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Concepts and Artistry in the Treatment of Scapho-Lunate Ligament Injuries

Kate E. Elzinga, MD, FRCSC¹, Sirichai Kamnerdnakta, MD¹, and Kevin C. Chung, MD, MS¹

¹Section of Plastic Surgery, The University of Michigan Health System; Ann Arbor, Michigan

Abstract

Scapho-lunate ligament injuries are highly challenging injuries to treat. Great uncertainty remains in determining which operative procedures are most effective. Furthermore, there is no consensus on whether surgical intervention changes the natural course of SL injuries. We present our assessment of SL injuries and the senior author's preferred surgical techniques.¹ Surgical videos are included. Operative procedures are selected based on the patient's timing and pattern of injury, degree of associated carpal changes and arthritis, and goals. Our post-operative management is described. Over the past 20 years, the senior author has had good success with these techniques but prospective, long-term outcome studies are needed to critically assess if these surgical techniques improve patients' long-term function and pain.

Introduction

Scapho-lunate (SL) ligament injuries are the most common cause of carpal instability.² Injuries range from an isolated SL ligament tear to a perilunate dislocation. Primary open repair is often possible for acute injuries. Chronic injuries are more complex and require careful consideration to determine the best course of treatment for each individual patient. Reconstructive efforts are focused on restoring the dorsal SL ligament, which is the strongest component of the ligament. Asymptomatic SL injuries are typically observed and monitored with periodic clinical and radiographic follow-up. Symptomatic patients are advised to try conservative measures first, including splinting, flexor carpi radialis (FCR) strengthening³, non-steroidal anti-inflammatory medications, and activity modification. If conservative measures are inadequate, operative treatment is pursued. We perform a ligament reconstruction (bone-ligament-bone graft or three-ligament tenodesis) or a salvage procedure (proximal row carpectomy (PRC) or limited carpal fusion) depending on the patient's age, health, occupation and avocations, and goals. The aims of treatment are to

Corresponding author: Kevin C. Chung, MD, MS, Section of Plastic Surgery, The University of Michigan Health System, 1500 E. Medical Center Drive, 2130 Taubman Center, SPC 5340, Ann Arbor, Michigan, USA, 48109-0340, kechung@med.umich.edu. This paper has not been presented.

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prevent wrist pain and disability and progression to scapholunate advanced collapse (SLAC)⁴ (Table 1).

Other options for surgical reconstruction of SL injuries include a dorsal capsulodesis using a portion of the dorsal intercarpal ligament (DIC)⁵; a volar capsulodesis using a portion of the long radiolunate ligament⁶; a palmaris longus tendon graft and suture anchors⁷; a scapholunatetriquetral tenodesis using a portion of the FCR tendon routed through transosseous tunnels in the scaphoid, lunate, and triquetrum⁸; the reduction and association of the scaphoid and lunate (RASL) procedure using a headless compression screw⁹; the scapholunate axis method (SLAM)¹⁰; and various arthroscopic-assisted techniques.^{11–18} Wrist denervation can be performed to help relieve wrist pain without addressing the SL deformity directly.¹⁹

History

The patient assessment begins with a detailed history. Pain, decreased strength, and a clunking sensation with activity may be described by the patient. The patient may be unable to do activities with the wrist loaded in extension. Patients may be able to describe pain originating from the SL interval over the dorsal-radial wrist or may describe vague, generalized symptoms throughout the wrist. One must be suspicious for a possible SL injury because symptoms can be difficult for patients to localize. Patients are asked about a history of trauma, generalized arthritis, or rheumatologic disease. A fall on an outstretch hyperextended wrist in ulnar deviation and midcarpal supination is the most common mechanism of injury. Previous wrist surgeries are noted. For example, SL dissociation can result from excessive capsular resection and injury to the dorsal SL ligament during dorsal wrist ganglion excision.^{20,21}

The functional impairment of the wrist injury is explored. Limitations in activities of daily living, work, and recreation are noted. The patient's goals and expectations are clarified. Past medical history, medications, allergies, and social history are discussed. Infection, rheumatoid arthritis, and crystal-induced arthropathies can lead to SL degeneration. SL dissociation can be diagnosed in up to 60% of patients with gouty arthropathy of the wrist²² and 26% of patients with pseudogout²³. In these cases, a salvage procedure is recommended because attempts at ligament reconstruction tend to fail. The crystalline deposits in pseudogout are often found within the articular cartilage as well as the intercarpal ligaments, making limited wrist fusion results less reliable than in degenerative osteoarthritis.²⁴

Physical Examination

The clinical examination focuses on provocative maneuvers to reproduce the patient's symptoms. Comparing the symptomatic wrist to the contralateral asymptomatic side is helpful. Swelling over the dorso-radial wrist is common with acute injuries. Tenderness at the SL interval (1cm distal to Lister tubercle over the dorsal wrist) can indicate an injury to the SL ligament. SL ballottement can reveal an SL injury when there is discomfort reproduced as the scaphoid and lunate are pushed in volar and dorsal directions divergently. Watson scaphoid shift test is performed; the examiner's thumb exerts force over the volar

distal pole of the scaphoid, preventing scaphoid flexion as the wrist is passively moved from extension and ulnar deviation to flexion and radial deviation. A positive test occurs when the proximal pole of the scaphoid subluxes over the dorsal lip of the radius. Pain and a clunk with the Watson scaphoid shift test indicate a complete dorsal SL ligament tear; a clunk alone can be observed in normal wrists.

Pain and weakness are present with wrist loading activities, particularly with wrist extension, such as pushing out of a chair or a push up. Range of motion and grip strength measurements are recorded for the bilateral hands. If there is no difference and the symptomatic wrist's grip strength remains normal, it is unlikely that the patient will be satisfied if they undergo wrist surgery. For patients considering salvage procedures, PRC and four-corner fusion result in 70–75% grip strength and 50–60% range of motion of the contralateral hand.²⁴

Diagnostic injections using local anesthetics can be used to determine if wrist denervation may be helpful.²⁵ Therapeutic corticosteroids can be used to temporarily alleviate wrist pain for patients who wish to avoid surgery or who are poor operative candidates.

Imaging

Standardized wrist radiographs (XRs) are the first investigation performed with the wrist in neutral in the flexion-extension and the radio-ulnar planes. Wrist deviation alters the carpal alignment; radial deviation of the wrist can cause the SL interval to appear wider while extension of the wrist interferes with the measurement of the radio-lunate angle. Additional bilateral clenched fist XR permit a dynamic comparison between the two wrists. Widening at the SL interval (Terry Thomas sign), an increase in the SL (over 60°), capito-lunate (over 15°), and/or radio-lunate angles (over 15°), flexion of the scaphoid (scaphoid cortical ring sign), disruption of Gilula lines, and dorsal intercalated segmental instability (DISI) (scaphoid flexion, lunate extension) are signs of a static SL injury when seen on plain wrist XRs (Figure 1). With dynamic SL instability, these signs are only visible with clenched fists XR; the plain wrist XRs are normal. The morphology of the lunate is assessed. A type 1 lunate has a single articulation with the capitate whereas a type 2 lunate has 2 articulations, one with the capitate and a second with the hamate. DISI deformity is more common with type 1 lunates.²⁴

Associated carpal changes are assessed including extension of the lunate, flexion of the scaphoid, and proximal migration of the capitate. Arthritic changes due to SLAC are noted; joint space narrowing at the radial styloid, luno-capitate interval, and scaphoid fossa of the radius may be present. Arthritic changes at the lunate fossa are rare, occurring only in advanced disease (SLAC grade 4). If seen, a total wrist arthroplasty or arthrodesis are the recommended surgical treatments.

Traction radiography is helpful for the diagnosis of SL injuries and treatment planning. Schädel-Höpfner *et al.* determined that a SL distance of 3mm or more at rest and an increase in this distance by 1mm or more with 5 kg of thumb traction were indicators of a SL injury.²⁶ If finger traction reduces the diastasis between the scaphoid and the lunate, the SL injury

is considered reducible and a SL reconstruction can be considered.²⁷ If the SL interval is irreducible, a soft-tissue SL reconstruction is unlikely to restore the carpal alignment and a limited arthrodesis or PRC should be considered instead.

MRI arthrogram and wrist arthroscopy can be helpful in predynamic and dynamic SL injuries to assess the SL ligament when XRs are normal or further information is desired. The SL interval is best assessed from the midcarpal portal with the arthroscope in the midcarpal ulnar portal and a probe in the midcarpal radial portal (Figure 2). Placement of the arthroscope through the midcarpal radial portal can cause widening of the SL interval resulting in a false positive finding of SL dissociation. The cartilage surfaces of the carpal bones and distal radius can be assessed. The articular cartilage must be intact to perform reconstructive surgery. Arthritic wrists require salvage procedures.

Classification

The history, physical exam, and investigations permit the surgeon to determine the acuity of the ligamentous injury, the degree of instability and symptomatology, associated carpal alignment and arthritic changes, and activity limitations to plan treatment (Table 2).

Static SL Instability

Patients with SL interval widening and rotatory subluxation (DISI) on plain XR have static SL dissociation. Static dissociation is the result of a complete SL ligament tear in conjunction with the disruption of the secondary scaphoid stabilizers (scaphotrapezial-trapezoidal, scaphocapitate, and radioscapocapitate ligaments).

Predynamic and Dynamic SL Instability

Patients with pain with provocative examination (Watson scaphoid shift test, SL ballottment test), SL ligament injuries visible on MRI or arthroscopy, and with no associated carpal alignment changes undergo clenched fist XR to distinguish predynamic instability from dynamic instability. Patients with predynamic instability have no widening of the SL interval on clenched fist view XR. These injuries are typically due to a stretch or partial injury of the SL ligament. Those with dynamic instability show widening of the SL interval with a clenched fist view XR; the secondary scaphoid stabilizers maintain the SL interval alignment at rest and on plain XR but do not prevent widening with activity and on clenched fist XR.

Treatment

A variety of surgical procedures exist to correct SL injuries. No long-term outcome data is available to clearly guide treatment. We present our preferred techniques, based on the senior author's experience.

Acute injuries are typically repairable. The greatest healing potential is present for injuries repaired within 2–3 weeks.²⁸ The SL ligament can be primarily repaired with sutures for mid-substance ruptures or with suture anchors for avulsions. The addition of a dorsal DIC

capsulodesis can augment the repair and help to maintain the corrected SL angle over time.
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Chronic tears, presenting 6 weeks after injury, typically require ligament reconstruction. The SL ligament is retracted and degenerated, which prevents primary repair in these cases. The SL interval must be reducible to permit ligament reconstruction. In irreducible cases or when arthritic generation of the carpus is present, ligament reconstruction is contraindicated; pain relief is best achieved by four-corner fusion or PRC.

Four-corner fusion and PRC are performed for SLAC grades 1–3. PRC is preferred for older patients and smokers to avoid the risk of a non-union that can occur with four-corner fusion. If there are degenerative changes of the lunate fossa, then wrist arthroplasty or arthrodesis is performed. Wrist arthroplasty is used in select low-demand, older patients who wish to preserve some wrist motion. Wrist arthroplasty is particularly helpful for patients with advanced arthritic changes bilaterally who have undergone a previous contralateral wrist arthrodesis.

Approach to the Dorsal Wrist

A longitudinal incision is made just ulnar to Lister tubercle over the dorsal wrist. The extensor pollicis longus tendon is released from the third dorsal compartment and retracted radially. The fourth extensor compartment is elevated and retracted ulnarly. The dorsal wrist capsule is opened longitudinally. The SL interval is assessed (Figure 3). All fibrotic scar tissue is debrided. The blood supply entering the dorsal ridge of the scaphoid is preserved.

Primary Scapho-Lunate Ligament Repair (See Video 1, which demonstrates Primary scapho-lunate ligament repair, available in the “Related Videos” section of the Full-Text article on PRSJJournal.com or, for Ovid users, available at INSERT HYPER LINK.) (Video Graphic 1)

0.045-inch K-wires are used as joysticks to reduce the SL interval. K-wires are placed dorsally in the lunate, from proximal to distal, and in the scaphoid, from distal to proximal. The lunate is flexed, the scaphoid is extended, and the SL interval is compressed (Figure 4). A 0.062 K-wire is placed across the reduced SL interval from the radial wrist, starting just distal to the radial styloid. Fluoroscopic guidance can be used to facilitate accurate placement (Figure 5). An additional K-wire is placed across the midcarpal joint from the scaphoid into the capitate to limit wrist motion during ligament healing. Reduction of the SL gap and restoration of the normal SL angle (30–60°) should be confirmed fluoroscopically. The K-wires are cut short and left buried under the skin post-operatively to avoid a pin track infection when the K-wires are left outside the skin for more than 3 weeks.

If the SL ligament is torn in its mid-substance, non-absorbable sutures are used for repair.^{1,30} If the SL ligament is avulsed from the scaphoid (most common) or lunate, 1–2 bone anchors are used for reinsertion. Non-absorbable horizontal mattress sutures are also placed from the torn ligament into the dorsal periosteum of the scaphoid or lunate based on the injury pattern.

Radial Styloidectomy

Radial styloidectomy is performed when degenerative arthritis changes are present between the radial styloid and the proximal scaphoid (SLAC grade 1). Fluoroscopic guidance is used to confirm placement of an osteotome for resection of the distal 4mm of the radial styloid. Further resection risks injury to the radio-scapho-capitate ligament and subsequent destabilization and ulnar translocation of the carpus.³¹

Bone-Ligament-Bone Reconstruction (See Video 2, which demonstrates Bone-ligament-bone graft scapho-lunate ligament reconstruction, with demonstrations of the Lister tubercle and the capito-hamate donor sites, available in the “Related Videos” section of the Full-Text article on PRSJJournal.com or, for Ovid users, available at INSERT HYPER LINK.) (Video Graphic 2)

Using joysticks, the SL interval is reduced. K-wires are placed across the SL interval and the midcarpal joint. The scaphoid and the lunate are prepared as recipient sites for the bone-ligament-bone graft. Using an osteotome and a rongeur, troughs are created in the dorsal ulnar scaphoid and radial lunate (Figure 6).

Multiple bone-ligament-bone donor sites are available. The Lister tubercle is a conveniently-located donor site that results in minimal donor site morbidity. The graft is harvested from the dorsal radius at Lister tubercle with the overlying periosteum and extensor retinaculum, between the second and third extensor compartments (Figure 7).³² The central 2mm of bone is removed from the graft on the back table (Figure 8). The graft is press fit into the recipient site (Figure 9). One 1.7mm screw is placed in each side of the graft into the scaphoid and lunate to further secure the graft (Figure 10).

We use the capito-hamate donor site most frequently. The capito-hamate ligament replaces the damaged SL ligament with another ligament, rather than periosteum and extensor retinaculum. The capito-hamate bone-ligament-bone graft is harvested from the mid-dorsal capitate and hamate along with the intervening capito-hamate ligament. Press fit and screw placement is performed in the same fashion as for the Lister tubercle graft (Figure 11).

A single incision is used to both bone-ligament-bone reconstructions. The dorsal longitudinal incision used for the SL ligament exposure is extended proximally to reach Lister tubercle or distally to reach the capito-hamate ligament.

Three-Ligament Tenodesis using the FCR Tendon (See Video 3, which demonstrates Three-ligament tenodesis using the FCR tendon for scapho-lunate ligament reconstruction, available in the “Related Videos” section of the Full-Text article on PRSJJournal.com or, for Ovid users, available at INSERT HYPER LINK)

The ulnar third of the FCR tendon is harvested using a series of small incisions over the volar radial wrist to reconstruct the SL ligament and to correct the alignment of the scaphoid and lunate. The tendon is divided at its musculotendinous junction in the forearm and harvested as a distally based graft with its insertion maintained on the base of the volar index finger metacarpal (Figure 12). The tendon is harvested no wider than 2.5mm to permit its smooth passage through the scaphoid.

Through a dorsal wrist approach, using a 3mm cannulated drill over a guidewire, we drill a tunnel in the scaphoid from the proximal-dorsal scaphoid to the distal-volar scaphoid (Figure 13). Larger 3.5–4mm drills risk fracturing the carpal bones.⁸ Irrigation is used to decrease drilling temperatures and subsequent thermal osteonecrosis.³³ A suture passer is used to pass the FCR tendon from the volar distal wrist, through the scaphoid tunnel, and to the dorsal proximal wrist (Figure 14). Using joysticks, the SL interval is reduced and a K-wire is placed across it. And additional K-wire is placed across the midcarpal joint, from the scaphoid into the capitate.

Using a bur, with copious irrigation to prevent bone heating and necrosis, a trough is made horizontally in the dorsal lunate (Figure 15). A bone anchor is placed into the center of the trough and the FCR tendon is secured down to it (Figure 16). A slit is made in the radio-triquetral ligament over the dorso-ulnar wrist and the FCR tendon is passed through this slit from deep to superficial. The FCR tendon is secured back to itself over the dorsal lunate using non-absorbable suture (Figure 17).

Post-Operative Management

The patient is immobilized post-operatively in a sugar tong plaster splint with the wrist in mid-supination. Two weeks after surgery, the patient's sutures are removed and the patient is placed into a Muenster splint or cast in mid-supination. Maintaining intracarpal supination maintains the reduction of the scaphoid to the lunate and prevents widening of the SL gap and SL malalignment.³⁴ Elbow flexion and extension are permitted, but forearm rotation is blocked for a total of 8 weeks. After 8 weeks, patients are transitioned into a volar wrist splint and supination and pronation exercises begin.

The buried K-wires are removed using local anesthetic 8 weeks post-operatively. After K-wire removal, the patient starts active range of motion exercises. Formal hand therapy is not required for most patients. We do not recommend passive range of motion exercises because injudicious stress on the wrist may disrupt the tenuous reconstruction. A pain-free wrist and prevention of arthritis are the goals of treatment, at the expense of some wrist motion. Patients are advised pre-operatively that full wrist flexion and extension are not expected to be regained post-operatively.

Patients are weaned out of their wrist splints from week 8 to 12 after surgery. Patients can return to contact sports 4–6 months post-operatively. We do recommend long-term occupation and sport changes if possible to preserve the wrist. Heavy labor jobs are discouraged. We recommended that patients do fist push-ups, bench press with the wrist in neutral, and avoid other activities that load the wrist in extension.

Conclusion

We recommend surgical management of symptomatic SL injuries rather than observation, although long-term outcome data are lacking to determine if surgical management of SL injuries changes the natural history of the disease. Patients are counselled and sharing-decision process occurs.

Acute SL injuries can often be managed with primary repair. Symptomatic chronic injuries require ligament reconstruction or salvage procedures if non-operative management is insufficient. Predynamic, dynamic, and static injuries are treated with unique operative procedures to restore the carpal anatomy and stability to with the goal of optimizing outcomes and preventing progression of SLAC.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Wrist XRs are performed. Scaphoid flexion, lunate extension, and widening of the SL interval are indications of a SL ligament injury. The normal scapholunate angle is $46^{\circ} \pm 15^{\circ}$; this angle is increased with dorsal intercalated segmental instability due to SL ligament injury.

Figure 2.

Radiocarpal wrist arthroscopy provides valuable information about the SL ligament, as well as the health of the cartilage of the carpal bones and distal radius. A Geissler grade 4 SL ligament injury is visible here, the 2.7mm arthroscope can be driven between the scaphoid and lunate.

Figure 3. Complete dissociation is seen here between the scaphoid and the lunate. This 24-year-old male tore the dorsal, membranous, and volar components of his right SL ligament during a forceful fall into the boards while playing hockey.

Figure 4.

This 45-year-old female patient sustained a complete left SL tear from a ground level fall. K-wires are used as joysticks to extend the scaphoid, flex the lunate, and compress the SL interval. This SL interval reduction is held by placing additional K-wires across the SL interval and midcarpal joint. The joysticks can then be removed.

Figure 5.

Intra-operative fluoroscopy is used to assess the position of the K-wire placed from the scaphoid into the lunate to maintain the SL interval reduction. Joysticks are used in the dorsal scaphoid and lunate to facilitate the reduction.

Figure 6. Troughs are created in the mid dorsal scaphoid and lunate as recipient sites for a bone-ligament-bone SL reconstruction.

Figure 7.
Here, a bone block is shown as it is harvested from Lister tubercle with the overlying periosteum and external retinaculum, between the second and third extensor compartments.

Figure 8.

Using a fine rongeur, the central 2mm of bone is removed from the graft on the back table to prepare it for inset. The overlying periosteum and extensor retinaculum are maintained; these structures will replace the damaged SL ligament.

Figure 9.

The Lister tubercle bone-ligament-bone graft is press fit into the recipient site. One segment of the bone graft is inserted into the dorsal scaphoid and the other segment is inserted into the dorsal lunate. The intervening periosteum and extensor retinaculum of the graft replace the damaged SL ligament.

Figure 10.

The bone-ligament-bone graft is secured with one 1.7mm screw into each segment. The screws are seen here in the scaphoid and lunate. Buried K-wires are used across the SL interval and midcarpal joint to prevent wrist motion during the first 8 weeks post-operatively.

Figure 11.

The capto-hamate bone-ligament-bone graft donor site is visible over the distal dorso-ulnar wrist. The graft is secured into the dorsal scaphoid and lunate with 1.7mm screws. The intervening capito-hamate ligament replaces the damaged SL ligament.

Figure 12.

The ulnar third of the FCR tendon is harvested through a series of small incisions over the volar radial wrist. The tendon graft should be 2.5mm or narrower to permit its smooth passage through the scaphoid tunnel.

Figure 13.

A guidewire is placed antegrade from the proximal dorsal scaphoid to the distal volar scaphoid. A cannulated drill is used to drill over the guidewire, creating a bone tunnel for passage of the FCR tendon graft.

Figure 14.

The FCR tendon is passed from the volar distal wrist, through the scaphoid tunnel, into the dorsal proximal wrist using a suture passer, as shown here, or a wire loop.

Figure 15.

Using a burr and a rongeur, a horizontal trough is made across the mid dorsal lunate, exposing the underlying cancellous bone to promote healing of the FCR tendon graft to the dorsal lunate.

Figure 16.

A bone anchor is placed in the center of the trough created over the dorsal lunate. The FCR tendon is secured down to the bone anchor.

Figure 17.

The FCR tendon travels through the scaphoid bone tunnel, runs in the trough over the dorsal lunate, passes through the radio-triquetral ligament, and is sutured back to itself over the dorsal lunate. (Illustration was previously published in Operative Techniques: Hand and Wrist Surgery, 3rd edition by Kevin Chung, Elsevier, 2017.)

Table 1

Progression of Scapho-Lunate Advanced Collapse (SLAC) of the Wrist

SLAC Stage	Radiographic Findings
I	Arthritic changes at the radial styloid
II	Arthritic changes at the radio-scaphoid fossa
III	Arthritic changes at the scapho-capitate joint, proximal migration of the capitate
IV	Arthritic changes at the radio-lunate fossa. Pancarpal arthritis.

Table 2

Treatment of Scapho-Lunate Injuries by Stage

Stage of SL Injury ⁹	Our Preferred Treatment
1. Partial SL ligament injury. Predynamic.	Activity modification. FCR retraining and strengthening. Splinting. NSAIDs.
2. Complete SL ligament injury. Repairable. Dynamic instability.	Primary repair
3. Complete SL injury. Non-repairable. Dynamic instability.	Bone-ligament-bone reconstruction
4. Complete SL injury. Non-repairable. Reducible rotary subluxation of the scaphoid. Static instability.	FCR three-ligament tenodesis ⁸
5. Complete SL injury. Non-repairable. Irreducible malalignment. Intact cartilage.	PRC or four-corner fusion
6. Complete SL injury. Irreducible malalignment. Cartilage degeneration. SLAC.	Limited arthritis: PRC or four-corner fusion Pancarpal arthritis: wrist arthroplasty or arthrodesis

Dynamic instability: SL interval changes are only apparent on provocative physical examination (Watson shift test), stress imaging (clenched fist view XR), or MRI.

Static instability: SL interval changes visible on plain XRs.