Scapholunate Advanced Collapse and Scaphoid Nonunion Advanced Collapse Arthritis—Update on Evaluation and Treatment

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Scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse are common patterns of wrist arthritis. Scaphoid nonunion advanced collapse is caused by trauma, whereas SLAC wrist may also result from chronic pseudogout and can appear bilaterally without a clear history of injury. Surgical treatment for SLAC wrist includes 4-corner arthrodesis, capitolunate arthrodesis, complete wrist arthrodesis, proximal row carpectomy (PRC), denervation, and radial styloidectomy. Scaphoid nonunion advanced collapse wrist has the additional surgical option of excision of the distal ununited scaphoid fragment. Controversy persists over the relative merits of PRC versus 4-corner arthrodesis and whether PRC may be performed in the setting of capitate arthritis. *(J Hand Surg 2011;36A:729–735. © 2011 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

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OUR UNDERSTANDING OF the scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse (SNAC) pattern of wrist arthritis dates back to 1984, when Watson and Ballet[1] reviewed 4,000 wrist x-rays and found degenerative wrist arthritis in 210 cases, of which the most common pattern (57%) was arthritis between the scaphoid, lunate, and radius. A unifying theory of underlying scapholunate ligament incompetence was developed to explain the initial arthritic wear at the radioscaphoid junction (stages I and II), which then progressed to involve the midcarpal joint (stage III) but spared the spherical radiolunate articulation. In Watson and Ballet's original descriptions, SLAC wrist was therefore a tripartite classification, without a pan radiocarpal stage 4, as has occasionally been described.[2] Four-corner arthrodesis (capitate-lunate-triquetrum-hamate) with scaphoid silicone prosthetic replacement (silicone replacement later omitted) was Watson and Ballet's recommended surgical treatment, favored over proximal row carpectomy. Vender et al[3] noted that scaphoid nonunion led to a similar sequence of arthritic degeneration except for the spherical proximal scaphoid fragment, which, tethered to the lunate via an intact scapholunate ligament, was spared from arthritic changes.

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ETIOLOGY OF SNAC/SLAC WRIST

The cause of SNAC is trauma leading to scaphoid fracture and subsequent nonunion resulting in abnormal joint kinematics. The cause of SLAC is usually thought to be traumatic injury to the S-L ligament; however, calcium pyrophosphate dehydrate crystal deposition disease (CPPD, or pseudogout) has been reported to be a frequent cause of SLAC-type x-ray changes as well.[4–6]

IS PAINFUL SLAC ARTHRITIS INEVITABLE WITH SCAPHOLUNATE LIGAMENT INJURY?

There is currently no scientific evidence that a scapholunate ligament injury visualized arthroscopically, without static x-ray changes, inevitably leads to

SLAC wrist. One study that observed 11 patients with arthroscopically proven grade 1 to 2 scapholunate ligament injuries over an average of 7 years found no radiographic progression, although pain persisted.[7] To date, there is no definitive evidence that reconstruction or repair of an acute or chronic scapholunate ligament injury delays or prevents radiographic arthritis.

Pain is not a universal finding with SLAC, and frequently an asymptomatic SLAC x-ray appearance may be detected in the contralateral wrist, making bilateral wrist x-rays highly advisable, and suggesting that the cause is not traumatic.[8–12] Elderly or middle-aged individuals with bilateral identical SLAC wrist x-rays may imply calcium pyrophosphate dihydrate deposition disease (as opposed to identical scapholunate ligament injuries) and may present with symptoms other than wrist pain (eg, carpal tunnel syndrome).

CLINICAL EVALUATION

The diagnosis of SLAC or SNAC wrist arthritis is made by history, physical examination, and wrist x-rays. Examination will often reveal a wrist joint effusion, dorsal radial wrist swelling, and tenderness at the radioscaphoid joint. Wrist motion will typically be reduced and should be correlated with the contralateral side. Evidence of carpal tunnel syndrome, trigger finger, and basilar joint thumb arthritis should be carefully assessed because these may be causing the presenting wrist and hand symptoms. Bilateral wrist x-rays are mandatory for purposes of comparison.

TREATMENT OPTIONS FOR SLAC/SNAC

Nonsurgical management

Symptomatic treatment with splints, modalities, and injection may suffice in many patients. There are no studies on the long-term success of nonsurgical treatment for SLAC or SNAC wrist, nor are there any long-term natural history studies.

Surgical options

Surgical treatment options for either SLAC or SNAC wrist include partial or complete wrist arthrodesis, proximal row carpectomy (PRC), denervation, or radial styloidectomy, whereas SNAC wrist has the additional potential treatment option of excision of the distal ununited scaphoid fragment. Most studies concerning treatment of SLAC/SNAC wrist have focused on the results of 4-corner arthrodesis with scaphoid excision or PRC. Controversy exists concerning whether PRC, or a modification thereof, may be performed when the capitate has arthritic changes.

Four-corner arthrodesis

The classic surgical procedure, as described by Watson and Ballet,[1] involved excision of the scaphoid with fusion of the capitate, hamate, lunate, and triquetrum with K-wire fixation and distal radius bone grafting. A silicone scaphoid replacement was part of the initial procedure, although this was later abandoned. A transverse incision was used; high-speed burs were not recommended owing to concerns about thermal necrosis. A separate transverse incision was employed to harvest the distal radius bone graft. The buried K-wires were removed at 6 weeks. Dacho et al[13] reported long-term results (average, 49 mo) using a similar technique in 49 patients. Kirschner-wire removal was at 12 weeks. Active range of motion (ROM) was 56% and grip strength was 76% compared with the opposite side. Pain relief was 34% at rest and 12% of patients required complete wrist arthrodesis for persistent pain or nonunion.[13] Bain and Watts[14] reported a 10-year follow-up of 4-corner arthrodeses in 31 patients using staples and bone graft. They found no deterioration in results between 1 and 10 years after the procedure.

Technical modifications of 4-corner arthrodesis

Circular plates versus K-wires: Since the original description of 4-corner arthrodesis, circular plate fixation has been introduced as an alternative to K-wire fixation (Fig. 1). The purported advantages of plate fixation include more stable fixation with less chance of nonunion. In addition, no K-wire removal is required. Several studies published in the past several years have shown disappointing results with plate fixation. Kendall et al[15] noted a 63% nonunion rate. Vance et al[16] reported a 26% nonunion rate. Shindle et al[17] showed a high (56%) complication and nonunion (25%) rate with circular plate fixation. Collins and Nola[18] found no advantage of circular plate fixation compared with K-wires at 2 years after surgery. In fact, a higher nonunion rate and less wrist motion were found with plate fixation. De Smet et al[19] noted that plate fixation was associated with worse ROM compared with K-wire or screw fixation.

Studies positively reviewing plate fixation include those of Merrell et al,[20] who reported 100% union of the capitolunate joint, 1 screw back-out, and 1 broken plate. Use of distal radius bone graft was recommended for optimal results. Several technical points that were thought to be important included the use of distal radius bone graft, careful hand debridement of the adjacent joint surfaces, adequate debris removal, sufficient screw number (at least 2 in each bone), and proper plate and screw sizing. Bedford and Yang[21] reported 100% union

FIGURE 1: Anteroposterior wrist x-ray showing circular plate fixation for 4-corner arthrodesis for a SLAC wrist. The capitolunate joint is not completely fused, although the patient was asymptomatic.

FIGURE 2: Anteroposterior wrist x-ray showing solid capitolunate fusion using cannulated screws for SLAC wrist. The triquetrum was left *in situ*.

with 11 months' follow-up in 15 patients undergoing circular plate fixation, with only 1 complication.

Position of lunate in fusion mass: The lunate usually rests in an extended (dorsal intercalated segment instability) position in the SLAC wrist. What position to place the lunate (extended, flexed, or neutral) in the fusion mass has been a subject of study. Wyrick et al,[22] in a clinical review of 4-corner arthrodeses, noted the postoperative capitolunate angle to range from 20° of lunate flexion to 30° of extension but found no statistical correlation between lunate position and ultimate wrist motion. DeCarli et al,[23] in a cadaveric study, found the total arc of motion of the fused wrist to be unaffected by fusing the lunate in neutral, 30° of extension, or 20° of flexion. However, the extended lunate position improved flexion at the expense of extension, and the flexed lunate had the opposite effect, improving extension and decreasing flexion.

Fusing only capitolunate joint with or without triquetrum excision: The technical goal of 4-corner arthrodesis is to achieve solid union of the capitolunate joint. Adding the hamate and triquetrum to the fusion mass was initially thought to improve fusion rates, and early reports limiting the arthrodesis to the capitolunate joint resulted in higher rates of nonunion.[24] More recent reports have examined capitolunate fusion as an alternative to 4-corner arthrodesis, with or without excision of the triquetrum to theoretically improve motion. Calandruccio et al[25] reported 14 wrists undergoing capitolunate arthrodesis with scaphoid and triquetrum excision (Fig. 2). Two cannulated headless screws were used for fixation. Two patients had a nonunion and results were similar to 4-corner arthrodesis. Gaston et al[26] compared the clinical outcomes of capitolunate arthrodesis with scaphoid and triquetral excision versus 4-corner arthrodesis, and they found a slight increase in flexion-extension in the 4-corner group, with 2 nonunions compared with 100% union in the capitolunate group. Scorbecea et al,[27] in a cadaveric study, found that capitolunate arthrodesis with triquetral and scaphoid excision improved motion but increased mean radiolunate contact pressures compared with simulated 4-corner arthrodesis. Dimitrios et al[28] reported a clinical series in which the proximal scaphoid was resected, a cannulated headless screw was placed from the distal scaphoid into the capitate, 1

FIGURE 3: Anteroposterior wrist x-ray after PRC for SLAC wrist. Some distal pole scaphoid remnants remain that do not require removal, because the distal pole is out of plane of the radius.

screw from the capitate to lunate, and the triquetrum was left *in situ*. No nonunions were reported, although 3 of 8 patients had persistent pain. Overall, the results of capitolunate arthrodesis with or without triquetrum excision appear comparable to standard 4-corner arthrodesis.

Conversion of 4-corner arthrodesis to complete wrist fusion

Gohritz et al[29] reported on 20 patients who underwent bilateral 4-corner arthrodesis, as well as 22 patients who underwent total wrist arthrodesis after unsuccessful 4-corner arthrodesis. Bilateral arthrodesis patients reported a 54% reduction of preoperative pain values at rest and a mean arc of flexion-extension of about 60°. Total wrist arthrodesis after 4-corner fusion reduced pain by 67% at rest, but rarely eliminated wrist pain.

PRC

How to manage the arthritic capitate

Traditional teaching holds that degeneration of the articular capitate surface is a contraindication to PRC (Fig. 3). Tang and Imbriglia[30] reported on 8 patients with capitate arthrosis who underwent osteochondral resurfacing of the capitate at the time of PRC, using grafts harvested from the resected carpals. At 18-month follow-up, results compared favorably with traditional PRC. Placzek et al[31] described PRC with capitate head resection and dorsal capsular interposition in 8 patients with 1-year follow-up. No improvement in ROM or grip strength was found, but pain relief was noted in 75% of patients. Kwon et al[32] reported on 8 patients with capsular interposition at the time of PRC for advanced arthritis, with a mean follow-up of 41 months. Range of motion and grip strength did not improve, but pain scores did. Arthritis progressed radiographically in 3 of 8 patients, unrelated to outcomes.

Is postoperative immobilization necessary?

Jacobs et al[33] studied the effect of postoperative immobilization after PRC. A total of 25 patients who were immobilized for 4 weeks postoperatively had similar outcomes to 13 patients who were not immobilized postoperatively, in a retrospective review.

WHICH TO CHOOSE—PRC OR 4-CORNER ARTHRODESIS—FOR SLAC/SNAC WRIST?

Watson and Ballet[1] originally recommended 4-corner arthrodesis over PRC for SLAC wrist owing to concerns that the capitate had a sharper radius of curvature than the lunate and did not fit well into the radius; in addition, they frequently found poor cartilage on the proximal capitate compared with the lunate. Despite these theoretical objections, excellent results have been reported with PRC for SLAC wrist with the purported advantages being earlier motion, no hardware, and no need for fusion to occur.

A decision analysis model of PRC versus 4-corner arthrodesis favored PRC.[34] A long-term (minimum of 10-year follow-up) assessment of PRC by DiDonna et al[35] noted that all patients who were older than 35 years of age at the time of surgery were satisfied and maintained satisfactory wrist ROM, grip strength, and pain relief. Of 22 wrists that required complete wrist arthrodesis at an average of 7 years after PRC, 4 were in patients under the age of 35 at the index procedure.

STUDIES COMPARING PRC WITH 4-CORNER ARTHRODESIS

Cohen and Kozin[36] compared 2 cohorts from separate institutions and noted no significant differences in outcomes between PRC and 4-corner arthrodesis. Vanhove et al[37] noted a higher complication rate with 4-corner arthrodesis versus PRC, and preferred PRC. De Smet et al[19] compared results of PRC with 4-corner and total

FIGURE 4: A Anteroposterior wrist x-ray of SNAC wrist with half of the proximal scaphoid remaining. The capitolunate joint appears to be uninvolved. **B** Incision for distal pole scaphoid excision. Dissection proceeds through the floor of the flexor carpi radialis sheath. **C** Distal pole of scaphoid being removed. **D** Gap after distal scaphoid removal.

wrist arthrodesis and noted better outcomes with PRC. Dacho et al[38] preferred PRC for patients who required less grip strength at work. Mulford et al,[39] in a systematic review of PRC versus 4-corner arthrodesis, found that PRC may provide better ROM, albeit with a higher risk of arthritis that may be asymptomatic. Grip strength, pain relief, and subjective outcomes were similar in both groups, although PRC lacked the complications of nonunion, hardware issues, and dorsal impingement.

In a concise summary of the results of PRC versus 4-corner arthrodesis, Kiefhaber[40] found that 85% of patients with either procedure had good or better pain relief, but that 25% with successful results still reported some discomfort most noticeable at end-range motion. Range of motion was 75° to 80° with either procedure, but usually 10° less with 4-corner arthrodesis. Strength was usually 80% of the opposite side with either procedure. Conversion to total wrist arthrodesis was equivalent. Kiefhaber's preference was for 4-bone arthrodesis in patients under 35 years of age and in high-demand patients in their 40s and 50s, with PRC reserved for older or less active patients.

DENERVATION

Denervation of the wrist joint can be either complete, involving attempted transection of all possible articular branches, or partial, typically involving sectioning of only the posterior or anterior interosseous nerves proximal to the wrist joint. Purported advantages of denervation include no compromise in wrist motion, no hardware or fusion, and no "burnt bridges."

Rothe et al[41] reported on 32 patients with stage 2 and 3 SLAC or SNAC wrist who underwent complete wrist denervation with an average follow-up of 6 years. A total of 32% reported no pain, 19% had pain when load-bearing, 15% had severe pain, and 6% had no improvement at all. Nineteen patients reported a considerable improvement.

Radu et al[42] studied 43 patients undergoing partial or complete wrist denervation, including SLAC and SNAC wrist diagnoses. Pain was only statistically significantly decreased at an average of 51 months' follow-up in the group without arthritic changes. Only 53% of patients with arthritis and carpal instability were satisfied with the surgery. A total of 76% of all patients with a complete denervation and 57% of patients with a partial wrist denervation reported some pain reduction.

COMPLETE WRIST ARTHRODESIS

Plate fixation is currently the standard technique for total wrist arthrodesis. Nagy and Buchler[43] recommended that the third carpometacarpal joint not be included in the fusion mass. Of 47 wrists that underwent third carpometacarpal joint arthrodesis, 20 had nonunion after plate removal. In comparison, 30 wrists that had the third carpometacarpal joint bridged by the plate, but not specifically fused, were all (except 1) free of symptoms after plate removal.

RADIAL STYLOIDECTOMY

Painful arthritic changes between the scaphoid and radial styloid in SLAC or SNAC wrist may be treated by radial styloidectomy, and in the case of SNAC wrist, by excision of the distal scaphoid fragment.

There has been little recent research on radial styloidectomy. Nakamura et al,[44] in a cadaver study, recommended against removing more than 3 to 4 mm to avoid increased risk of carpal instability resulting from detachment of the radiocarpal ligaments. Yao and Osterman[45] reported arthroscopic techniques for radial styloidectomy, although no detailed results were given.

DISTAL SCHAPHOID POLE EXCISION

Downing[46] reported excision of both the radial styloid and the distal fragment of the scaphoid. Excision of the distal fragment was not recommended when less than half the proximal scaphoid remained. Malerich et al[47] excised the distal scaphoid fragment in 19 patients with SNAC wrist and noted improvement in pain, ROM, and grip. Of 19 patients, 13 had complete pain relief. Resection of the distal fragment was not recommended for patients with capitolunate arthritis.

Ruch and Papadonikolakis[48] reported on 13 patients undergoing distal pole resection for scaphoid nonunion and recommended the procedure for patients with refractory nonunion and a competent scapholunate ligament.

Excision of the distal ununited scaphoid fragment is a worthwhile procedure for patients with radioscaphoid pain due to chronic SNAC wrist without capitolunate arthritis (Fig. 4).

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