) or full tear (FT) of the dorsal and/or volar portions (ruptured SLL). The SLL ruptures were further stratified into 2 groups: PT (partial or total loss of continuity in the dorsal or volar segment) and FT (total loss of continuity in the dorsal and volar segments).

Posterior radioscaploid angle measurement

The same examiner and an orthopedic surgeon with 10 years of clinical experience measured the PRSA

(in degrees, with an accuracy of 0.5°) on sagittal images using the same procedure as described by Gondim Teixeira et al.⁹ First, we identified the image with the dorsal-most point of the scaphoid. If this point was similar in 2 or more images, the one located closest to the center of the scaphoid fossa of the radius was selected for analysis. Then, a line passing through the dorsal and volar rims of the scaphoid fossa of the radius was drawn on this image. A second line was drawn, passing through the dorsal rim of the radius and the dorsal-most point of the scaphoid. The angle between these lines was designated the PRSA (Fig. 1).

Group definition

Radiographic and CT arthrogram data were used as the reference standard. Using those data, 3 groups were defined. The positive SLI groups consisted of patients who had at least one pathological radiographic variable and PT or FT on the CT arthrogram. The negative SLI group consisted of patients who had normal radiographs and CT arthrogram. The questionable SLI groups consisted of patients who had either at least one pathological radiographic variable or PT or FT on the CT arthrogram.

Statistical analysis

Quantitative variables are described as mean \pm SD or median and interquartile range. Qualitative variables are described as numbers and percentages. Interobserver variability was measured with the intraclass correlation coefficient and its 95% confidence interval. Quantitative radiological and CT data were compared between groups using the Wilcoxon test with Holm-Bonferroni correction for multiple comparisons. This comparison was performed for readers 1 and 2). Between-group characteristics were compared using Fisher test or chi-square test, depending on the nature of the data.

The sensitivity, specificity, cutoff value, and area under the curve (AUC) value for the PRSA were determined using receiver operating characteristic (ROC) curve analysis. We performed ROC analysis to predict positive or negative SLI. For this purpose, the cutoff value was chosen to maximize the specificity and sensitivity of r . The significance threshold was set at .05 (2-tailed tests).

RESULTS

Mean age of the 40 patients enrolled in the study was 46 ± 13 years. There were 18 women and 22 men. Sixteen patients were in the positive SLI group (40%), 5 were in the questionable SLI group (12%),

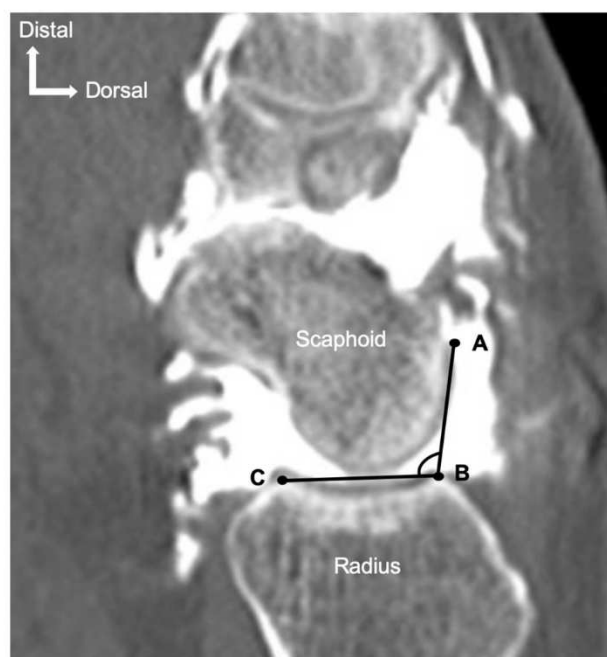


FIGURE 1: Posterior radioscapoid angle measurement. The dorsal-most point of scaphoid (A) is identified. Then, dorsal (B) and volar (C) rims of scaphoid fossa of radius are selected. Two lines are drawn: one from dorsal rim of scaphoid fossa to the dorsal-most point of scaphoid (A to B) and another between dorsal and ventral rims of radial scaphoid fossa (B to C). The angle formed by these 2 lines is the posterior radioscapoid angle.

and 19 patients in the negative SLI group (47%). Interobserver variability for each radiographic variable was deemed excellent (SLG static: 0.79; SLG dynamic: 0.81; and SLA: 0.91). Table 1 summarizes data for each group.

Radiographic evaluation

For the 2 readers, all radiographic variables were significantly higher in the positive SLI group than the negative SLI group ($P < .05$). When the positive SLI and questionable SLI groups were compared, only the SLG static and SLG dynamic variables were significantly higher in the positive SLI group ($P < .05$). There was no identifiable difference in any parameters ($P > .05$) between the negative SLI and questionable SLI groups, although the values were generally higher in the questionable SLI group.

Computed tomography arthrogram evaluation

Upon the CT arthrogram, 3 wrists had an FT of the SLL, 17 had a PT, and 20 had normal SLL. In the positive SLI group ($n = 16$), an FT of the SLL was found in 3 wrists and a PT in 13. In the questionable

TABLE 1. Radiography and CT Arthrogram Findings in Each Group

Parameter	Positive SLI (n = 16)	Negative SLI (n = 19)	Questionable SLI (n = 5)
Age, y (mean \pm SD)	54 \pm 11	39 \pm 12	53 \pm 6
Sex (% women / men)	6% / 94%	68% / 32%	60% / 40%
Radiographs (median [interquartile range])			
SLG static, mm			
R1	2.5 (2.2–3.5)	1.5 (1.3–1.9)	1.3 (1–1.7)
R2	2.7 (2.2–2.9)	1.4 (1.3–1.9)	1.5 (1–1.7)
SLG dynamic, mm			
R1	3.9 (3–4.8)	2.2 (1.9–2.4)	2.1 (1.9–2.7)
R2	3.6 (2.8–4.7)	2 (1.8–2.6)	2.2 (1.7–2.7)
SLA (degrees)			
R1	82 (68–83)	57 (55–64)	61 (53–70)
R2	82 (68–85)	56 (49–63)	64 (50–64)
CT arthrogram, n	3 FT 13 PT	19 normal	0 FT 4 PT 1 normal

SLI group (n = 5), a PT was found in 4 wrists; in the other wrist, the SLL appeared normal. There was no FT in this group.

Posterior radioscaphoid angle assessment

The PRSA median values were lowest in the negative SLI group and similar in the positive SLI and questionable SLI groups. The positive SLI group and questionable SLI groups had significantly higher PRSA value than the negative SLI group ($P < .05$). The difference in PRSA values between the positive SLI and questionable SLI groups was not significant ($P = .84$) (Table 2, Figs. 2, 3A).

Diagnostic performance for chronic SLI with PRSA

Because of the similar sample size in the positive SLI (n = 16) and negative SLI (n = 19) groups and the small size of the questionable SLI group (n = 5), only the positive and negative groups were included in the ROC analysis. Thus, PRSA (area under the curve, 0.73) with a threshold of 103° was the best parameter for differentiating patients with and without SLI, with a specificity of 86% and sensitivity of 79% (Fig. 3B).

DISCUSSION

The current study showed that PRSA values were significantly different between patients with and without SLI. The threshold value of 103° was the best cutoff for differentiating patients in those 2 groups, with a specificity and sensitivity of 86% and 79%, respectively.

Despite the small sample size of the questionable SLI group (n = 5), compared with the negative SLI groups, the PRSA value was higher. Also, the

positive SLI and questionable SLI groups had similar median values (110° and 111° , respectively). Therefore, PRSA may be relevant for differentiating between the questionable SLI and negative SLI groups.

Without SLI, the scaphoid exhibits both flexion-extension and radioulnar deviation motion during radioulnar deviation motion of the wrist. The dorsal extrinsic ligaments (dorsal radiocarpal and dorsal intercarpal) and dorsal component of the SLL provide dorsal stability, preventing the tendency toward dorsal displacement of the scaphoid, yet allow relative free motion of the scaphoid.⁶

Dorsal displacement of the scaphoid is an important element of the pathogenesis of SLI.

These positional abnormalities of the scaphoid contribute to the development of SLAC wrist. Classically described as a rotatory subluxation of the scaphoid with dorsal intercalated segment instability deformity, static SLI manifests as a complex deformity with dorsal subluxation of the unit formed by the scaphoid and the capitate. This deformity explains the dorsal radioscaphoid contact and lunocapitate decentering with lunate instability in extension that is the origin of the radioscaphoid and midcarpal osteoarthritis that appears later.¹¹

Gondim Teixeira et al⁹ showed that in patients with SLL tears, high PRSA values were correlated with the presence of SLAC wrist. The threshold value of 114° was deemed optimal for identifying SLAC wrist.

To date, the evaluation of dorsal scaphoid displacement has been subjective, which has hampered its usefulness for the diagnosis of SLI. Athlani et al¹² used a radiographic evaluation of

TABLE 2. Findings for PRSA in Each Group

Parameter	Positive SLI (n = 16)	Negative SLI (n = 19)	Questionable SLI (n = 5)
PRSA, degrees (median [interquartile range])	110 (104–116)	98 (97–102)	111 (110–114)
<i>P</i> value	Positive vs negative <.01*	Negative vs questionable <.01*	Questionable vs positive .84

*Statistically significant ($P < .05$).

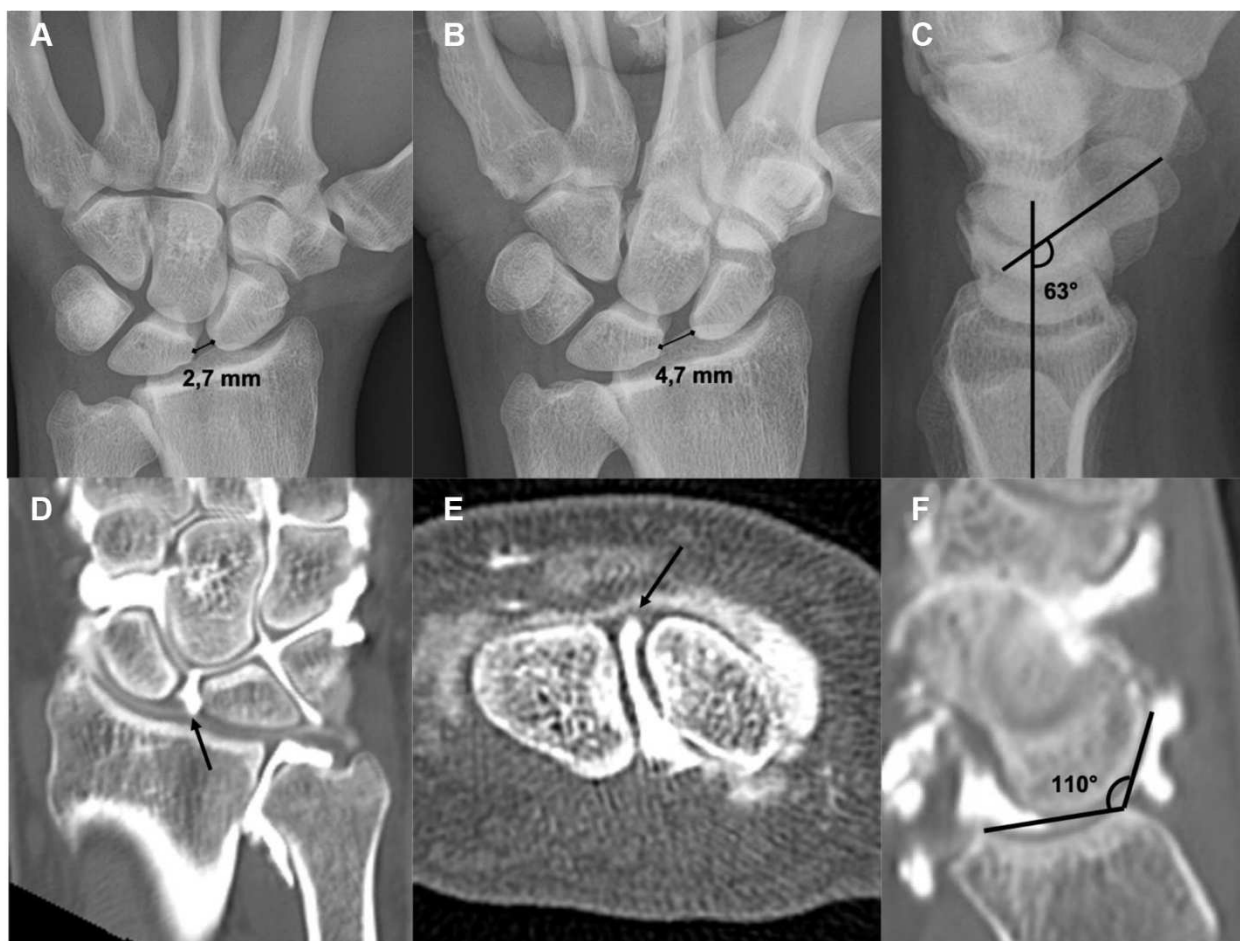


FIGURE 2: Example of chronic SLI in a 30-year-old man with a long history of chronic right wrist pain. **A** Standard anteroposterior radiograph showing SLG static position, which was measured at 2.7 mm. **B** Dynamic anteroposterior view in clenched fist showing SLG dynamic position, which was measured at 4.7 mm. **C** Standard lateral radiograph showing SLA, which was measured at 63°. **D** Frontal CT arthrogram slice showing tear of scapholunate ligament (arrow). **E** Axial CT arthrogram slice showing full tear of scapholunate ligament (arrow). **F** Sagittal CT arthrogram slice showing PRSA, which was measured at 110°.

dorsal scaphoid subluxation. On a lateral view, dorsal displacement of the proximal pole of the scaphoid with respect to its radial fossa and the posterior horn of the lunate is seen in the case of SLI. Using this method, quantification is not possible; however, the PRSA is a quantifiable measurement. Although the PRSA is not measurable on plain radiographs, it can

be measured on sagittal CT and MR images. Thus, PRSA evaluation is interesting because it is quantitative and reproducible.

Meister et al⁸ evaluated the presence of a dorsal subluxation of the proximal pole of the scaphoid on sagittal MR images when the SLL was torn. They found a high positive predictive value with a

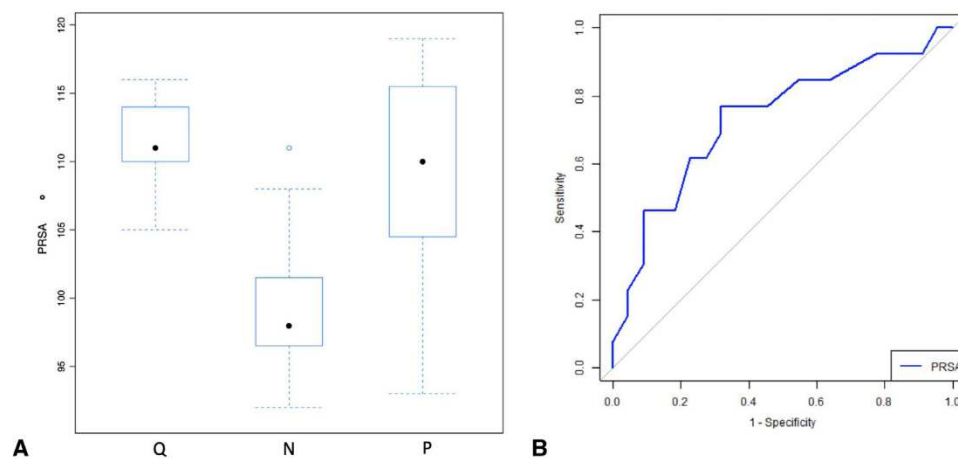


FIGURE 3: **A** Box plot graph showing distribution of the PRSA in groups. **B** Receiver operating characteristic curve for the diagnosis of SLI using the PRSA.

specificity of 100%, whereas it was 86% in our study. Their sensitivity was similar to ours (72% vs 79%).

The presence of dorsal scaphoid displacement (PRSA > 103°) and its quantification could be used as an imaging marker of injury of the scapholunate complex (SLL and extrinsic ligaments) and the severity of SLI. Thus, it might be possible to identify and treat patients with early-stage SLI.^{13–15}

Abou Arab et al¹⁶ and Rauch et al¹⁷ described a protocol in which dynamic 4-dimensional CT was used to analyze the carpus during radioulnar deviation and clenched fist movements. Their initial findings were encouraging in terms of the diagnostic accuracy. A dynamic analysis of the SLG found significant differences in patients with and without SLI. A dynamic analysis of PRSA using 4-dimensional CT could also be interesting, especially during radioulnar deviation movements.

The primary limitation of this study lay in the choice of the sample. We included patients with a painful wrist with tenderness to palpation over the scapholunate joint. We suspected these patients had SLI. Thus, it may have been a high-prevalence sample in which a much higher proportion of patients were likely to have SLI than in a more general wrist pain population. This may have spuriously inflated the sensitivity and specificity of the test.

Second, there was a small number of patients in each group, especially the questionable SLI group (n = 5). Third, the SLL ruptures and SLI were not confirmed by arthroscopy, which is generally considered the true reference standard for the diagnosis. However, CT arthrogram has a high sensitivity and specificity for the diagnosis of SLL tears (95% to 100% and 86% to 100%, respectively),¹⁸ and

arthroscopy is an invasive procedure that places the patient at risk for an infection, nerve lesion, pain, or stiffness.¹⁹ Obdeijn et al²⁰ reported large interobserver and intra-observer variability of wrist arthroscopy. Magnetic resonance arthrogram can be also performed to assess SLL tears with good sensitivity and specificity (65% to 89% and 90% to 100%, respectively).¹⁹ Lee et al²¹ compared axial and oblique axial planes on multidetector CT arthrogram and MR arthrogram to evaluate the dorsal and volar parts of SLL. The accuracy of both examinations in revealing SLL tear was higher using the oblique axial plane. The overall accuracy for detecting SLL tear on CT arthrogram improved from 94% to 100% and from 89% to 94% on MR arthrogram. According to that study, the accuracy of reformatted oblique axial imaging on CT arthrogram performed better than direct oblique axial imaging with MR arthrogram, most likely because of the improved spatial resolution and interactive nature of CT reformation.

Finally, the degree of scaphoid flexion may have influenced the PRSA values, especially in cases of static SLI with a large scapholunate diastasis. Indeed, the dorsal-most point of the scaphoid is radially displaced, near the radial styloid, and there is dorsal angulation of the radial articular surface plane, leading to underestimation of PRSA.

Posterior radioscaphoid angle analysis offers a quantitative tool for the evaluation of dorsal scaphoid displacement in suspected cases of SLI. Values over 103° are associated with SLI, including for patients presenting with questionable initial radiography findings. Abnormal PRSA values could indicate notable biomechanical changes in the wrist.

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