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ORIGINAL ARTICLE

The Sonographic Squeeze Test: Assessing the Reliability of the Dorsal Scapholunate Ligament

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Background: There is no universally accepted imaging method to diagnose scapholunate ligament (SLL) tears. Our aim was to use sonography to evaluate the reliability of SLL length at baseline compared with a standardized dynamometer maneuver in healthy normals.
Materials and methods: Sonographic exams from 31 consented asymptomatic patients between 18 years and 45 years of age were collected on a total of 60 wrists. The length of the SLL was measured superficially and at a depth of 3.0 mm during static and dynamic squeeze maneuver. Inter- and intraexaminer reliability was performed using the intraclass correlation coefficient (ICC).
Results: The superficial ligament length measured 0.60 cm ± 0.11 cm with a deep measurement of 0.20 cm ± 0.06 cm. Dynamic evaluation revealed superficial and deep measurements at 0.62 ± 0.12 cm and 0.20 ± 0.06 cm, respectively. There was no significant difference between the SLL length at rest and during the squeeze test. The interexaminer and intraexaminer reliability was rated at fair to very good.
Conclusion: The evaluation of the dorsal SLL by sonographic squeeze test is reliable. Future studies will apply this method to suspected SLL tears.

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Introduction

Tears of the scapholunate ligament (SLL) are the most common cause of carpal instability. It usually results from a hyperextension and axial load injury to the wrist [1]. If left untreated, SLL tears may lead to scapholunate advanced collapse (SLAC), a painful condition with significant disability and morbidity [2].

SLL injury poses a challenge for diagnosis because there is no universally accepted imaging method for its diagnosis [3]. It has been reported that the dorsal aspect is the most sonographically accessible portion of the SLL and is visualized, at least partially, in up to 78% of normal wrists [4]. Sonography is capable of dynamic assessment, but there is no reliable dynamic maneuver for assessing the stability of scapholunate articulation. In addition, static measurements often vary widely between sonographers; therefore, the development of a reliable dynamic maneuver that simulates the mechanism of injury is preferred. Many sonographers currently assess the patient's SLL by means of the passive radial and ulnar deviation of the wrist with the fist clenched [5]. However, this method has been proven to be unreliable [4]. Our aim was to evaluate the reliability of SLL length at baseline and during a standardized dynamic maneuver under ultrasound. We hypothesized that a tightly clenched squeezed fist, without radial or ulnar deviation, would be a reliable method for assessing the SLL in a normal sample.

Materials and methods

The study protocol was approved by the Institutional Review Board and informed written consent was obtained. Asymptomatic patients between the ages of 18 years and 45 years were recruited. Exclusion criteria included wrist pain within the past year, prior injury to the wrist, including nonspecific sprain/strain, fractures and dislocation or subluxation, prior wrist surgery, carpal arthritis, and developmental anomalies. Data was collected, on one or both wrists, from 31 individuals for a total of 60 wrists. There were 20 males and 11 females (mean age 26.1 $\pm$ 3.8 years). The participants were scanned utilizing the GE LOGIQ E9 sonographic unit (GE Healthcare, Milwaukee, WI, USA). The ML 6—15 MHz high-resolution transducer was used for all the patients. Prior to the initiation of the examination, the patient demonstrated a single 100% maximum voluntary contraction (MVC) utilizing a Jamar Hydraulic Hand Dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA) and then a value of 30% of this MVC was calculated. To obtain 100% MVC, the patient was instructed to slowly squeeze the dynamometer to maximal contraction. Then, the dorsal aspect of the wrist was scanned according to the following protocol: The wrist was pronated on the examination table and was stabilized within a bivalve cast (Fig. 1) to standardize the amount of wrist flexion in each patient. The Jamar dynamometer was then placed within the patient's grasp. The transducer was applied to the dorsal wrist and Lister's tubercle was located in the short axis. A short-axis linear slide was made distally, and the SLL and joint space was identified. After this point, two different data collection techniques were carried out.

Fig. 1 Image showing the patient positioning used in the evaluation of the dorsal scapholunate ligament. The wrist is placed in a bivalved cast with approximately 45° of carpal flexion.

In Technique 1, a static image of the scapholunate joint space and ligament was sonographically captured in the long axis. Immediately after the image was captured and without moving the transducer, the patient squeezed a grip strength dynamometer at 30% of their MVC, and a cine loop image of the SLL during this clenched fist maneuver was captured. The patient was instructed to squeeze the grip strength dynamometer for a duration of 6 seconds to ensure that the cine loop image was captured while the scapholunate joint was under the applied load. This finalized the data collection for Technique 1.

In Technique 2, positioning of the patient was similar; however, data collection was as follows: the transducer was applied to the dorsal wrist in a short axis and Lister's tubercle was sonographically located. A short-axis linear slide was initiated starting at Lister's tubercle and ending at the proximal aspect of the capitate, which ensured that the longitudinal aspect of the SLL and joint space was imaged entirely. Then, this process was repeated while the patient squeezed the dynamometer at 30% MVC. The participant was instructed to squeeze the grip strength dynamometer for a duration of 6 seconds to ensure that the cine loop image was captured while the scapholunate joint was under the applied load. Static images and dynamic 30% MVC images were compared, prior to data analysis, utilizing side-by-side image comparison to ensure that congruent bony articular landmarks were obtained (Fig. 2).

Ligament measures were performed on the Logiq E9 using digital calipers. All data were recorded in a Microsoft Excel file. The length of the SLL was determined by measuring a tangential line between a point at the most superficial articular aspect of the scaphoid and a point at the most superficial articular aspect of the lunate (M1; Fig. 3). An additional measurement of the length of the SLL at a depth of 3 mm was taken from the superficial tangential line (M2; Fig. 3). Measurements of the ligament length were taken during the static and dynamic maneuver at 30% MVC. Mean and standard deviation were analyzed on the collected data. The interexaminer reliability was assessed between the primary investigator, a third-year radiology resident, and a musculoskeletal sonographer, who has 21 years of experience in performing and teaching sonography. Participants were selected for interexaminer

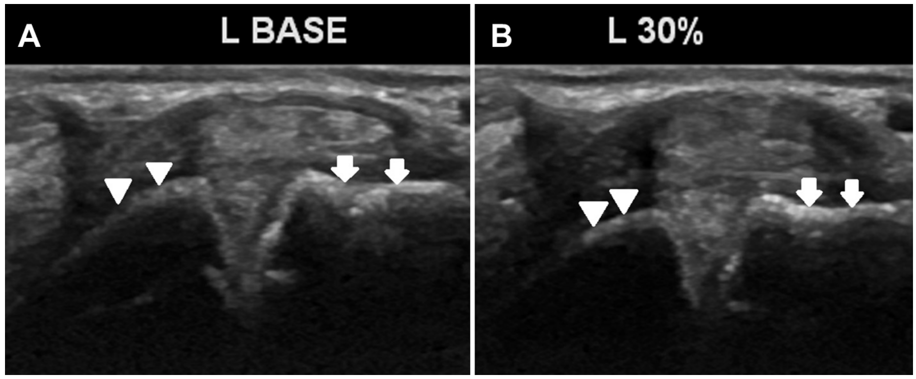

Fig. 2 A compilation image of side-by-side comparison of static L Base (A) and dynamic L 30% (B) long-axis images of the scapholunate ligament prior to placing measurements. This is used to ensure that consistent bony landmarks are utilized during baseline and dynamic assessment. White arrowheads depict the dorsal surface of the scaphoid. White arrows depict the dorsal surface of the lunate.

reliability assessment using a random number generator. Inter- and intraexaminer reliability analysis was performed using the intraclass correlation coefficient (ICC) and IBM SPSS 18 software (IBM Corporation, Armonk, New York, USA).

Results

The superficial ligament length measured 0.60 cm $\pm$ 0.11 cm with a deep measurement of 0.20 cm $\pm$ 0.06 cm. Dynamic evaluation revealed superficial and deep measurements at 0.62 $\pm$ 0.12 cm and 0.20 $\pm$ 0.06 cm, respectively (Table 1). There was no significant difference between the SLL length at baseline and during a squeeze test at 30% of MVC. The interexaminer reliability was rated as good, and the intraexaminer reliability analysis rated fair to very good (Table 1).

Discussion

Our analysis indicated that sonographic evaluation of the dorsal scapholunate joint using a dynamic squeeze maneuver was reliable. The reliability criteria described by Dawson and Trapp [6] outlines intraclass correlation coefficient's (ICC's) 0.41—0.60 as fair, 0.61—0.80 as good, 0.81—0.92 as very good, and 0.93—1.00 as excellent agreement. The 95% confidence interval (CI) showed the highest variability at the deep measurement during the dynamic evaluation, partly because of echoic drop-out of the deep ligament as the patient applied the squeeze. There was high variance of the static superficial measurement of Technique 2. In Technique 2, the data were collected as cine loop images during short-axis linear slides along the ligament longitudinally. It is highly unlikely that the exact same frames were compared between examiners, and there appeared to be some variance in the ligament length along the longitudinal axis. This may be the reason why, in previous studies, quantitative evaluation of the SLL has been less reliable. Gathering cine loop images would more closely mimic a sonographic examination of the SLL between multiple examiners where different bone landmarks may be selected, which in turn could produce different lengths. Overall, Technique 1 provided the highest rate of agreement.

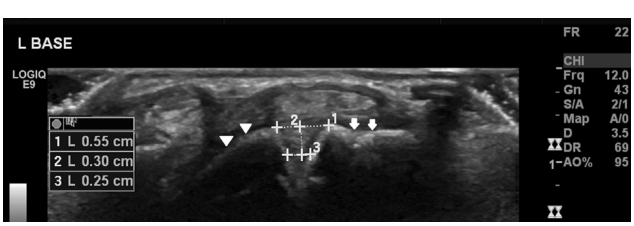

Fig. 3 A long-axis image of the scapholunate ligament showing superficial and deep measurements. White arrowheads depict the dorsal surface of the scaphoid. White arrows depict the dorsal surface of the lunate.

Finlay et al [7] was able to show in a small sample size of patients with a high clinical suspicion for SLL tear that sonography was accurate in predicting SLL tears based on the presence of a normal appearing SLL. However, Griffith et al [4] reported that the SLL was only completely visible in 78% of normal wrists.

Slater et al [2] and Viegas et al [8], in separate cadaveric studies, demonstrated a maximum diastasis between the scaphoid and lunate during a clenched fist maneuver after a 100-N load was applied to the flexor digitorum superficialis and profundus tendons. Based on this study, we arrived at our application of 30% MVC. A load of 100 N is approximately 22.5-lbs force (10.2 kg-force). We tested the MVC of six individuals prior to the final conceptual design and concluded that all of them would be able to achieve a grip strength force production of at least 100 N (22.5-lbs force or 10.2 kg-force), which was slightly below the mean of the 30% MVC of the tested individuals. Additionally, there was difficulty with patient movement at levels above 60% MVC.

There was significant discrepancy in the literature regarding the length of the SLL. Sokolow et al [9] reported 3.0—5.0 mm whereas Tanaka et al [10] measured with magnetic resonance imaging and reported approximately 1.8 mm. Our mean measurement of the SLL was 0.60 $\pm$ 0.11 cm. It is likely that the differences observed between the ligament lengths as measured with magnetic resonance imaging and sonography are because of the increased spatial resolution in the near field that can be

Table 1 Reliability analysis.

Interexaminer reliability	Technique 1				Technique 2			
	Static		Dynamic		Static		Dynamic	
	M1[a]	M2[b]	M1	M2	M1	M2	M1	M2
Intraclass correlation coefficient	0.736	0.767	0.698	0.657	0.620	0.635	0.723	0.640
95% confidence interval	0.515–0.865	0.566–0.882	0.457–0.844	0.393–0.820	0.177–0.854	0.202–0.861	0.352–0.897	0.209–0.863
	Technique 1				Technique 2			
	Static		Dynamic		Static		Dynamic	
	M1	M2	M1	M2	M1	M2	M1	M2
Intraclass correlation coefficient	0.926	0.761	0.901	0.588	0.804	0.799	0.832	0.597
95% confidence interval	0.852–0.964	0.556–0.879	0.802–0.951	0.294–0.780	0.512–0.930	0.500–0.928	0.570–0.940	0.142–0.844

[a] Refers to the superficial measurement of the scapholunate ligament length.
[b] Refers to the measurement of the ligament length obtained at a depth of 3.0 mm.

obtained with sonography [11]. Plain film examination measuring the scapholunate joint space and not necessarily the SLL generally reported normal values at 2.0 mm [12]. There was agreement that the scapholunate joint space was better visualized by sonography than by plain radiography [7]. Our measurement of the superficial aspect of the ligament (Fig. 3, M1), which did not necessarily correspond to the joint space that would be visible with plain radiography, was larger than the joint space measurement reported by Pliefke [12]. During data collection, we noted that there is a variation of the tangential angles of the dorsal superficial articular surfaces of both the scaphoid and lunate. We did not attempt to quantify these varying tangential angles during our study. We feel that these varying angles would not be appreciable with a planar imaging modality, such as a posteroanterior (PA) projection of the wrist. Additionally, static measurements often proved unreliable for the evaluation of ligamentous rupture because of wide variance. Pliefke et al [12] recently demonstrated that a 3.5-mm diastasis between the scaphoid and lunate proved the presence of scapholunate dissociation, although they indicated that a smaller distance did not necessarily rule out the presence of scapholunate dissociation.

A 2001 study of the SLL using sonography reported a mean measure of the dorsal ligament at 4.2 mm (range 2.3–6.3 mm) in the neutral position [4]. Our mean measure of the superficial ligament length at baseline was 0.60 $\pm$ 0.11 cm, whereas the deep measurement was 0.20 $\pm$ 0.06 cm. This discrepancy in the ligament length has plausible explanations. First, our study protocol included a larger degree of carpal flexion during the baseline and squeeze maneuver (Fig. 1). During carpal flexion, the scaphoid rotates further around the capitate than the lunate, producing a pseudodissociation during flexion [9]. More specifically, the capitate acts as a double fulcrum allowing the scaphoid and lunate to rotate around the fulcrum in a 3D fashion strutted from the flat articular surface of the radius [13]. Additionally, our protocol used a superficial line tangential to the surfaces of the lunate and scaphoid. This line connected articulating surfaces of the scaphoid and lunate (Fig. 3). It has been described that dynamic evaluation during radial and ulnar deviation of the dorsal SLL with sonography is unreliable because of inconsistent bony landmarks and dynamic repositioning [4]. However, during the squeeze maneuver, the scapholunate interval was evaluated without the use of radial and/or ulnar deviation, therefore enabling the measurements to be taken at consistent bony landmarks. The application of a clenched fist provided an axial load to the carpus due to the synergistic action of the flexor and extensor musculature [14]. Other studies have supported the use of a clenched fist as a moment for axial loading within the carpus [2,8,15]. Additionally, modern sonographic unit consoles enable the simultaneous evaluation of two different images. Using this advantage, the sonologist can confirm consistent bony landmarks prior to the measuring of the SLL, enabling a reliable method to document dynamic changes. Occasionally, during data collection, the transducer moved slightly with the application of the squeeze test. In that event, the transducer was repositioned with a short-axis linear slide and/or anisotropic tilt until the same dynamic landmarks were re-obtained.

In our reference sample, dynamic squeeze did not produce any significant increase in the ligament length. Interestingly, a recent cadaveric report of dynamic arthroscopic evaluation of the SLL revealed a 0.3 ± 0.6-mm ligament length increase of the intact ligament, a finding the authors attributed to degenerative laxity. The average age of the cadavers in that study was 80.3 years old [15]. The mean age for the participants in our study was 26.1 ± 3.8 years. Our results for the length and dynamic response of the superficial aspect of the ligament are similar to figures reported in the gross anatomy and arthroscopy literature [9,15].

It has been reported that the dorsal aspect is the most sonographically accessible portion of the SLL and is visualized, at least partially, in up to 78% of normal wrists [4]. Our study could not confirm this as we visualized compact fibrillar echotexture spanning the scapholunate articulation in every examination. Possible reasons for this may include our use of a large carpal flexion angle (therefore exposing more area of the dorsal SLL) and the use of a high-resolution transducer.

One of the limitations of our study was the use of a college convenience sample whose ligament characteristics may not reflect the general population. Although the SLL is a U-shaped structure with dorsal, ventral, and proximal sections, we limited our evaluation to the dorsal section. There is no definable point along the longitudinal aspect of the ligament at which to measure, and there is variation in the bone surface geometry where the SLL attaches. However, we believe that comparison of a static to a dynamic length would provide more clinically relevant information than acquiring a static image alone. Although ligament diastasis has been demonstrated in cadaveric specimens where ligaments have been sectioned, it is still not known how an injured SL ligament will react to a clenched fist. Future work will evaluate this method in a clinical sample of injured SLL.

Conclusion

This study introduces a novel sonographic method for dynamic evaluation using the squeeze test of the SLL. We report adequate inter- and intraexaminer reliability. Future studies that apply this method to suspected SLL tears with surgical proof and a larger sample size are needed.

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