RSL Fusion with Excision of Distal Scaphoid and Triquetrum: A Cadaveric Study

Gregory Ian Bain, PhD, MBBS, FRACS, FA(Ortho)^{1,2,3,4,5} Aman Sood, BMBS, FRACS^{3,5}
Chong Jin Yeo, MBChB, MRCS, MMed, FAMS (Hand Surgery)⁶

¹ Shoulder and Upper Limb Surgeon, Private Practice, South Australia, Australia

² Department of Orthopaedics and Trauma, and Discipline of Anatomy and Pathology, University of Adelaide, South Australia, Australia

³ Department of Orthopaedics, Royal Adelaide Hospital, Adelaide, South Australia, Australia

⁴ Department of Orthopaedics, Modbury Public Hospital, Adelaide, South Australia, Australia

⁵ Orthopaedics SA, Adelaide, South Australia, Australia

⁶ Hand and Microsurgery Section, Department of Orthopaedic Surgery, Tan Tock Seng Hospital, Singapore

Address for correspondence Gregory Ian Bain, PhD, MBBS, FRACS, FA (Ortho)A, Shoulder and Upper Limb Surgeon, Private Practice, 196 Melbourne Street, North Adelaide, 5006, South Australia, Australia (e-mail: greg@gregbain.com.au).

J Wrist Surg 2014;3:37–41.

Abstract

Radioscapholunate (RSL) fusion has been utilized for treatment of radiocarpal arthritis for patients with an intact midcarpal joint. This preserves midcarpal joint motion while alleviating pain. Dart thrower's motion (DTM), which has been emphasized recently, is mainly a midcarpal joint motion.

Question A cadaveric study was designed to measure and compare the range of motion (ROM) of the human wrist before and after an RSL fusion, followed by distal scaphoid excision, and finally excision of the triquetrum.

Methods Twelve embalmed adult cadaveric upper limbs were assessed. The wrist motion was measured with an electrogoniometer. Measurements of the flexion–extension plane and radial–ulnar deviation plane were obtained for baseline after capsulotomy, after simulated RSL fusion with memory staples, after distal scaphoidectomy, and after excision of the triquetrum.

Results The effects of scaphoid and triquetrum excision were expressed as improvements in movement over that of the preceding step. RSL fusion alone resulted in a decrease of the flexion–extension (F-E) arc by 36% and the radioulnar deviation (R-U) arc by 30%. Excision of the distal scaphoid with RSL improved the F-E arc by 34% and the R-U arc by 34%. With excision of the triquetrum, the F-E arc improved further by 13% and the R-U arc by 21%. The ROM of the simulated RSL fusion with distal scaphoidectomy is improved with excising the triquetrum, mainly through an increase in ulnar deviation motion. RSL fusion with distal scaphoidectomy and triquetrectomy can be an alternative to total wrist arthrodesis for patients with an intact midcarpal joint.

Keywords

- limited wrist arthrodesis
- radioscapholunate fusion
- triquetrum excision
- carpal excision
- distal pole of scaphoid excision

Isolated radioscapholunate (RSL) fusion was first reported by Gordon and King¹ in 1961 as a treatment modality where the radiocarpal joint is the only affected compartment. This preserves midcarpal motion while alleviating pain through

the limited arthrodesis.^{2–6} The procedure maintains carpal height, yields satisfying grip strength, and relieves pain predictably as compared with proximal row carpectomy or four-corner fusion with scaphoid excision.⁷ The midcarpal

joint provides similar motion to the dart thrower's motion (DTM). The importance of DTM in everyday use of the hand and wrist has been emphasized recently.^{8,9} This motion is largely from the midcarpal joint. With the scaphoid spanning both the proximal and distal rows, the scaphoid will act as a block to this motion if it cannot flex out of the way during radial deviation. With excision of the distal scaphoid, the DTM motion is improved^{10,11} by an increase in radial deviation and flexion of the wrist. This also decreases the development of midcarpal joint arthritis.¹¹ There is a suggestion that distal scaphoidectomy increases the union rate of the RSL fusion.¹²

A cadaveric study had demonstrated that excision of the triquetrum improved residual wrist motion after midcarpal stabilization.¹³ We hypothesize that excision of the entire triquetrum in addition to distal scaphoid excision and RSL fusion will further increase the range of motion (ROM). A cadaveric study was designed to measure and compare the ROM of the human wrist before and after an RSL fusion, followed by distal scaphoid excision, and finally excision of the entire triquetrum.

Materials and Methods

Twelve embalmed adult cadaveric upper limbs from three men and three women were obtained from the Department of Anatomical Sciences at the University of Adelaide. Limbs were severed at the level of the upper forearm. The radius and ulna were fixed in a neutral position, with a threaded Steinmann pin through the distal radius and ulna. Skeletal markers were placed dorsally along the line of the radius and third metacarpal for measurement of radial and ulnar deviation. Markers were also placed along the ulnar border of the forearm and fifth metacarpal for measurement of flexion and extension. The midcarpal joint was located by inserting a 23-gauge needle between the lunate and capitate. The center of rotation in the proximal head of the capitate was marked 0.5cm distal to the lunocapitate joint.

The forearm was secured to the dissecting table. The same investigator (AS) performed all dissections. A dorsal longitudinal incision was made in the skin and in the extensor retinaculum, releasing the extensor pollicis longus tendon from the third extensor compartment. A longitudinal capsulotomy was then performed and an adequate exposure achieved. Careful dissection was performed to avoid damage to the radial, ulnar, palmar radiocarpal, and interosseous ligaments. Any congenital anomaly or osseous lesion was excluded by direct observation. The radiocarpal and midcarpal joints were preserved in all specimens. The dorsal capsule was sutured with one Ethibond nonabsorbable surgical suture (U.S.P., Ethicon, Somerville, NJ, USA). Baseline wrist motion was then measured.

The forearm was clamped to the dissecting table. A previously reported method of wrist motion measurements was used.¹⁴ The wrist was allowed to hang freely over the end of the dissection table, with 1.5 kg of skeletal traction attached through the third metacarpal head for assessment of flexion and extension. It is attached through the second metacarpal head when measuring ulnar deviation and the fifth metacarpal

Fig. 1 The electrogoniometer was centered at the level of the proximal capitate and aligned with the proximal and distal markers.

head for measurements of radial deviation. An electrogoniometer (EVAL, Greenleaf Medical, Palo Alto, California, USA) was used to measure wrist motion. The electrogoniometer was centered at the level of the proximal capitate (►Fig. 1) and aligned with the proximal and distal markers.

Next, the wrist was held in a neutral position and titanium–nickel alloy memory staples (Depuy International Ltd, Leeds, Yorkshire, UK) were used to simulate a fusion with stabilization of the radioscapholunate interval. One staple was used to stabilize the distal radius to the scaphoid, and the other from the distal radius to the lunate (►Fig. 2). The dorsal capsule was sutured again, and measurements were repeated.

Next, the distal half of the scaphoid was excised (►Fig. 3). The dorsal capsule was sutured and the range measured again.

Finally, the triquetrum was excised (►Fig. 4). The dorsal capsule was again sutured and measurements repeated. No further capsular dissection was performed after the initial exposure. The distal poles of the scaphoid and triquetrum were removed piecemeal, preserving the surrounding ligaments. The relevant intercarpal ligaments were severed only when required for scaphoid and triquetrum excision.

Wrist flexion, extension, and radial and ulnar deviation were measured. Each measurement was repeated three times by the same observer to counter bias and interobserver error. The measurements were recorded (a) at baseline, (b) following RSL stabilization with an intact scaphoid and triquetrum, (c) after distal scaphoid excision, and (d) after triquetrum excision. The increase or decrease of motion was the comparison of a set of measurements with that of the preceding step.

Statistical analysis was performed including a paired-sample *t*-test in which $p < 0.05$ was determined as a statistically significant change.

Fig. 2 Simulated RSL fusion with staples.

Fig. 3 Simulated RSL fusion with distal scaphoid excision.

Fig. 4 Simulated RSL fusion with distal scaphoid and entire triquetrum excision.

Results

All values are rounded to the nearest whole number. Data are presented as the mean with standard deviation (SD) being listed in brackets (► **Tables 1** and **2**). The baseline wrist flexion was 59° (6°) and extension was 57° (3°), giving a flexion–

extension (F-E) arc of 116° (10°). The baseline radial deviation was 22° (3°) and ulnar deviation was 24° (3°), giving a radioulnar (R-U) arc of 46° (6°). The effects of scaphoid and triquetrum excision were expressed as improvements in movement over that of the preceding step.

RSL fusion alone resulted in limitation of flexion by 23° (39%) and extension by 19° (33%), and of F-E arc by 42° (36%, $p < 0.01$). The radial deviation was limited by 8° (36%), ulnar deviation by 6° (25%) and R-U arc by 14° (30%, $p < 0.01$).

Excision of the distal pole of the scaphoid significantly increased the F-E arc by 25° (34%, $p < 0.05$), with contributions from the flexion by 13° (36%) and the extension by 12° (32%). The R-U arc increased by 11° (34%, $p < 0.01$), largely because of the increase in the radial deviation by 8° (57%). Changes in flexion and ulnar deviation with scaphoid excision were not statistically significant.

Excision of the triquetrum showed minimal increase in F-E arc of 12° (13%), with small but statistically significant increase in flexion of 7° (14%). It further increased the R-U arc by 9° (21%), largely due to an increase in ulnar deviation of 8° (38%). Changes in extension and radial deviation with triquetrum excision were not statistically significant.

After excision of the distal scaphoid and triquetrum, the F-E arc had improved to be similar to the baseline (112° vs 116° or 97% of baseline), and the R-U arc was greater than the baseline (52° vs 46° or 113% of baseline) (► **Table 1**, ► **Figs. 5** and **6**).

Discussion

RSL fusion has been used as a predictable treatment option for various forms of radiocarpal joint arthritis to alleviate pain. Our cadaveric study has shown that RSL fusion alone limited the F-E arc by 36% and the R-U arc by 30%. The excision of the distal scaphoid improved the F-E arc by 34% and the R-U arc by 34%, compared with an RSL fusion alone. Majority of the improvement is in the radial deviation of the R-U arc.

Table 1 Measured wrist motion

Procedures	Flexion	Extension	F-E arc	% [#]	RD	UD	R-U arc	% [*]
Capsulotomy	59 ± 6	57 ± 3	116 ± 10	—	22 ± 3	24 ± 3	46 ± 6	—
RSL stabilization	36 ± 6	38 ± 5	74 ± 7	64	14 ± 4	18 ± 4	32 ± 5	70
Distal scaphoid excision	49 ± 7	50 ± 6	99 ± 9	85	22 ± 7	21 ± 4	43 ± 8	93
Triquetrum excision	56 ± 9	56 ± 9	112 ± 7	97	23 ± 7	29 ± 5	52 ± 9	113

Data are expressed as the mean measured ROM in degrees ± standard deviation (SD). %[#] is the percentage from the baseline F-E arc. %^{*} is the percentage from the baseline R-U arc.

Table 2 Percentage change in wrist motion

Procedures	Flex	Ext	F-E arc	RD	UD	R-U arc
RSL fusion	−39	−33	−36	−36	−25	−30
Distal scaphoid excision	36	32	34	57	17	34
Triquetrum excision	14	12	13	5	38	21

Data represent percentage change in ROM with each stage of the procedure.

Fig. 5 Mean wrist flexion-extension arc after each "procedure." With the additional excision of the triquetrum, the F-E arc is similar to the baseline.

Fig. 6 Mean wrist radioulnar deviation arc after each "procedure." With the additional excision of the triquetrum, the R-U arc exceeds that of the baseline.

The increase in ulnar deviation that we observed was due to the excision of the triquetrum (38% increase over RSL with distal scaphoid excision). The triquetrum acts as a block after RSL fusion. Crisco et al¹⁵ showed that the triquetrum-hamate joint is less constrained in radial extension than it is in ulnar flexion, and the concave distal ridge of the hamate may guide the triquetrum toward the hook of the hamate until it is fully engaged, which could block further ulnar deviation of the wrist. Excision of the triquetrum will avoid problems of triquetrohamate degeneration as well.

There is concern that removal of the distal scaphoid will decrease the vascularity and hence affect the union rate. Garcia-Elias et al have reported improved fusion for their clinical study on RSL fusion with distal scaphoidectomy.¹¹ They reported no nonunions in their patients with RSL fusion and distal scaphoidectomy, compared with nonunion rates of 6% to 27% of RSL fusion alone reported by other studies.^{5,11,16,17} They theorized that distal scaphoid excision removes a strong lever arm and actually unloads the RSL fusion so that fusion rates improve and incidence of secondary midcarpal arthritis decreases.¹¹

Concerns have been raised about carpal stability after triquetrum excision, as there are major volar and dorsal ligament restraints that attach to the triquetrum. Bain et al¹⁸ performed RSL fusion with distal scaphoid and entire triquetrum excision for 23 patients with radiocarpal joint degenerative disease for various etiologies in a prospective study with a mean of 32-month follow-up and did not encounter any nonunions or wrist instabilities. That study showed that there was minimal reduction in the F-E arc (66° to 57°), but an increase in the R-U arc (22° to 43°) from pre- to postoperative motions. All patients except one were satisfied with the procedure. Nineteen of the 23 patients had no restrictions to their activities. We postulate that the carpal stability is maintained as long as the volar radio-scaphocapitate (RSC), long radiolunate (LRL), and short radiolunate (SRL) ligaments are kept intact and a good dorsal capsulotomy closure is performed. Bain et al immobilized the wrist postoperatively with a cast for up to six weeks.¹⁸

Two other comparable cadaveric studies have looked at the effects of RSL fusion with excision of the distal scaphoid and entire triquetrum; they showed that wrist motions in the cadaveric wrists came close to normal levels.^{19,20} Pervaiz et al reported that with the excision of the triquetrum, the F-E arc returned to 87–97% of normal and the R-U arc to 119–137% of normal.¹⁹ Berkhout et al in their study showed the F-E arc returning to 88% of the original and the R-U arc to 98% of the original after triquetrum excision.²⁰

Another benefit will be the amount of native bone graft available for the arthrodesis procedure with excision of both the distal scaphoid and the entire triquetrum. In many clinical cases the scaphoid is compromised and the triquetrum is of better bone quality. Use of bone from the triquetrum will lower morbidity as compared with having to harvest bone graft from another donor site.

We have identified some weaknesses of this study. The gains in motion will be higher than in clinical scenarios, since connective tissue stiffness, scar tissue formation, and edema are not present in a cadaveric study. The use of embalmed specimens may alter the biomechanics as compared with fresh frozen specimens, and that alteration may affect comparisons with other studies. Physiologic motion was not strictly replicated, since the weights were applied directly to the metacarpals rather than to the wrist flexor and extensor tendons proximal to the wrist. However, the study does indicate that the triquetrum can act as a physical block to ROM after an RSL fusion. Even with these effects taken into account, the RSL fusion with distal scaphoidectomy and excision of the entire triquetrum is still likely to exceed the functional requirements of the wrist for daily activities in both the F-E plane (30° of extension and 5° of flexion) and the R-U deviation plane (10° of radial deviation and 15° of ulnar deviation).²¹

To conclude, the ROM of the simulated RSL fusion with distal scaphoidectomy is improved with the addition of excising the entire triquetrum. The improvement is mainly through the increase in ulnar deviation motion. RSL fusion with distal scaphoidectomy and entire triquetrum excision

can be a useful alternative to total wrist arthrodesis for patients with an intact midcarpal joint.

Acknowledgment

We thank the Ray Last Laboratory for their generous support and for providing access to their premises.

Note

Study performed at University of Adelaide Ray Last Anatomy Laboratory, South Australia, Australia.

Conflict of interest

None

Ethical Review

No ethical review required.

References

- Gordon LH, King D. Partial wrist arthrodesis for old un-united fractures of the carpal navicular. *Am J Surg* 1961;102:460–464
- Kilgus M, Weishaupt D, Künzi W, Meyer VE. Radioscapholunate fusion: long-term results [in German]. *Handchir Mikrochir Plast Chir* 2003;35(5):317–322
- Murray PM. Radioscapholunate arthrodesis. *Hand Clin* 2005;21(4):561–566
- Sturzenegger M, Büchler U. Radio-scapho-lunate partial wrist arthrodesis following comminuted fractures of the distal radius. *Ann Chir Main Memb Super* 1991;10(3):207–216
- Nagy L, Büchler U. Long-term results of radioscapholunate fusion following fractures of the distal radius. *J Hand Surg [Br]* 1997;22(6):705–710
- Inoue G, Tamura Y. Radiolunate and radioscapholunate arthrodesis. *Arch Orthop Trauma Surg* 1992;111(6):333–335
- Cohen MS, Kozin SH. Degenerative arthritis of the wrist: proximal row carpectomy versus scaphoid excision and four-corner arthrodesis. *J Hand Surg Am* 2001;26(1):94–104
- Wolfe SW, Crisco JJ, Orr CM, Marzke MW. The dart-throwing motion of the wrist: is it unique to humans? *J Hand Surg Am* 2006;31(9):1429–1437
- Crisco JJ, Coburn JC, Moore DC, Akelman E, Weiss AP, Wolfe SW. In vivo radiocarpal kinematics and the dart thrower's motion. *J Bone Joint Surg Am* 2005;87(12):2729–2740
- McCombe D, Ireland DC, McNab I. Distal scaphoid excision after radioscaphoid arthrodesis. *J Hand Surg Am* 2001;26(5):877–882
- Garcia-Elias M, Lluch A, Ferreres A, Papini-Zorli I, Rahimtoola ZO. Treatment of radiocarpal degenerative osteoarthritis by radioscapholunate arthrodesis and distal scaphoidectomy. *J Hand Surg Am* 2005;30(1):8–15
- Mühdorfer-Fodor M, Ha HP, Hohendorff B, Löw S, Prommersberger KJ, van Schoonhoven J. Results after radioscapholunate arthrodesis with or without resection of the distal scaphoid pole. *J Hand Surg Am* 2012;37(11):2233–2239
- Bain GI, Sood A, Ashwood N, Turner PC, Fogg QA. Effect of scaphoid and triquetrum excision after limited stabilisation on cadaver wrist movement. *J Hand Surg Eur Vol* 2009;34(5):614–617
- Meyerdierks EM, Mosher JF, Werner FW. Limited wrist arthrodesis: a laboratory study. *J Hand Surg Am* 1987;12(4):526–529
- Kamal RN, Rainbow MJ, Akelman E, Crisco JJ. In vivo triquetrum-hamate kinematics through a simulated hammering task wrist motion. *J Bone Joint Surg Am* 2012;94(12):e85
- Garcia-Elias M, Lluch A. Partial excision of scaphoid: is it ever indicated? *Hand Clin* 2001;17(4):687–695, x x.
- Larsen CF, Jacoby RA, McCabe SJ. Nonunion rates of limited carpal arthrodesis: a meta-analysis of the literature. *J Hand Surg Am* 1997;22(1):66–73
- Bain GI, Ondimu P, Hallam P, Ashwood N. Radioscapholunate arthrodesis - a prospective study. *Hand Surg* 2009;14(2-3):73–82
- Pervaz K, Bowers WH, Isaacs JE, Owen JR, Wayne JS. Range of motion effects of distal pole scaphoid excision and triquetral excision after radioscapholunate fusion: a cadaver study. *J Hand Surg Am* 2009;34(5):832–837
- Berkhout MJ, Shaw MN, Berglund LJ, An KN, Berger RA, Ritt MJ. The effect of radioscapholunate fusion on wrist movement and the subsequent effects of distal scaphoidectomy and triquetrectomy. *J Hand Surg Eur Vol* 2010;35(9):740–745
- Palmer AK, Werner FW, Murphy D, Glisson R. Functional wrist motion: a biomechanical study. *J Hand Surg Am* 1985;10(1):39–46