Early Experience With (Dry) Arthroscopic 4-Corner Arthrodesis: From a 4-Hour Operation to a Tourniquet Time

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Purpose Scaphoidectomy and 4-corner arthrodesis (4CA) is an effective procedure for treating several degenerative conditions of the wrist. Recently, the arthroscopic approach to this operation was described. Although it is conceptually appealing, certain aspects make its application difficult. We present our technique for dry arthroscopic scaphoidectomy and 4CA, which reduces the operative time to less than 2 hours.

Methods Four consecutive patients underwent scaphoidectomy and 4CA. In each case, we performed the operation with a dry arthroscopic technique using cannulated screws for rigid fixation. We performed bone grafting from the distal radius in 2 patients and from the scaphoid itself in the other two. The relevant operative details are the use of a scapholunate portal, the resection of the scaphoid with a pituitary rongeur, and the placement of bone graft in a dry arthroscopic environment. Range of motion exercises are started 2 to 3 weeks after the operation.

Results The first operation took 4 hours. The last 2 were completed in 1 hour 45 minutes and 1 hour 55 minutes, respectively. No complications occurred. No operations were converted to an open procedure.

Conclusions Although the operation has a steep learning curve, it is conceptually appealing. It is too early to prove that the arthroscopic procedure has better results than the open 4CA; nevertheless, in our opinion it represents the future of wrist surgery. *(J Hand Surg 2012;37A:2389–2399. Copyright © 2012 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Wrist arthroscopy, wrist osteoarthritis, scaphoid nonunion, SNAC, SLAC.

IN 1984, WATSON and Ballet[1] described the so-called "4-corner arthrodesis" (4CA). Its prime indication is to treat wrists with degeneration of the head of the capitate (scapholunate advanced collapse [SLAC]/ scaphoid nonunion advanced collapse [SNAC] stage III). This is a contraindication for proximal row carpectomy (PRC).[2] A recent study[3] showed stable results of the scaphoidectomy and 4CA between 1 and 10 years postoperatively, which demonstrate its long-term reliability. Although this technique is widely used, considerable discussion exists in the literature as to the best method of fixation (circular plate vs Kirschner wires vs headless screws).[4–10]

In a pioneering paper, Ho[11] described a method of arthroscopic partial wrist arthrodesis, including arthroscopic 4-corner arthrodesis (A-4CA). Although the idea of minimizing the surgical insult to the wrist is appealing, the technical difficulties of the operation, including more than 3 hours' operative time, make implementation challenging. Some of the procedural struggles come from the infusion of saline. Specifically, it is difficult to place bone graft in the continuously irrigated joint accurately without resorting to compli-

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Surgical Technique

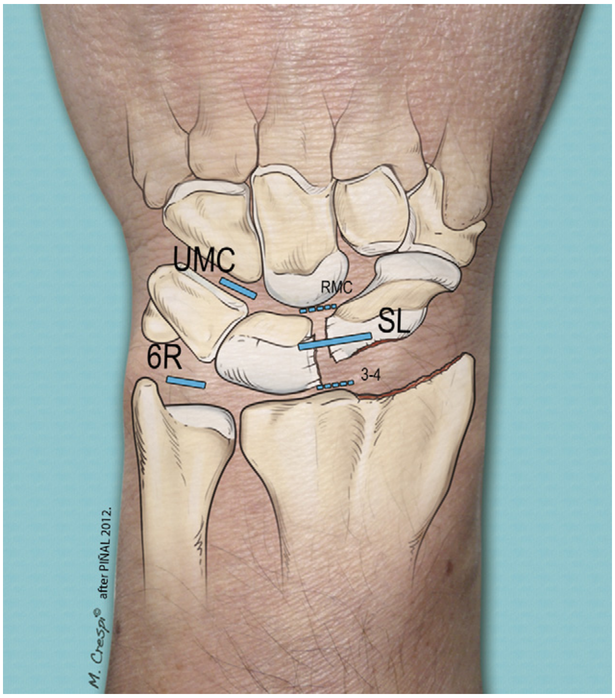


FIGURE 1: The SL portal is located midway between the 3–4 and radial midcarpal portals. RMC, radial midcarpal.

FIGURE 2: Straight articulated rongeur and angulated rongeur used during the procedure.

cated maneuvers (use of a Foley balloon, etc).[11] Furthermore, as the length of the procedure increases, the infusion fluid continues to extravasate and the swelling becomes more pronounced. This masks bony landmarks, making accurate insertion of guidewires for bony fixation difficult. Finally, the scaphoid has to be removed by a burr, which is time consuming and precludes saving this bone as a source of bone graft. In all, these difficulties have made the procedure unappealing.

We have endorsed the dry arthroscopy technique (arthroscopy without infusing saline) as ideal to carry out wrist arthroscopy in general.[12] It is particularly useful in complex operations such as distal radius fixations and in any semi-open operation.[13–15] With this technique, most difficulties mentioned for the wet A-4CA as described by Ho[11] are circumvented. Specifically, bone graft can be accurately placed, and the swelling does not mask the bony landmarks. Although those were major advances, initially the procedure still took long in our hands (nearly 4 hours in our first complete attempt). Through our experience carrying out arthroscopic PRC and other "ectomy" procedures, we have been increasingly employing rongeurs to remove the carpals and minimizing the use of burrs. With all of these modifications, we have been able to refine the operation and diminish the operative time to one that is competitive with the open procedure. The purpose of this article was to describe the technique of A-4CA using the dry arthroscopic technique, underscoring the steps taken and improvements made to reduce the operative time to less than 2 hours (ie, 1 tourniquet time).

SURGICAL TECHNIQUE

The procedure is performed with the dry arthroscopy technique as described previously.[12,15] A custom-made device is used for traction. This makes it easier to place the hand on traction for arthroscopy and release the traction for use of fluoroscopy without losing sterility.[16] In the dry arthroscopic technique, the optic cavity within the wrist is maintained by distraction of the hand; fluid is used only to clear the joint of debris by flushing the joint intermittently with saline. Details of the technique itself can be found elsewhere. Only the specific steps that apply to the A-4CA technique will be highlighted below.

Scapholunate portal

In SNAC and SLAC wrists, the radial-sided carpal anatomy is distorted. Therefore, the ulnar portals are established first, specifically the 6R and ulnar midcarpal (UMC) portal. The radiocarpal joint is assessed as to the feasibility of the operation by specifically investigating the quality of the cartilage of the lunate fossa and lunate. The alternative A-PRC is considered if the capitate's cartilage is preserved while viewing it from the UMC portal. Then, a third 1.5-cm transverse scapholunate (SL) portal is created at a location between the 3–4 and radial midcarpal portal sites. This SL portal overlies the scaphoid pathology (SL gap or scaphoid nonunion)

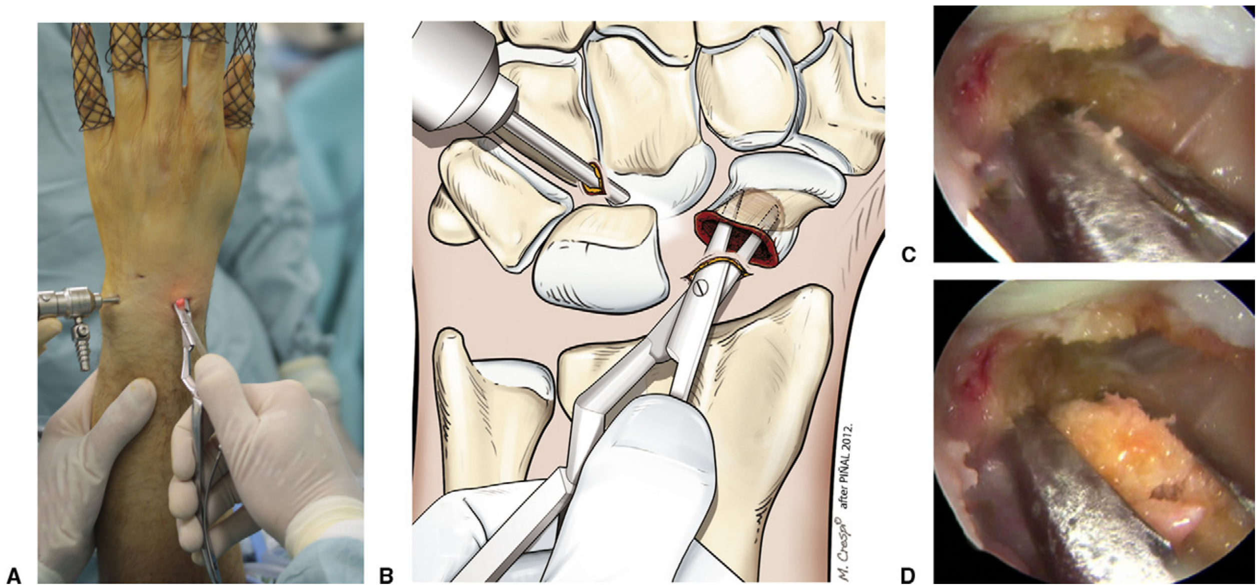


FIGURE 3: The process of scaphoid resection with a rongeur. **A** The rongeur has been inserted through the SL portal, whereas the scope is in 6R for orientation purposes (see text). **B** With the scope in UMC, the surgeon scoops out the middle third of the scaphoid with the rongeur. **C**, **D** Corresponding arthroscopic view.

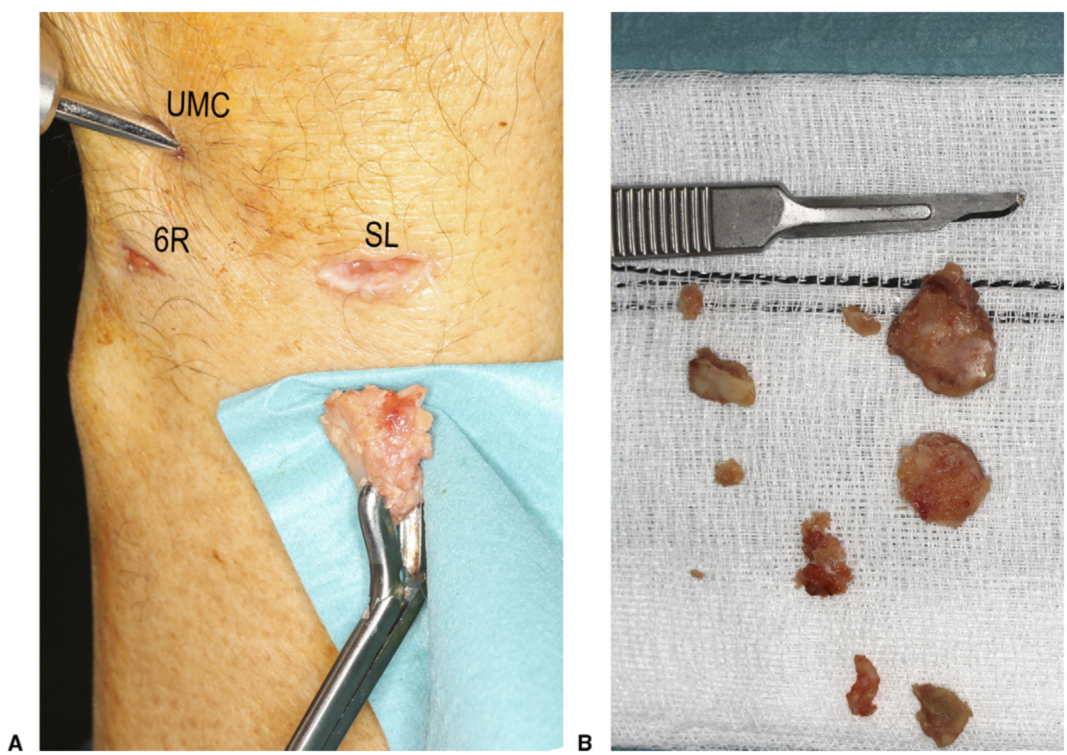


FIGURE 4: **A** A large piece of a scaphoid osteophyte is extracted from the dorsal aspect of the capsule with the 90° angled rongeur. **B** Note the great number of small bone fragments and loose bodies that had to be removed from the wrist capsule in this advanced SNAC wrist.

(Fig. 1). Visual input from the ulnar side of the wrist is needed at the time of creation of this portal, because palpation is often misleading. The most convenient and direct path to the joint is located with a needle before making the actual incision on the skin. The use of a mini-incision/large portal is possible in the dry tech-

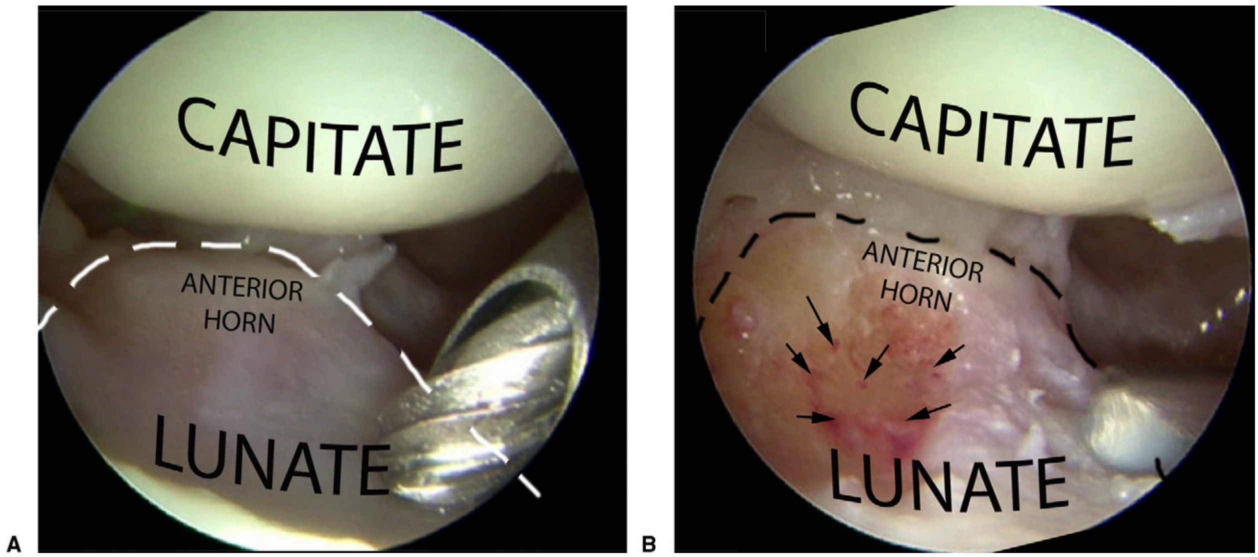


FIGURE 5: A The anterior horn of the lunate is easily accessible with arthroscopy. **B** The cartilage and subchondral bone are removed until bleeding points are seen (arrows) (scope in UMC; burr in SL portal).

nique because maintenance of fluid competence in the joint is not a concern.

Once the 6R, UMC, and SL portals are established, hypertrophic synovium is resected with a 2.9-mm shaver. Both the 6R and SL portals are used for instrumentation during this part of the procedure, to effectively resect the synovium. The scarred dorsal capsule, which adheres to the dorsal aspect of the extended lunate and tethers it, is also resected in this early part of the operation. These maneuvers allow for a larger working environment within the joint and for later correction of the lunate extended deformity. The resection continues until the lunate is released; rarely the extensor tendons are visualized, and rarely the dorsal radiotriquetral ligament needs to be excised. In some instances we have introduced a Freer elevator and applied pressure to the scarred capsule to make it yield.

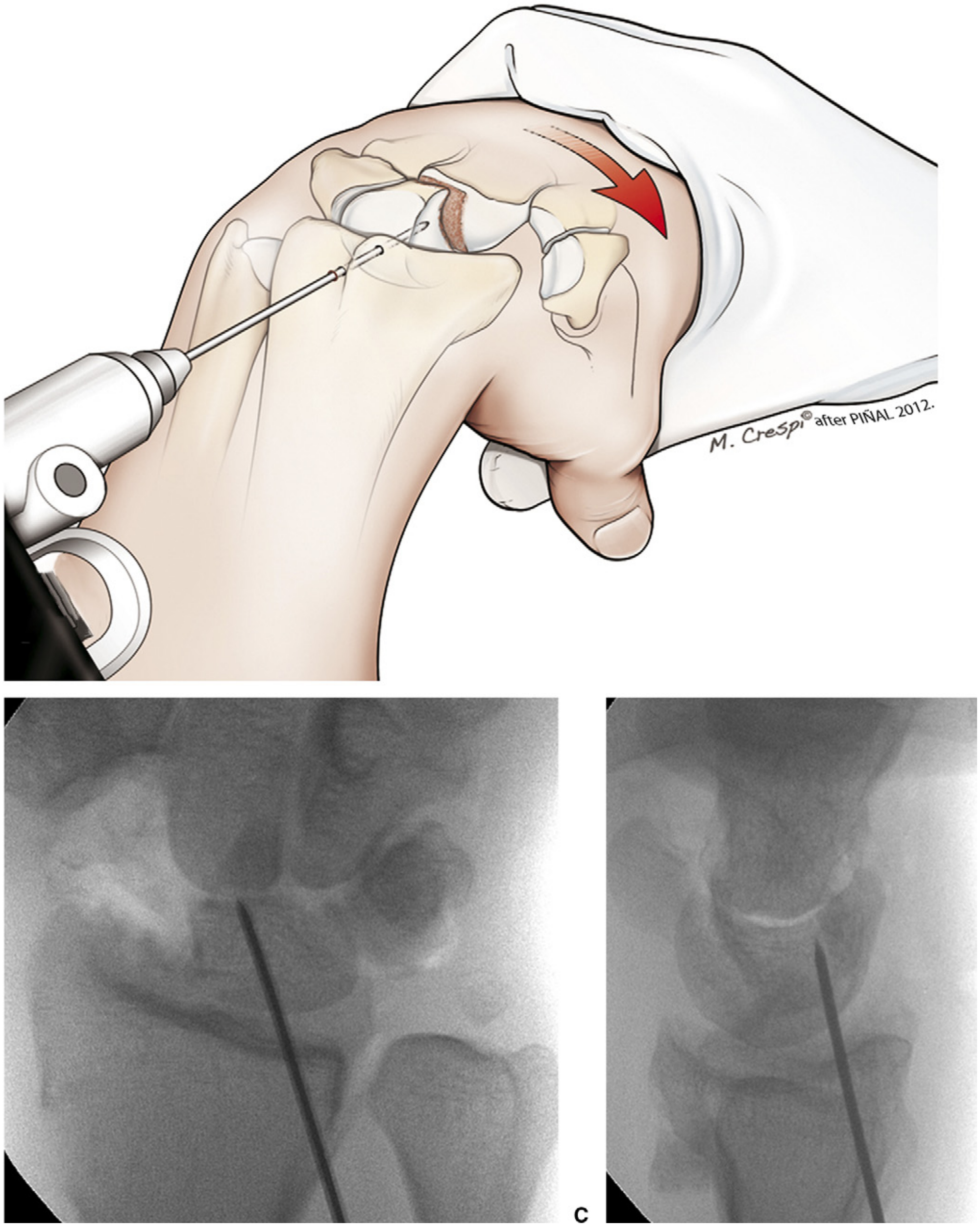
Scaphoid excision

The previous description of A-4CA and A-PRC[11,17] resected the bone with a burr, but as stated, it is time consuming and the scaphoid cannot be reused as bone graft (as in our first 2 patients when distal radius bone graft was used). Furthermore, in longstanding scaphoid nonunion, many small bone fragments are loosely attached to the capsule. These are extremely difficult to remove with the burr because the burr needs to work against a stable surface to be efficient. We find the use of pituitary rongeurs of different angulations to be expeditious for removing the scaphoid and loose bodies (Fig. 2).

The process of excising the scaphoid with a rongeur has to follow a prescribed manner so as not to waste the valuable cancellous bone graft. As a general principle, one should avoid placing instrumentation through the 6R portal, to avoid accidental injuries of the cartilaginous surface of the proximal lunate or lunate fossa. In some cases of SLAC wrists, it may be difficult to orientate oneself at the beginning of the resection process, and the lunate rather than the scaphoid is at risk of being excised. Placing the scope in 6R at this early stage will protect the lunate while the most proximal aspect of the scaphoid is being resected. Once all doubt is cleared, the scope is placed in the UMC portal and the straight articulated rongeur is inserted through the SL portal. The proximal pole is first excised piecemeal and discarded. This exposes cancellous bone inside the scaphoid, which is cored out and placed in a container. Once the middle third is emptied of cancellous bone, the scaphoid shell is removed in piecemeal fashion and discarded. The process is repeated for the distal pole, saving the cancellous bone and discarding the outer cortex and ligamentous attachments of the scaphoid (Fig. 3). With this method, the scaphoid can be removed in 15 minutes and a sufficient amount of bone graft will be saved for the later arthrodesis.

After scaphoid resection, small bone fragments remain attached to the dorsal capsule (osteophytes and loose bodies). These are difficult to remove using only the straight rongeur. We have found a 90° angled small rongeur useful for this (Fig. 4).

A



B C

FIGURE 6: A The critical reduction of the lunate is accomplished by hyperflexing the wrist while the surgeon translocates the wrist radially. **B**, **C** A Kirschner wire introduced proximal to the 4–5 portal and directed toward the 3–4 portal will hit the center of the lunate.

Bone preparation for arthrodesis

After scaphoid resection, the cartilage and subchondral bone at the site of the 4-corner arthrodesis are removed with a burr (Fig. 5). Particular attention is paid to the lunotriquetral joint. A trough is created at the distal portion of this articulation for placement of bone graft. Because of the inherent rigidity of the capitohamate joint, it is not burred. During this portion of the procedure, a 3.0-mm pineapple burr is preferred because it tends not to get caught on bone and produces a more even surface of bone as opposed to pits created by the round burr. During burring, the suction of the instrument is maintained in the off position. Otherwise, the suction stirs up the contents of the joint and obscures the visual field. To remove debris and prevent the burr from clogging, aliquots of 5 to 10 mL saline are flushed through the scope's side valve with a syringe. The suction is turned on at that specific time, and once the debris is removed the suction is again turned off. Because of the large portals used in this procedure, the

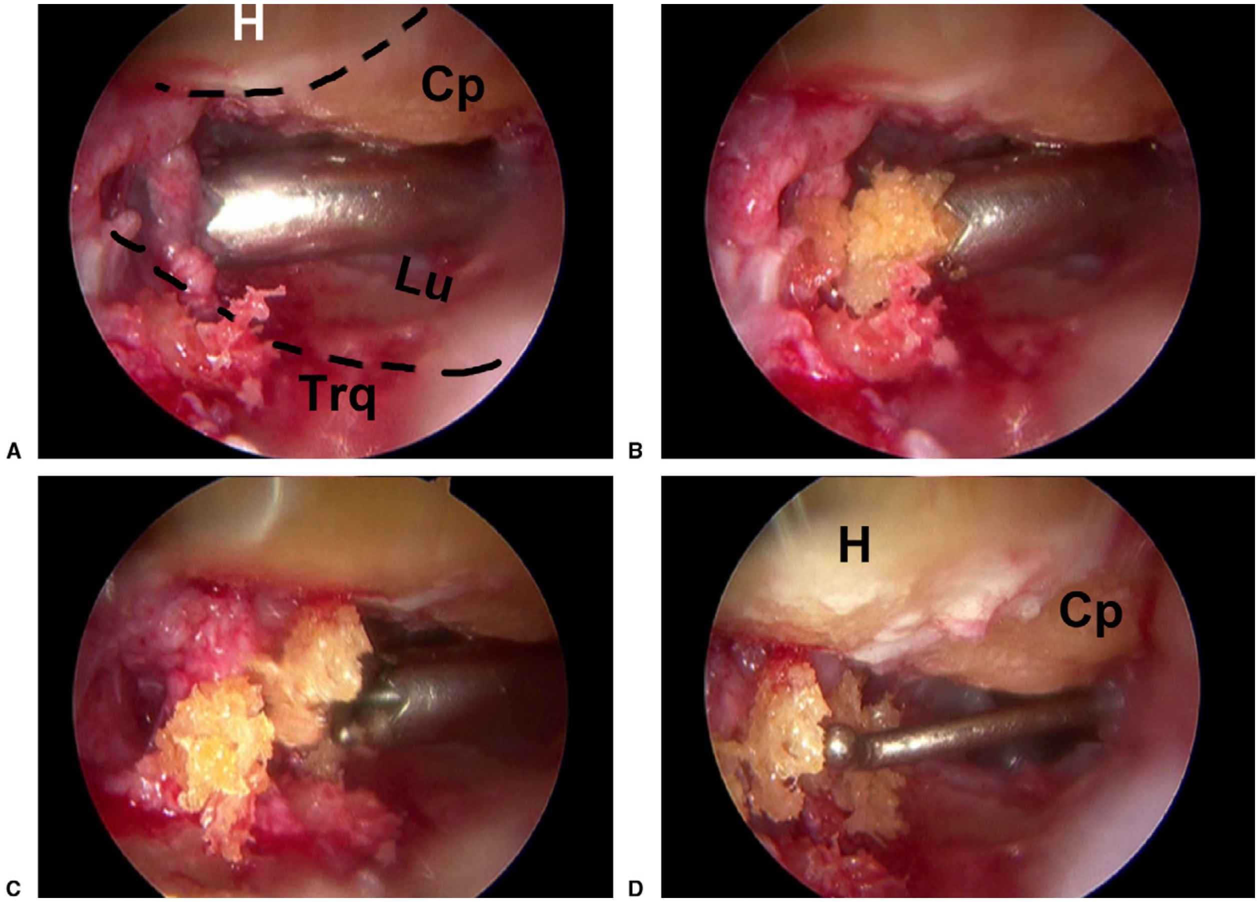


FIGURE 7: The process of introducing the bone graft into the midcarpal space. **A** A 3.5-mm drill guide, fully loaded with cancellous bone graft introduced from the SL portal, is facing the volar aspect of the lunate and triquetrum. Lu, lunate; Trq, triquetrum. **B** The plunger (the shoulder hook in this case) is starting to push the bone graft into the joint space. **C** All of the bone graft has been delivered in the joint. **D** The shoulder probe or a small Freer elevator is used to compress the bone against the palmar ligaments. H, hamate; Cp, capitate.

surgeon must occlude the SL portal with his or her thumb to create a closed space for the suction to work.

Lunate reduction and stabilization

After the joint surfaces are appropriately prepared, the hand is removed from the custom-made traction device to reduce the lunate. To correct the extended and ulnar translated lunate, the wrist is maximally flexed and radially translated (Fig. 6A). The lunate reduction is maintained with a Kirschner wire (1.25 mm), which is inserted about 2 cm proximal to the 4–5 portal and directed slightly radially[18] (Fig. 6B, C).

Bone grafting

With the lunate reduced, the hand is again placed on traction to allow for the placement of bone graft under arthroscopic guidance. The cavity during traction is large, but we focus on filling the anterior aspects of the lunocapitate and triquetrohamate joints as well as the most distal aspect of the lunotriquetral joint only. For the other surfaces, bone graft is not needed because cancellous bone will contact cancellous bone once the joint is reduced. After trying several devices and methods, the technique we now employ to deliver the bone graft inside the joint is a 3.5-mm drill guide. The cancellous bone is loaded into the guide outside the wrist, and the guide is then placed into the joint through the SL portal. A shoulder probe, acting as a plunger, then delivers the bone into the joint, and the bone graft is manipulated into the appropriate position with a small Freer elevator or the probe itself (Fig. 7).

Another advantage of the dry technique is apparent during this step: The bone graft does not float within the joint cavity created by the scaphoidectomy, and the consequence of losing bone graft as it migrates to inappropriate locations within the wrist is avoided.

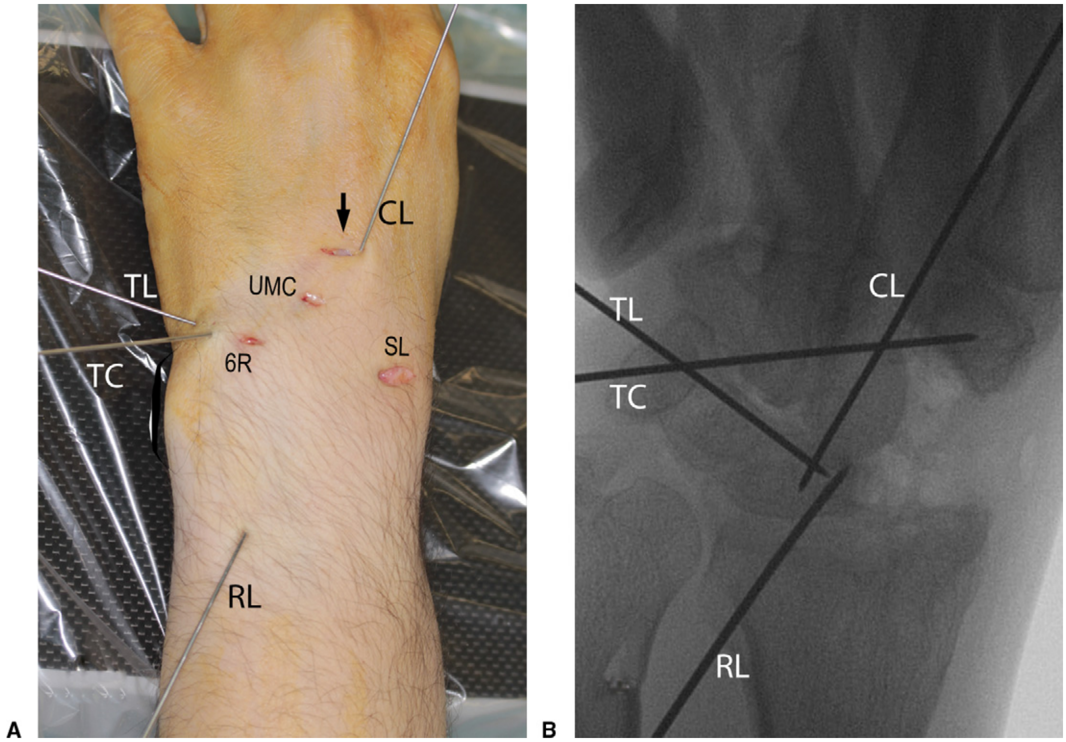


FIGURE 8: View of the hand **A** and corresponding fluoroscopic view **B** at the end of the insertion of the guidewires. Note that the hand is not swollen, even at this late stage of the operation. TC, triquetrocapitate; TL, triquetrolunate; RL, radiolunate; CL, capitolunate. The arrow points to the incision needed for the insertion of the capitolunate screw.

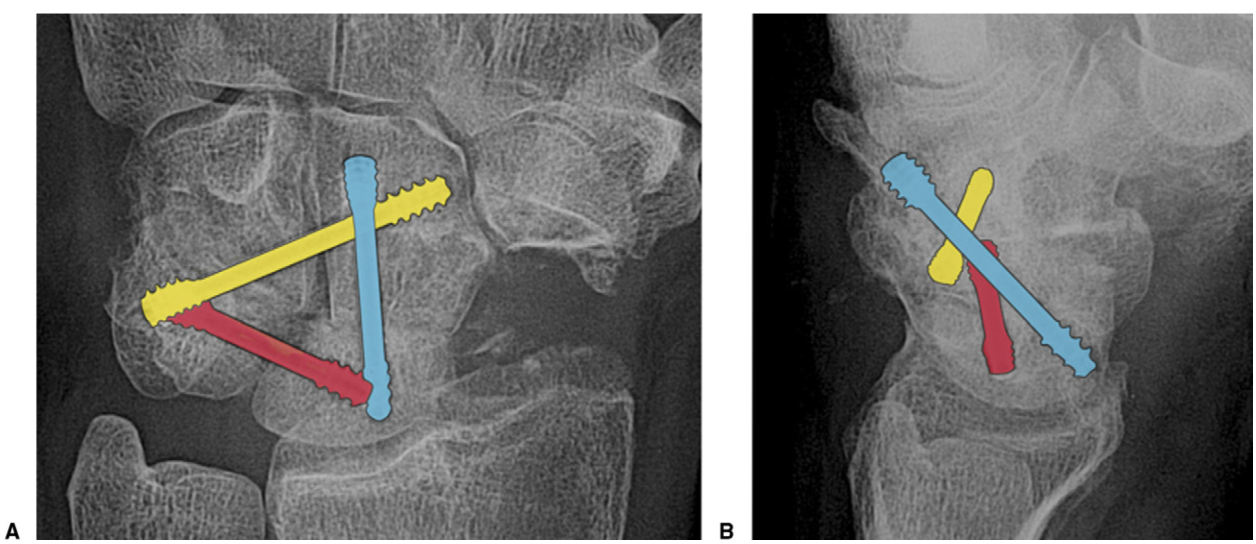


FIGURE 9: Ideally, the screws should be placed to avoid collision and provide maximal purchase. **A** PA and **B** lateral views of the postoperative x-rays of patient 1.

Midcarpal reduction and fixation

After the bone graft is placed, the hand is taken off traction, the midcarpal joint is reduced, and the guidewires for the cannulated screws are inserted. This critical step, the trickiest part of the operation in our opinion, is greatly facilitated by the dry arthroscopic technique; the bony anatomy is easily palpated because the swelling that results from the classic wet technique is avoided (Fig. 8).

The guidewires are placed in such a fashion as to maximize purchase and avoid screw collision: The capitolunate screw is directed from the dorsal distal

A

B

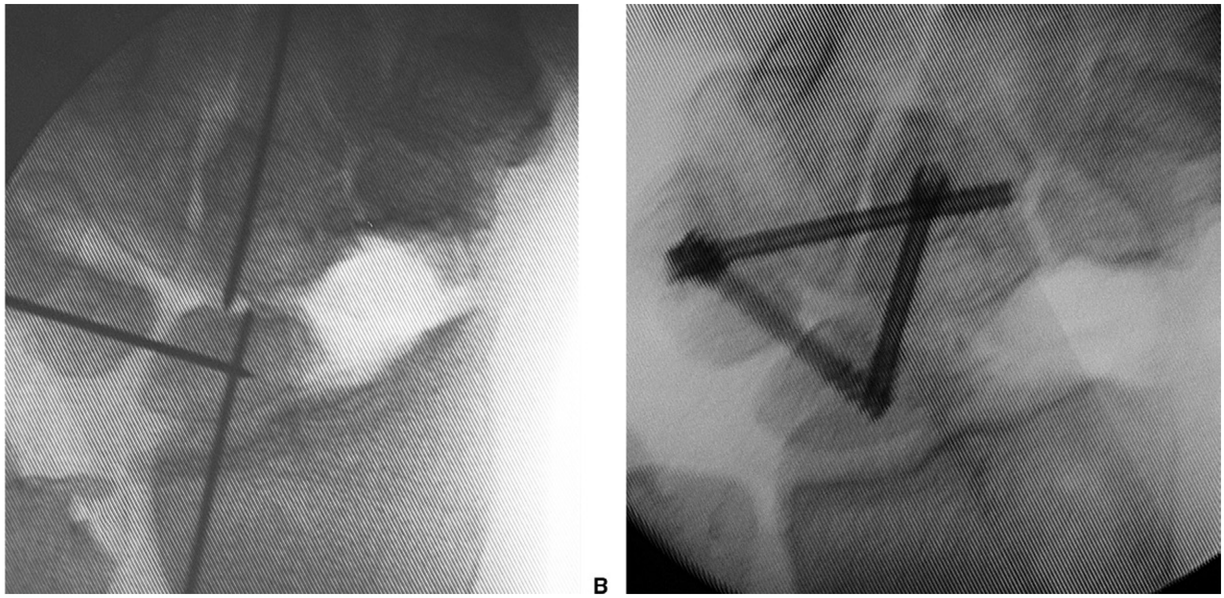


FIGURE 10: A Despite total scaphoid resection and reduction of the capitate, the pointed styloid was still too close to the carpals, and we were concerned about abutment. **B** The large radial space is shown after the styloidectomy.

aspect of the capitate to the volar proximal aspect of the lunate, the triquetrolunate screw is directed from the volar triquetrum to the dorsal lunate, and the triquetrocapitate screw is directed from the dorsal distal triquetrum to the volar distal capitate. This technique avoids the problem of 1 screw interfering with placement of the next (Fig. 9).

A small transverse incision is made at the base of the long finger metacarpal for guidewire insertion and later drilling of the capitate. This allows for protection of the extensor tendon of the third finger. The surgeon's hand must be oriented nearly parallel to the patient's wrist during insertion of this guidewire; otherwise, the lunate is missed.

Correct placement of the guidewires is confirmed on fluoroscopy. Screws of appropriate length and size (presently we use 3-mm titanium AutoFIX^{TM} [Small Bone Innovations, New York, NY]) are inserted percutaneously after predrilling the canal in the standard fashion. The radiolunate Kirschner wire is removed and a final fluoroscopic check is performed. Although the carpal height is restored by repositioning the capitate on the lunate, the radial styloid may continue to abut the carpus. In this case, the styloid should be resected. This actually takes little time to complete with the rongeur. Care should be taken to preserve intact the RSC ligament origins on the radius (Fig. 10).

Finally, the SL portal incision is closed with intradermal sutures and the other portals are dressed with nonadherent gauze.

Postoperative protocol

The patients are placed in a volar-based wrist splint postoperatively. As soon as clinical signs of bony healing occur (absence of pain on palpation at the arthrodesis sites), exercises are commenced. This usually occurs by the 2nd to 3rd week, and initially self-directed active range of motion exercises are permitted several times a day. At the 5th to 6th week, assisted exercises are added and the patient is weaned from the splint. Passive exercises are then added. In 1 patient who had a 15° flexion contracture, progressive casting was started at the 8th week to improve the lack of extension.

CLINICAL EXPERIENCE

Our clinical experience (Table 1) is limited to 4 consecutive cases (after several previous aborted attempts). We have refined the operative technique to the point where the last 2 procedures were carried out in less than a tourniquet time (improved from 4 h in our first completed case). Specifically, the first patient, a 53-year-old who presented with an SNAC wrist, underwent a 4-hour operation: 2 hours of operating followed by 20 minutes of reperfusion time, and then 1 hour 45 minutes more of operating. The second patient, a 63-year-old patient who presented with an SNAC wrist, had a 3 hour 10 minute procedure (including 20 min of tourniquet rest). The third procedure, on a 47-year-old with an SNAC wrist, was completed in 1 hour 45 minutes. Finally, the fourth procedure (for an SLAC wrist in a 34-y-old patient), was completed in 1 hour 55 minutes.

TABLE 1. Demographics and Results

Case	Age	Sex	Hand	Pathology	Bone Graft	Styloid Resection	Capitolunate Angle (°) Preoperatively/ Postoperatively	Bony Union (Plain X-rays)			Active Extension-Flexion (°) Preoperatively/ Postoperatively	Grip (kg) Preoperatively/ Postoperatively/ Contralaterally	Pain (Visual Analog Scale) Preoperatively/ Postoperatively	RTW (mo)	Follow-Up (mo)
								CL	TH	TL					
1	53	M	ND	SNAC III	Radius	Yes	+50/−5	+	+	+	40–50/55–33	34–56–54	9.5/0	2.5	26
2	63	M	D	SNAC III	Radius	No	+37/+5	+	+	+	20–26/15–52	26–40–52	8/0.5	3.5	15
3	47	M	ND	SNAC III	Scaphoid	Yes	+25/0	+	+	?	25–35/30–35	28–40–50	9/2	5	9
4	37	M	ND	SLAC III	Scaphoid	No	+35/−5	+	+	+	60–45/52–20	36–36–52	9/1.5	4	6

D, dominant; ND, nondominant; capitolunate angle, positive = extended, negative = volar flexed; CL, capitolunate; TH, triquetrohamate; TL, triquetrolunate; +, bony trabeculae; ?, doubtful union; pain visual analog scale, 0 = no pain and 10 = maximum imaginable pain; RTW, return to work or activities.

We used bone graft from the radius in the first 2 patients, whereas the scaphoid itself was the source of the graft in the latter two. We performed no other concomitant procedures. No procedure was converted to an open approach. No complications occurred and all patients healed uneventfully, except for a doubtful union on a lunotriquetral joint in 1 case (Fig. 11).

DISCUSSION

Arthroscopic scaphoidectomy and A-4CA is theoretically an appealing procedure for a variety of reasons: better assessment of cartilage damage, preservation of blood supply to the carpals (possibly speeding up bony healing), preservation of proprioception (possibly offering better protection from degeneration), and minimization of postsurgical scarring and swelling (possibly resulting in better long-term range of motion). However, performing this procedure with classic wet arthroscopy has the disadvantages of a long operating time, massive swelling, and difficulty with bone graft placement. The operation as described here allows the procedure to be completed in less than 2 hours (ie, in less than 1 tourniquet time).

This technique was not successful on the first try, but we made several progressive changes until we developed this operative procedure. After many aborted attempts, we were able to complete the 4CA fully arthroscopically (case 1). The dry technique itself was not sufficient to carry out the operation in less than tourniquet time. In this first case, we realized the difficulty of removing the loose osteophytes and incorporated the use of the angulated rongeur to remove them. We employed this technique in the second patient and began to incorporate the straight rongeur to remove parts of the scaphoid (based on our experience in A-PRC). However, we discarded this bone and harvested cancellous bone from the radius, subsequently adding operative time in doing so. In the last 2 cases, we preserved the bone graft from the scaphoid as described above (Fig. 12). Undoubtedly, our arthroscopic technique has also improved in this period, contributing to the shortened operative time.

The specific strategies that seem to have a major impact on shortening operative time in the A-4CA with the dry technique are the following: (1) A larger SL portal allows for introduction of pituitary rongeurs and instrumentation, because loss of fluid through the incision is not a concern. Moreover, with the rongeur technique, the cancellous bone is preserved for bone graft and loose bodies are more easily retrieved from the joint. (2) When inserting cancellous bone graft, it is placed at the arthrodesis site and does not migrate with

FIGURE 11: Scaphoid nonunion advanced collapse stage III. **A**, **B** Preoperative plain x-rays. **C**, **D** X-rays at 15 months.

the infusion fluid throughout the rest of the wrist. Furthermore, the use of a large-bore drill guide allows quick and easy placement of the bone graft in the midcarpal space. (3) Without the infusion of fluid, distortion of bony landmarks does not occur. Placement of the guidewires and cannulated screws is therefore more easily achieved. Although this triangular construct is somewhat complex and tricky, it has an enormous advantage: the capitate-lunate arthrodesis is stabilized without violating the proximal articular cartilage of the lunate, as it is when a screw is inserted in the proximal to distal direction,[8,10] and it is more stable than tenuous single screw fixation.[9] In addition, the triquetrum acts as a living plate to the capitate-lunate arthrodesis by fixing 1 screw to the lunate and the other to the capitate. Moreover, this triangular construct provides compression of both the triquetrohamate and lunatotriquetral spaces, favoring fusion.

The aim of this report was not to prove better results than with open 4CA, but to show that A-4CA is conceptually appealing and feasible in a competitive time. We should warn that A-4CA ranks among the most

FIGURE 12: The amount of bone graft that can be harvested in a scaphoid nonunion.

difficult operations one can perform arthroscopically. It has a steep learning curve even for skilled arthroscopists and requires the surgeon to have precise spatial orientation at the time of guidewire placement. Nevertheless, the possibility of achieving complex fixations through minimally invasive surgery represents the future of wrist surgery and the direction in which we should head.

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