EDITOR'S CHOICE

Proximal Row Carpectomy and 4-Corner Arthrodesis in Patients Younger Than Age 45 Years

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Purpose To examine the long-term outcome of patients aged less than 45 years who underwent either proximal row carpectomy (PRC) or 4-corner arthrodesis (4CA) for wrist arthritis.

Methods We reviewed a retrospective cohort of 89 patients aged less than 45 years who underwent either 4CA (n = 51) or PRC (n = 38) for wrist arthritis. Mean follow-up was 11 years in the 4CA group and 18 years in the PRC group.

Results Overall, there were no differences between groups in the need for revision surgery. Complications included 6 nonunions in the 4CA group (12%), 1 infection in each group, and 11 patients who experienced radiocarpal impingement (8 4CA and 3 PRC). There was no difference in the number of patients reporting moderate or severe pain between the PRC and 4CA groups. Mean flexion-extension arc was 54° after 4CA, compared with 73° after PRC. Patients who underwent 4CA had slightly improved grip strength (65% of the opposite side) compared with those who had PRC (54%). Mean postoperative Disabilities of the Arm, Shoulder, and Hand questionnaire scores were 32 versus 19 (PRC vs 4CA) and patient-rated wrist evaluation scores were 27 versus 28 (PRC vs 4CA). Comparing radiographic arthritis, the 10-year outcome, free of moderate/severe arthritis for the PRC and 4CA groups, was 70% and 71%, respectively.

Conclusions Both PRC and 4CA represent a good surgical option for young patients with wrist arthritis, with similar complication rates, postoperative pain levels, wrist function, and long-term outcomes free of arthrodesis. Proximal row carpectomy has improved motion and fewer complications. *(J Hand Surg Am. 2017;■(■):■−■. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Carpectomy, corner, arthrodesis, row, proximal, young.

Despite many innovations in surgical techniques over the past half-century, treatment of wrist arthritis continues to be challenging with controversy surrounding treatment and technique. When degenerative changes spare one or more critical articulations in the wrist, such as the lunate facet, motion-sparing procedures are preferred over total wrist arthrodesis. Although motion-preserving procedures such as proximal row carpectomy (PRC) or 4-corner arthrodesis (4CA) have been used successfully in older, low-demand patients,[1−15] there is controversy about the best option for the younger, high-demand patient.[2,5,10,13,14,16−19]

Since its description by Stamm,[20] excision of the proximal carpal row has proven to relieve pain and preserve motion predictably as a treatment for radioscaphoid arthritis in cases of grade 2 scapholunate advanced collapse (SLAC), scaphoid nonunion

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advanced collapse arthritis, and Kienböck disease.[1–15,18] Historically this procedure is reserved for early SLAC arthritis in which there is still preservation of capitate and lunate fossa cartilage. Advantages of PRC include the procedure's simplicity and relatively rapid recovery, whereas its disadvantages relate to the potential for development of radiocapitate (RC) arthritis. Although RC arthritis may be related to excessive loads on the capitate head during wrist motion because of a mismatch in its radius of curvature and that of the lunate fossa,[2,5,12–15,17–19,21–25] there has not been a definitive link between RC arthritis and patients' pain and wrist motion.[2,5,10,13–18,25,26]

Since the first report by Watson and Ryu,[26] scaphoid excision with capitate–lunate–hamate–triquetral arthrodesis (4CA) has been demonstrated to relieve pain predictably while preserving carpal height and motion through the native radiolunate (RL) articulation.[2,10,13,14,16–18,27,28] Disadvantages of 4CA include a risk of nonunion, potentially prolonged wrist postoperative immobilization, technical complexity, and increasing rates of RL arthritis on recent longer-term studies.[2,10,13,14,16–18] Like PRC, the development of radiographic findings of RL arthritis has not been correlated with poor clinical outcomes in these studies.

Although PRC does not have indications identical to 4CA, there are many situations in which the surgeon may decide between these motion-preserving procedures to provide patients with pain relief, such as in cases of stage 2 SLAC or scaphoid nonunion advanced collapse arthritis[2]; unfortunately for situations in which both PRC and 4CA may be offered, the best procedure for a young active patient remains unclear.[5,19,27,28] The purpose of this study was to examine long-term results, complications, and wrist function in patients who were aged less than 45 years when they underwent either PRC or 4CA for wrist arthritis.

MATERIALS AND METHODS

After we obtained institutional review board approval, we performed a review of all patients aged less than 45 years who underwent PRC or 4CA at a single institution over a 36-year period, by 12 different surgeons. Exclusion criteria included an underlying diagnosis of spasticity or arthrogryposis, Kienböck disease, Volkmann ischemic contractures, juvenile arthritis, or inadequate follow-up, defined as less than 2 years of clinical follow-up.

TABLE 1. Demographics and Surgical Considerations (n = 103)

Demographics	4CA	PRC
Patients	51	38
Follow-up, y (mean [range])	11.3 (2–23)	17.9 (2–41)
Age, y (mean [range])	34 (14–44.9)	34 (15–44.9)
Gender (male:female)	46:5	28:12
Involved dominant hand (n [%])	19 (37)	25 (49)
Laborers	24 (47)	29 (57)
Smokers	10 (20)	12 (24)
Etiologies		
Posttraumatic	45	30
Preiser disease	0	2
Other arthritis	6	6
Preoperative		
Total arc of wrist motion	72	72
Grip strength	60	50
Concomitant surgical procedures (n [%])		
Selective neurectomy	18 (35)	10 (20)
Duration of immobilization, wk (mean [range])	6.6 (4–12)	5.1 (4–8)

Demographics and surgical considerations

Overall, 89 patients aged less than 45 years underwent either PRC (n = 38) or 4CA (n = 51) between 1976 and 2009. Table 1 lists the demographic, preoperative characteristics and surgical considerations. The PRC group had longer follow-up, more females ($P < .05$) and laborers ($P < .05$), and fewer posttraumatic etiologies ($P < .05$), whereas the groups were similar in age, numbers of individuals who smoked, preoperative arc of motion, and number of selective neurectomies (posterior interosseous ± anterior interosseous nerves) performed.

Clinical evaluation

Medical records were reviewed for demographic information, surgical indications and techniques, operative and postoperative interventions, and clinical outcomes. Range of motion was measured using a goniometer in the clinic, whereas grip strength was averaged over 3 consecutive measurements using a dynamometer (Jamar, Cambridge, MA) as a percentage of the opposite side. Subjective patient outcome measures were obtained through a

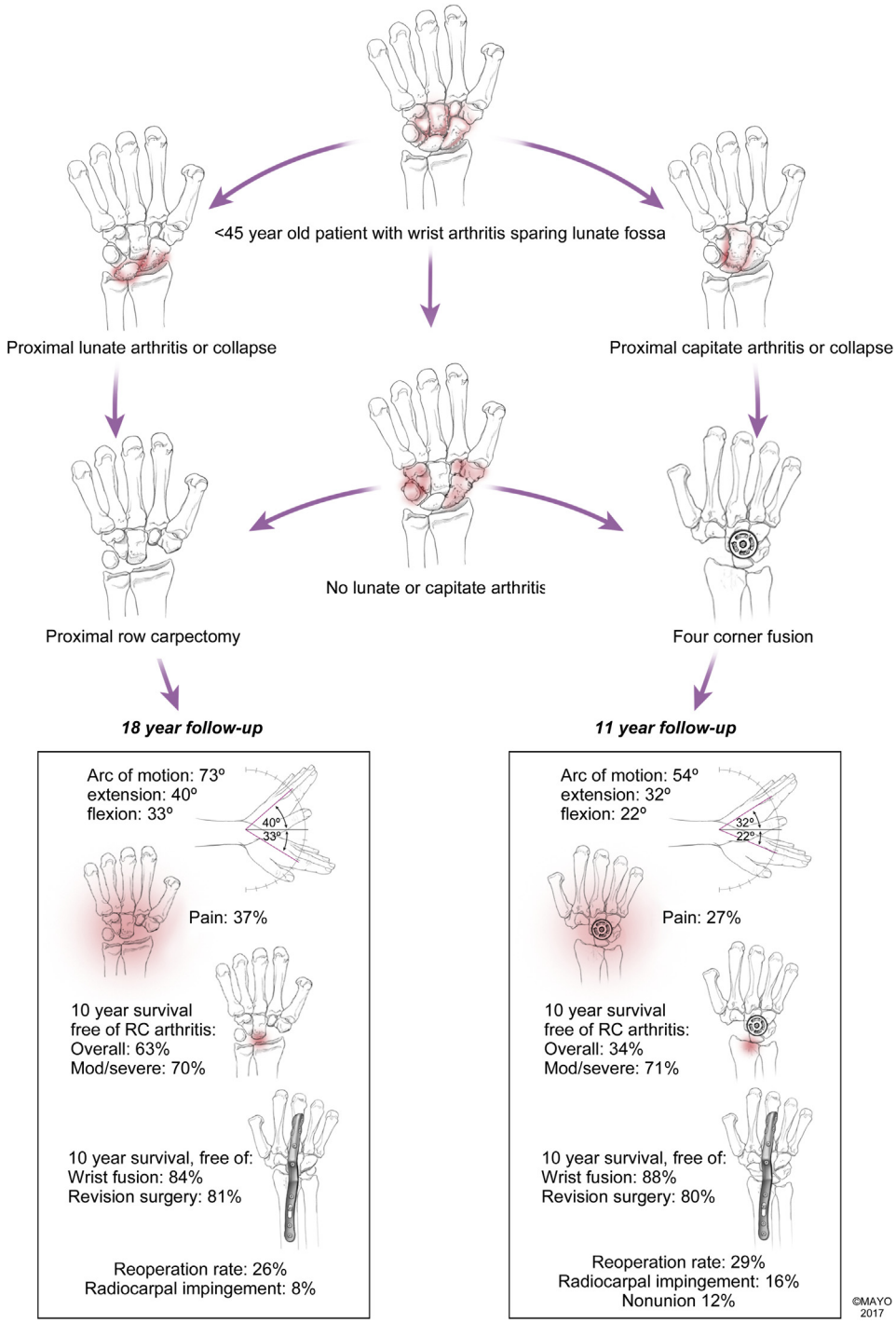

FIGURE 1: Considerations for wrist arthritis sparing the lunate fossa in patients aged less than 45 years. At long-term follow-up, young patients undergoing PRC or 4CA had similar rates of clinical outcomes, revision surgery, radiocarpal arthritis, and complications.

questionnaire sent to all patients. The questionnaire asked about pain relief (pain was graded as none, mild, moderate with activities, moderate, or severe) and patient satisfaction, and included the Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH) and patient-related wrist evaluation (PRWE) scores.[29] Revision surgery was defined as either total wrist arthrodesis or conversion of the bony carpus to another motion-sparing procedure (eg, total wrist arthroplasty or revision of a failed 4CA). Secondary surgery was defined as all reoperations that were not classified as revision surgeries affecting the function of the involved wrist (eg, radial styloidectomy, irrigation and debridement, distal radioulnar joint procedures). Finally, reoperation was defined as all revision surgeries (including arthrodeses) and

secondary surgeries. Postoperative radiographs were evaluated for signs of RC (or RL) arthritis according to the previously established 4-point Jebsen classification system.[29]

Statistical analysis

We examined reoperation-free, arthrodesis-free, revision-free, and arthritis-free intervals using the Kaplan–Meier method, employing Cox proportional hazard regression analysis to compare the 2 procedures and determine the impact of different variables within each procedure. Variables and outcomes were assessed using chi-square test (or Fisher exact test) for categorical variables and Student *t* tests for continuous variables. $P < .05$ was considered statistically significant.

RESULTS

Figure 1 shows our considerations when evaluating a patient aged less than 45 years with radiocarpal arthritis that spares the lunate fossa, as well as the results of this series.

Reoperations, revisions, and complications

Median follow-up was 9.5 years (range, 2–23 years; mean, 11 years) in the 4CA group and 18 years (range, 2–41 years; mean, 18 years) in the PRC group. Comparing the 2 procedures, there were 10 revisions in the 4CA group (20%) at a mean of 11 months postoperatively, compared with 9 patients in the PRC group (24%) at a mean of 40 months postoperatively (Table 2). In the 4CA group, there were 6 total wrist arthrodeses (12%) for recurrent pain (n = 4) and nonunion (n = 2), as well as 4 revision 4CAs (8%) for nonunions. In the PRC group, there were 8 total wrist arthrodeses (21%) for recurrent pain, as well as one conversion to a total wrist arthroplasty for recurrent pain. There was no difference between PRC and 4CA in the time interval free of arthrodesis or revision surgery, including 10-year time interval free of arthrodesis or revision surgery, which was at or above 80% for both groups (Fig. 2, Table 3). Selective neurectomy or duration of immobilization did not affect the rate of revision surgery, arthrodesis, or reoperation.

In addition to the 19 revision surgeries, there were 6 additional postoperative reoperations, including 4 radial styloidectomies and one distal radioulnar joint (distal radioulnar joint) reconstruction in the 4CA group, and one irrigation and debridement in the PRC group. There was no significant difference in reoperation-free survival between the PRC and 4CA groups (Fig. 2, Table 3).

TABLE 2. Arthrodeses, Revisions, and Reoperations

Demographics	4CA	PRC
Patients	51	38
Reoperations (n [%])	15 (29)	10 (26)
Revision surgeries	10 (20)	9 (24)
Arthrodeses	6	8
Total wrist arthroplasty	0	1
Revision 4CA	4	0
Secondary surgeries	5 (10)	1 (3)

Complication rates in the 4CA and PRC groups were 30% and 11%, respectively. Complications in the 4CA group included 6 nonunions (12%), 1 infection (2%) and 8 cases of radiocarpal impingement (16%). In comparison, complications in the PRC group involved one infection (3%) and 3 cases of radiocarpal impingement (8%). Smokers ($P < .05$) and laborers ($P < .05$) had higher risk of nonunions in the 4CA group.

Clinical and patient-reported outcomes

Upon examination of clinical outcomes in all patients who had not undergone wrist arthrodesis or revision surgery, there was a significant improvement in preoperative to postoperative pain levels in both groups ($P < .05$) (Table 4). However, overall there were no significant differences between preoperative and postoperative total arc of motion, radial or ulnar deviation, or grip strength. Of note, whether the dominant hand was involved did not lead to a significant difference in postoperative grip strength ($P = .21$).

Comparative clinical outcomes between the 4CA and PRC groups are demonstrated in Table 4. Patients with proximal row carpectomy had superior flexion-extension arcs ($P < .05$). Although patients with 4CA had improved DASH scores ($P < .05$), there was no difference in postoperative PRWE scores ($P = .57$). Univariate analysis demonstrated improved wrist motion in males after 4CA ($P < .05$). No other factors had a significant impact on clinical outcomes.

Radiographic analysis

Postoperative radiographs were analyzed at a median radiographic follow-up 6 years after 4CA (range, 2–16 years; mean, 7.2 years) and 8 years after PRC (range, 2–25; mean, 9 years). At last follow-up, 39% had either grade 2 or worse RL (4CA) or RC (PRC) arthritis.

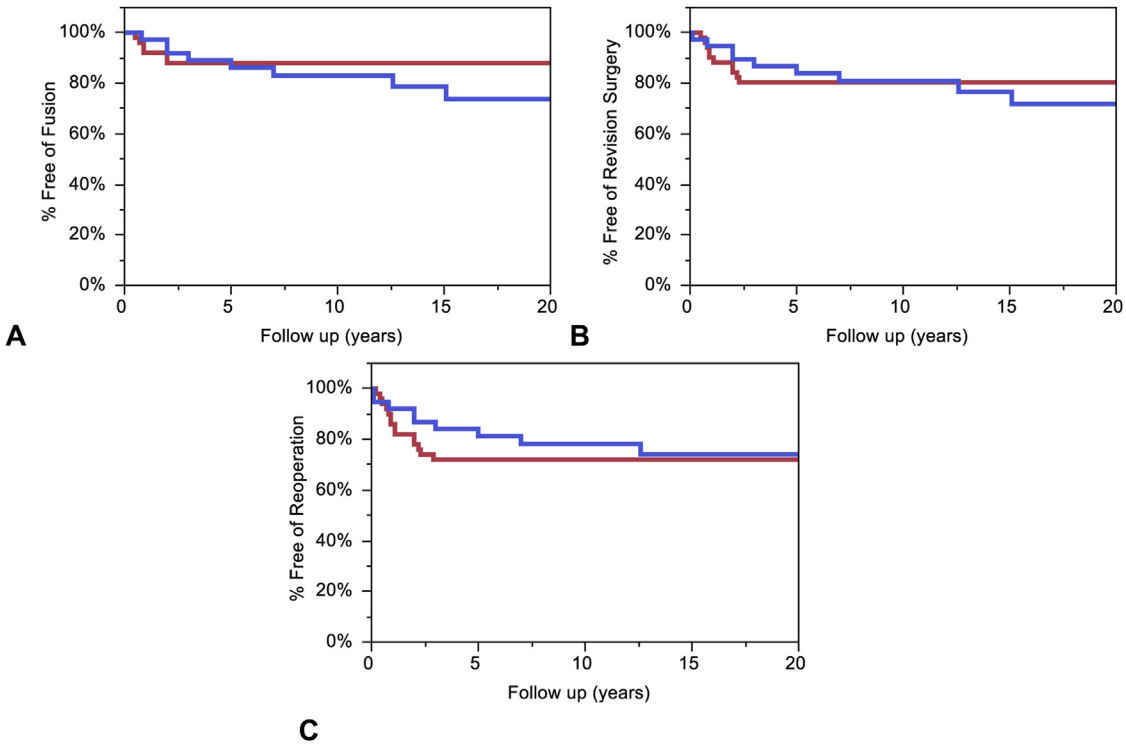

FIGURE 2: Survival free intervals of **A** total wrist arthrodesis, **B** revision surgery, and **C** reoperation after PRC (blue) and 4CA (red). (A) The 10-year survival free interval of arthrodesis for the 4CA compared with the PRC group was 88% versus 84%, respectively (P = .35). (B) At 10 years, the survival free interval of overall revision surgery was 80% for the 4CA group, compared with 81% for the PRC group (P = .81). (C) The 10-year reoperation-free survival interval for the 4CA group compared with the PRC group was 71% versus 78%, respectively (P = .56).

TABLE 3. Estimated Component Survivorship for Various Repeat Revision End Points

End Point	5 y Survivorship (%)	10 y Survivorship (%)	20 y Survivorship (%)	P Value
Free of arthrodesis				.35
4CA	88 (±5)	88 (±5)	88 (±5)	
PRC	87 (±6)	84 (±6)	75 (±8)	
Any revision surgery				.81
4CA	80 (±6)	80 (±6)	80 (±6)	
PRC	87 (±6)	81 (±7)	71 (±8)	
Reoperation				.56
4CA	72 (±6)	72 (±6)	72 (±6)	
PRC	84 (±6)	78 (±7)	74 (±8)	

Values are given as Kaplan–Meier survival estimates (± standard error).

There were no significant differences in the rates of RC (PRC) and RL (4CA) arthritis (Fig. 3, Table 5).

DISCUSSION

Proximal row carpectomy and 4CA have been shown to be effective treatment options for radiocarpal arthritis, because both procedures provide pain relief and preserve some wrist motion.[2–4,6,7,12–19,26] Although PRC is not recommended in cases in which there is evidence of midcarpal arthritis, there are many cases of radiocarpal arthritis in which either procedure could be performed based on surgeon preference. Recent reports called into question the long-term durability of PRC resulting from high rates of RC arthritis[2,13–15,17–19,21–25]; other reports criticized the high rates of complications and loss of

TABLE 4. Clinical and Radiographic Outcomes

Outcome Measure	Rating	*P* Value
Pain relief (n [%], none/mild)		
4CA	37 (73)	.70
PRC	24 (63)	
Flexion-extension arc (degrees)		
4CA	54 ± 6	< .01
PRC	73 ± 5	
Radial deviation (degrees)		
4CA	14 ± 2	.47
PRC	13 ± 2	
Ulnar deviation (degrees)		
4CA	18 ± 3	.30
PRC	21 ± 2	
Grip strength (% of opposite side)		
4CA	65 ± 6	.14
PRC	54 ± 4	
DASH score		
4CA	19 ± 2	< .01
PRC	32 ± 3	
PRWE score		
4CA	28 ± 2	.57
PRC	27 ± 2	

Values are mean ± standard error unless noted.

motion seen after 4CA.[2,13,14,16–18,25,26] Given these potential drawbacks for each procedure, particularly in younger, more active patients, controversy remains regarding the optimal treatment for patients with radiocarpal arthritis that spares the lunate facet and midcarpal joint. Although some have suggested that young age and work as a laborer are important risk factors for worse outcomes after PRC,[5,19] the concern for symptomatic nonunion and potential for RL arthritis in 4CA make this recommendation controversial. Therefore, the purpose of this study was to examine the time interval free of revision surgery, arthrodesis, complications, and arthritis, as well as extremity function in patients aged less than 45 years who underwent either PRC or 4CA.

This study included 60% laborers, at a mean follow-up of 14 years. Consistent with prior reports,[2–4,5–7,10,12–19,25,26] both PRC and 4CA produced predictable pain relief as well as preservation of wrist motion and extremity function. We formulated an algorithm summarizing these considerations and the findings of this study that enable patients and surgeons to make an informed decision more easily (Fig. 1). Patients undergoing PRC have improved wrist flexion-extension arc of motion. There were minimal differences in pain relief, patient-reported outcomes scores, and conversion to arthrodesis or revision surgeries.

One important consideration when evaluating motion-sparing procedures for wrist arthritis in young patients is the need for future revision surgery or conversion to total wrist arthrodesis. Studies reported conversion rates to total wrist arthrodesis of 0% to 17% for PRC and 4CA.[2–4,5–8,10–18,21,26,30] Although some initial comparison studies reported a higher rate of wrist arthrodesis in PRCs,[10,16] other studies challenged this finding.[2,14,17] A systematic review by Saltzman et al[18] reported a mean weighted conversion rate to total wrist arthrodesis of 10% for 4CA, compared with 7.1% for PRC. Some studies suggested that young patients and laborers have an increased risk of failure after PRC.[4,5,15,17,21] In our series, the younger ages of patients did not negatively affect the rate of revision or arthrodesis surgery, because the 10-year total wrist arthrodesis-free and revision-free intervals for PRC were 84% and 81%, respectively, and for 4CA were 88% and 80%, respectively. Furthermore, occupation as a laborer and smoking led to higher overall rates of revision surgery and total wrist arthrodesis, particularly after patients underwent 4CA. Combined with good pain relief and reasonable functional scores from both procedures, it appears that many of these younger and active patients could achieve good wrist stability and function without the need for further surgery.

One concern with 4CA surgeries has been the relatively high rates of complications, such as nonunion, hardware irritation, and radiocarpal impingement.[2,10,13,14,16–18] Studies suggested that compared with PRC, 4CA has an approximate 10% to 20% increased complication rate, including nonunions and radiocarpal impingement.[2,10,13,14,16–18,26] In our series of patients aged less than 45 years, there was an increased rate of complications in the 4CA group compared with the PRC group, including nonunion (12% vs 0%) and radiocarpal impingement (16% vs 8%). This led to a slightly high rate of reoperation in the 4CA group. Occupation as a laborer and smoking also increased the risk for reoperations and the rate of nonunions after 4CA, whereas these factors were not associated with increased complications after PRC.

A concern regarding performing PRC in younger patients has been the high rates of RC joint degeneration over time.[2,5,12–15,17–19,21,24,25] Because of the mismatched radius of curvature of

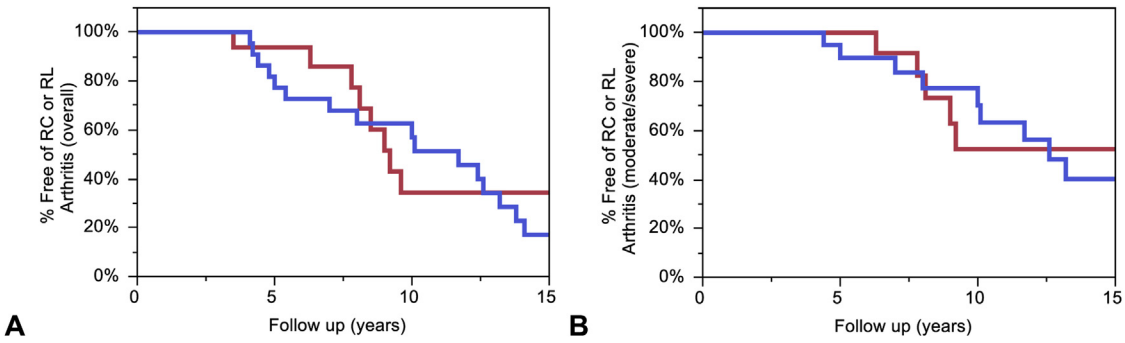

FIGURE 3: Survival free interval of radiographic **A** any and **B** moderate/severe radiographic arthritis after PRC (blue) or 4CA (red). (A) The 10- and 15-years survival free intervals of RL (4CA) were 34% and 34%, compared with 63% and 17%, respectively, for RC (PRC) ($P = .86$). (B) The survival free interval of moderate/severe (grade 2 or worse) RL and RC arthritis at 10 years was 71% versus 70%, respectively, and at 15 years was 71% versus 40%, respectively ($P = .96$).

TABLE 5. Estimated Radiographic Arthritis Survivorship

End Point	5 y Survivorship	10 y Survivorship	15 y Survivorship	*P* Value
Radiocarpal arthritis (any)				.86
4CA	94 (±6)	34 (±4)	34 (±14)	
PRC	82 (±8)	63 (±11)	17 (±9)	
Radiocarpal arthritis (moderate/severe)				.96
4CA	100 (±0)	71 (±14)	71 (±19)	
PRC	90 (±7)	70 (±11)	40 (±13)	

Values are given as Kaplan–Meier survival estimates (± standard error).

the proximal capitate and the lunate fossa, which creates the potential for instability and unequal load distribution,[6,22,23] the joint's articular cartilage may break down over time. Studies have found high rates of RC degenerative changes; long-term follow-up studies demonstrated radiographic arthritis in 14 of 17 patients with a minimum 10-year follow-up[5] and 8 of 11 patients with a minimum 20 years' follow-up.[15] In our series, the 10- and 15-year time interval free of moderate/severe RC arthritis after PRC was 70% and 40%, respectively. This was worse (not significantly) than comparative 10 and 15-year survival free intervals of moderate/severe RL arthritis after 4CA of 71% and 71%, respectively. However, these results should be interpreted in light of the more than 1.5 years' longer radiographic follow-up in the PRC group compared with the 4CA group.

Ultimately, the goal of either of these motion-sparing procedures is to achieve a pain-free, functional wrist. Many studies examining PRC, 4CA, or both procedures together demonstrated that these procedures achieved a pain-free, stable joint with preserved motion in the majority of patients,[2–4,6,7,10,12–14,16–18,25,26] with minimal differences between the 2 procedures.[2,10,13,16–18,25,26] In our series, PRC led to improved wrist motion, with slightly higher grip strength in the 4CA group, yet minimal clinically relevant differences in patient-reported outcome scores. Laborers achieved good rates of pain relief and preservation of motion with both procedures. Complications tended to occur earlier in patients treated with 4CA than in those with PRC. Also, patients with 4CA had better DASH scores that focused more on disability, although they did not have significantly different PRWE scores, which focused on wrist pain and function. These differences should be examined further in adequately powered prospective studies.

A potential limitation of many comparative studies between PRC and 4CA has been the assumption that the 2 comparison groups have the same disease severity at the time of treatment. A decision analysis on the subject done by Graham and Detsky[31] indicated that the preferred treatment is PRC. This decision analysis allowed a comparison between alternative treatments and may also provide insight into aspects of a problem that would be difficult or

impossible to evaluate by a cohort study such as this. Owing to our study's retrospective nature, we are also not able to guarantee equivalent disease severity between groups. Additional limitations of our study include the potential for recall bias, because the surveys were completed many years after the original surgery. Furthermore, because we were able to assess only the final outcome at last follow-up, we are unable to follow changes in patient-reported outcome, pain scores, or wrist and hand function over time. Using revision surgery as an end point also might be problematic, because there may be cases in which revision surgery is indicated but not carried out for any number of reasons. The effect of that is to make the index procedure spuriously appear more successful. Finally, although we excluded patients with insufficient follow-up and diagnoses of neuromuscular conditions and juvenile rheumatoid arthritis, the patient population still represented a wide variety of surgical indications, which added many confounders to our analysis. Despite these limitations, this was a large comparative series examining a high-risk (young, high-demand) patient population undergoing either PRC or 4CA.

REFERENCES

1. Begley BW, Engber WD. Proximal row carpectomy in advanced Kienbock's disease. *J Hand Surg Am*. 1994;19(6):1016–1018.
2. 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.
3. Crabbe WA. Excision of the proximal row of the carpus. *J Bone Joint Surg Br*. 1964;46:708–711.
4. Culp RW, McGuigan F, Turner M, Lichtman D, Osterman A, McCarroll H. Proximal row carpectomy: a multicenter study. *J Hand Surg Am*. 1993;18(1):19–25.
5. DiDonna ML, Kiefhaber TR, Stern PJ. Proximal row carpectomy: study with a minimum of ten years of follow-up. *J Bone Joint Surg Am*. 2004;86(11):2359–2365.
6. Imbriglia JE, Broudy AS, Hagberg WC, McKernan D. Proximal row carpectomy: clinical evaluation. *J Hand Surg Am*. 1990;15(3):426–430.
7. Inglis AE, Jones EC. Proximal-row carpectomy for diseases of the proximal row. *J Bone Joint Surg Am*. 1977;59(4):460–463.
8. Jebson P, Hayes EP, Engber W. Proximal row carpectomy: a minimum 10-year follow-up study. *J Hand Surg Am*. 2003;28(4):561–569.
9. Jorgensen EC. Proximal-row carpectomy: an end-result study of twenty-two cases. *J Bone Joint Surg Am*. 1969;51(6):1104–1111.
10. Krakauer JD, Bishop AT, Cooney WP. Surgical treatment of scapholunate advanced collapse. *J Hand Surg Am*. 1994;19:751–759.
11. Lumsden BC, Stone A, Engber WD. Treatment of advanced-stage Kienbock's disease with proximal row carpectomy: an average 15-year follow-up. *J Hand Surg Am*. 2008;33(4):493–502.
12. Tomaino MM, Delsignore J, Burton RI. Long-term results following proximal row carpectomy. *J Hand Surg Am*. 1994;19(4):694–703.
13. Wyrick JD. Proximal row carpectomy and intercarpal arthrodesis for the management of wrist arthritis. *J Am Acad Orthop Surg*. 2003;11(4):277–281.
14. Wyrick JD, Stern PJ, Kiefhaber TR. Motion-preserving procedures in the treatment of scapholunate advanced collapse wrist: proximal row carpectomy versus four-corner arthrodesis. *J Hand Surg Am*. 1995;20(6):965–970.
15. Wall LB, Didonna ML, Kiefhaber TR, Stern PJ. Proximal row carpectomy: minimum 20-year follow-up. *J Hand Surg Am*. 2013;38(8):1498–1504.
16. Tomaino MM, Miller RJ, Cole I, Burton RI. Scapholunate advanced collapse wrist: proximal row carpectomy or limited wrist arthrodesis with scaphoid excision? *J Hand Surg Am*. 1994;19(1):134–142.
17. Dacho AK, Baumeister S, Germann G, Sauerbier M. Comparison of proximal row carpectomy and midcarpal arthrodesis for the treatment of scaphoid nonunion advanced collapse (SNAC-wrist) and scapholunate advanced collapse (SLAC-wrist) in stage II. *J Plast Reconstr Aesthet Surg*. 2008;61(10):1210–1218.
18. Saltzman BM, Frank JM, Slikker W, Fernandez JJ, Cohen MS, Wysocki RW. Clinical outcomes of proximal row carpectomy versus four-corner arthrodesis for post-traumatic wrist arthropathy: a systematic review. *J Hand Surg Eur Vol*. 2015;40(5):450–457.
19. Wagner ER, Bravo D, Elhassan B, Moran SL. Factors associated with improved outcomes following proximal row carpectomy: a long-term outcome study of 144 patients. *J Hand Surg Eur Vol*. 2016;41(5):484–491.
20. Stamm TT. Excision of the proximal row of the carpus. *Proc R Soc Med*. 1944;38(2):74–75.
21. Ali MH, Rizzo M, Shin AY, Moran SL. Long-term outcomes of proximal row carpectomy: a minimum of 15-year follow-up. *Hand (N Y)*. 2012;7(1):72–78.
22. Blankenhorn BD, Pfaeffle HJ, Tang P, Robertson D, Imbriglia J, Goitz RJ. Carpal kinematics after proximal row carpectomy. *J Hand Surg Am*. 2007;32(1):37–46.
23. Hogan CJ, McKay PL, Degnan GG. Changes in radiocarpal loading characteristics after proximal row carpectomy. *J Hand Surg Am*. 2004;29(6):1109–1113.
24. Tang P, Gauvin J, Muriuki M, Pfaeffle JH, Imbriglia JE, Goitz RJ. Comparison of the "contact biomechanics" of the intact and proximal row carpectomy wrist. *J Hand Surg Am*. 2009;34(4):660–670.
25. Tang P, Wei DH, Ueba H, Gardner TR, Rosenwasser MP. Scaphoid excision and 4-bone arthrodesis versus proximal row carpectomy: a comparison of contact biomechanics. *J Hand Surg Am*. 2012;37(9):1861–1867.
26. Watson HK, Ryu J. Evolution of arthritis of the wrist. *Clin Orthop Relat Res*. 1986;202:57–67.
27. Strauch RJ. Scapholunate advanced collapse and scaphoid nonunion advanced collapse arthritis—update on evaluation and treatment. *J Hand Surg Am*. 2011;36(4):729–735.
28. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J Hand Surg Am*. 1984;9(3):358–365.
29. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med*. 1996;29(6):602–608.
30. Richou J, Chuinard C, Moineau G, Hanouz W, Hu W, Le Nen D. Proximal row carpectomy: long-term results. *Chir Main*. 2009;29(1):10–15.
31. Graham B, Detsky AS. The application of decision analysis to the surgical treatment of early osteoarthritis of the wrist. *J Bone Joint Surg Br*. 2001;83(5):650–654.