



ELBOW

Outcomes of anconeus interposition for proximal radioulnar synostosis



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Background/Hypothesis: Proximal radioulnar synostosis after elbow injuries can produce debilitating contractures. The estimated range of motion required to perform many activities of daily living is a 100° arc of forearm rotation. We hypothesized that excision of heterotopic bone and anconeus flap interposition could restore functional pronosupination in patients with proximal radioulnar synostosis.

Methods: Patients with proximal radioulnar synostosis were subdivided into 2 groups on the basis of etiology: (1) as a complication after distal biceps tendon repair or (2) as a result of direct trauma to the proximal forearm/elbow. All patients underwent an excision of the synostosis with interposition of an anconeus flap and were observed clinically for a minimum of 6 months.

Results: Twenty-three patients (16 men, 7 women) were included, with a mean age of 47 years and mean clinical follow-up of 4.8 years. Mean arc of forearm rotation improved from 21° to 132°, pronation increased from 12° to 70°, and supination increased from 9° to 62° ($P < .0001$). Patients with biceps tendon repair etiology ($n = 7$) displayed greater gains in pronation and a trend toward greater total forearm rotation than did those with a traumatic etiology ($n = 16$).

Conclusion: Anconeus interposition flap for management of proximal radioulnar synostosis produces significant and reliable clinical improvement in elbow pronosupination. Patients with biceps tendon repair etiology had a trend toward greater motion improvement than that of patients with a traumatic etiology. The degree of improvement seen would provide nearly full restoration of functional motion, resulting in minimal limitations in activities of daily living.

Level of evidence: Level III.

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Keywords: Proximal radioulnar synostosis; anconeus interposition; elbow trauma

Heterotopic bone formation after elbow injuries has been well recognized.¹⁹ More recently, various studies have documented the debilitating loss of pronosupination that

can result from proximal radioulnar synostosis and the improvements that can be obtained by operative management.^{1-3,5,6,10,16,18,20}

The arc of motion required at the elbow for activities of daily living has been extensively studied.^{4,8,9,13-15} The motion required for normal tasks is often cited as 30° to 130° of flexion, with 50° of both pronation and supination.⁹ However, more recent studies assessing modern tasks with the increased accuracy of 3-dimensional motion tracking

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systems have found that only 50° of pronation and supination would still result in several limitations.^{4,8,13-15} All patients in this series were frustrated with their decreased mobility and sought remedy.

The anconeus interposition flap as an adjunct after excision of bone and scar that is restricting motion has been reported and has shown promise in restoring motion after these injuries.^{1,10,16} We hypothesized that excision of heterotopic bone and anconeus flap interposition could restore and maintain functional forearm rotation—a 100° arc of prono-supination—in patients with proximal radioulnar synostosis.

Materials and methods

This is a retrospective comparative study of 29 adult patients with partial or complete proximal radioulnar synostosis who underwent an excision of the synostosis and interposition of an anconeus flap between 1997 and 2011. All patients had presented with complaints of loss of motion of the forearm and difficulty with activities of daily living. The surgeries were performed by 1 of 2 senior elbow surgeons who subsequently performed all follow-up evaluations. An attempt was made to contact all 29 patients to undergo a clinical examination if the patient had less than 6 months of follow-up in the medical record. One patient had died of unrelated causes and 5 patients could not be contacted or refused to participate, leaving 23 patients with an average follow-up of 57 months (range, 6-171 months) (Table I).

Sixteen patients had undergone the procedure for a synostosis related to a previous fracture or a dislocation of the elbow (Fig. 1). They had the following original diagnoses: 8 patients had sustained fracture-dislocations of the elbow, 3 had proximal both-bone forearm fractures, 2 had sustained intra-articular gunshot wounds, 2 had proximal ulna fractures, and 1 patient had both distal humerus and proximal ulna fractures. These patients had undergone an average of 2.8 operative procedures (range, 1-5) before presenting to our facility with complaints of loss of forearm rotation.

The proximal radioulnar synostosis was evaluated before anconeus interposition by the Jupiter and Ring modification⁵ of the classification system initially proposed by Vince and Miller.²⁰ In this system, grade III synostosis involves the proximal third of the forearm and is divided into 3 subgroups. Grade IIIA synostosis is located at or distal to the bicipital tuberosity, IIIB involves the radial head and proximal radioulnar joint, and IIIC describes synostosis that is contiguous with heterotopic bone about the distal humerus. Of the 16 patients in the trauma cohort, 2 had grade IIIA synostosis and 13 had grade IIIB; 1 patient's radiographs were unavailable. Eleven patients had complete synostosis with no forearm rotation at the time of presentation (7 fixed in neutral, 2 in pronation, 2 in supination), whereas 5 patients had incomplete synostosis with some minimal residual motion.

Seven patients had developed a radioulnar synostosis after undergoing a distal biceps tendon repair. All patients had undergone a single procedure for the repair before development of the synostosis. Five patients had a repair through a 2-incision technique, 4 of whom had complete synostosis fixed in a neutral position with no residual motion and 1 of whom had 10° of forearm rotation. One patient had a repair with an endobutton technique

Table I Demographic data and results comparing trauma and biceps tendon rupture etiology cohorts

| | Biceps cohort (range) | Trauma cohort (range) | <i>P</i> value |
|----------------------|--------------------------|--------------------------|----------------|
| N | 7 | 16 | — |
| Age, years | 49 (39-58) | 46 (19-68) | .51 |
| Gender (M:F) | 5:2 | 11:5 | .82 |
| Laterality (R:L) | 4:3 | 9:7 | .87 |
| Follow-up, months | 64 (6-148) | 54 (6-171) | .67 |
| Previous operations | 1.0 (1-1) | 2.8 (1-5) | .002 |
| Synostosis class | | | |
| Grade IIIA | 6 | 2 | |
| Grade IIIB | 0 | 13 | .001 |
| Not available | 1 | 1 | |
| Preoperative motion | | | |
| Pronation | 9 (0-30) | 14 (0-80) | .60 |
| Supination | 13 (0-90) | 7 (0-70) | .61 |
| Total | 21 (0-90) | 21 (0-100) | .96 |
| Extension | 1 (0-10) | 29 (0-70) | — |
| Flexion | 136 (130-140) | 118 (70-140) | — |
| Total | 135 (130-140) | 89 (0-145) | — |
| Postoperative motion | | | |
| Pronation | 84 (60-90) | 64 (0-90) | .07 |
| Supination | 69 (10-90) | 58 (0-90) | .45 |
| Total | 153 (80-180) | 122 (17-180) | .17 |
| Extension | 0 (0-0) | 25 (0-70) | — |
| Flexion | 138 (130-140) | 122 (70-150) | — |
| Total | 138 (130-140) | 97 (0-145) | — |
| Complications | 1 | 2 | — |

and had 90° of supination preoperatively, and 1 patient had a suture anchor fixation technique with 30° of pronation and 20° of supination preoperatively. Six patients had grade IIIA synostosis, and 1 patient's pre-resection radiographs were unavailable.

Surgical technique

Because the location of the heterotopic bone was usually most prominent on the dorsal aspect of the radioulnar surfaces (Fig. 2), the surgical approach included the dorsal limb of anconeus interval, permitting a simultaneous elevation of the myofascial flap based proximally. This allowed later interposition into the very region where there is the least distance between the radius and the ulna, thereby acting as a barrier precluding regrowth of the bridging heterotopic bone.

A proximally based anconeus myofascial flap interposition was used for treatment of radioulnar synostosis in our patients. The anconeus was exposed through a posterior-lateral approach as described by Pankovich.¹² The silhouette of the anconeus was identified, and it was elevated as a full-thickness myofascial flap with use of electrocautery. The flap was raised subperiosteally off of the ulna in a distal to proximal fashion to preserve the proximal vascular supply of the anconeus through the recurrent posterior interosseous artery. The proximal aspect was left intact to the lateral aspect of the olecranon to protect the vascular pedicle, which has been shown to have a mean length of 3.1 cm.¹¹ The posterior interosseous nerve remains protected anteriorly within

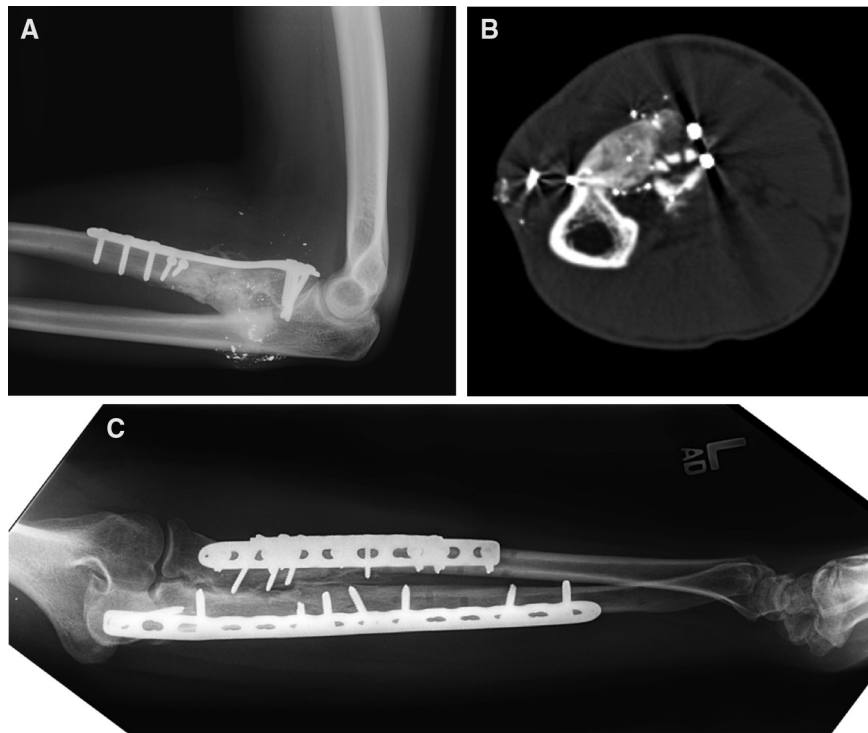


Figure 1 (A) Lateral radiograph and (B) axial computed tomography slice of a patient who developed a complete synostosis after a gunshot wound and subsequent surgical fixation. (C) Forearm radiograph of a patient with extensive proximal radioulnar synostosis extending near the mid-diaphysis.

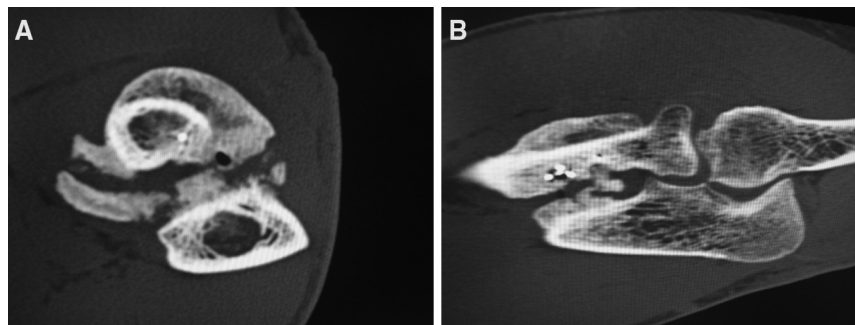


Figure 2 (A, B) Representative computed tomography images showing the location of heterotopic bone formation in a patient who previously had a biceps tendon repair.

the supinator muscle. The flap was typically raised to its origin on the lateral epicondyle while not violating the lateral collateral ligament of the elbow. The radial head and synostosis could then be visualized.

With the synostosis exposed, the heterotopic bone was initially cut along the ulna, leaving it adherent to the proximal radius. The bone was then removed in a piecemeal fashion with new regions of bone presented into the operative area by rotating the radius. Particular attention was paid to preservation of the biceps tendon insertion into the radial tuberosity as it was not infrequently surrounded by heterotopic bone, thereby requiring meticulous local heterotopic bone excision. After the excision, both supination and pronation were evaluated to see if satisfactory range had been restored. Once the motion was restored, the forearm was pronated and the distal tip of the flap was sutured to the periosteum of the

radial tuberosity. If local periosteal tissue was insufficient, a bone suture anchor was occasionally used. The wound was then closed in standard fashion.

Postoperatively, the patient was placed in an extension splint, usually held in maximal supination, and physical therapy was initiated on the day after surgery, with both active and passive mobilization. The splint was continued for nighttime wear for a variable number of weeks after surgery, depending on the patient's flexion and extension range of motion at the elbow as well as the progress with forearm rotation. Prophylaxis with indomethacin was used at the surgeon's discretion for 7 patients (6 in the trauma cohort, 1 in the biceps cohort). These patients were early in the study, and routine prophylaxis is not currently used unless the patient has an underlying risk factor. No patient was treated with postoperative radiation.

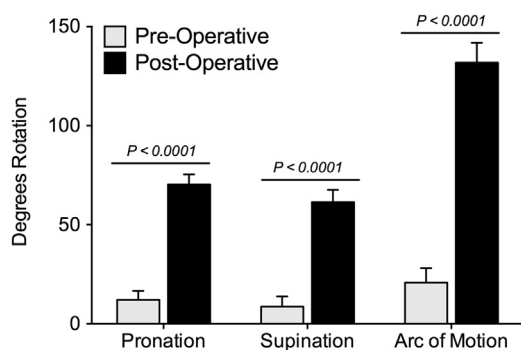


Figure 3 Comparison of preoperative and postoperative range of motion after anconeus interposition ($n = 23$), with standard error bars.

Statistics

Continuous demographic variables were compared with a Student t test, and categorical variables were tested with a χ^2 analysis. Preoperative and postoperative values were analyzed by a paired Student t test. Differences between the 2 groups were analyzed by a Student unpaired t test.

Results

Twenty-three patients (16 men, 7 women) were included, with a mean age of 47 years (range, 19-68 years) and mean clinical follow-up of 57 months (range, 6-171 months). There were no significant differences between the trauma cohort and the biceps repair cohort with respect to age ($P = .51$) or follow-up duration ($P = .67$) (Table I). The trauma cohort had undergone a significantly greater number of operations before presentation ($P = .002$).

All patients had an increase in their pronation-supination arc and no patient had a loss of motion in the flexion-extension plane. The aggregate mean preoperative pronation-supination arc of 21° increased to 132° postoperatively ($P < .0001$) (Fig. 3). Mean pronation increased from 12° to 70° ($P < .0001$), and supination increased from 9° to 62° ($P < .0001$).

There were no significant differences in preoperative pronation-supination arc between the two cohorts (Table I). Both the trauma and biceps cohorts showed significant improvements in pronation, supination, and total forearm rotation ($P < .0001$). The biceps repair cohort had significantly greater improvement in pronation ($P = .048$) but no significant differences in supination improvement ($P = .80$) or total forearm rotation ($P = .20$) (Fig. 4).

Complications included 3 hematomas. Two of the hematomas were in the trauma cohort; 1 required operative irrigation and débridement, and 1 was treated conservatively. One hematoma developed in the biceps tendon rupture cohort and was evacuated in the office setting. There were no neurovascular complications observed in this cohort. In addition, no biceps tendon insertional injuries were noted intraoperatively or at latest follow-up.

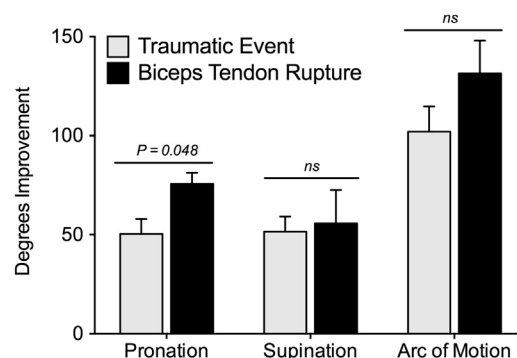


Figure 4 Comparison of improvements in forearm motion between two etiologies of proximal radioulnar synostosis: after proximal forearm trauma ($n = 16$) and after a distal biceps tendon repair ($n = 7$), with standard error bars. Patients with a biceps tendon repair etiology had significantly greater improvements in pronation. No differences were observed in supination or total rotational arc improvement. *ns*, not significant.

Discussion

Our findings document that anconeus interposition flap for management of proximal radioulnar synostosis can be used to reliably improve elbow rotational arc, pronation, and supination. The degree of improvement seen would provide nearly full restoration of functional motion and minimal limitations in activities of daily living.^{4,8,9,13-15}

The ideal operative management technique to address proximal radioulnar synostosis remains unknown, with variable results reported in the literature (Fig. 5). In the largest series, Failla et al documented results of operative management of 20 patients with post-traumatic fixed proximal radioulnar synostosis.² All patients underwent excision of heterotopic bone, with additional interposition of various materials (silicone, fascia, fat, muscle, polyethylene sheeting) performed in 12 patients. Intraoperatively, passive forearm pronation-supination (documented in 15 patients) improved to 121° (pronation 67° , supination 55°). This motion was not sustained as mean forearm rotational arc had decreased to 55° at most recent follow-up.

Jupiter and Ring described their experience with resection of proximal radioulnar synostosis in 18 extremities, with free fat graft interposition used in 8 cases.⁵ One patient with a closed head injury had recurrent synostosis. After a minimum follow-up of 2 years, the remaining cohort demonstrated a mean forearm pronation-supination improvement of 139° (pronation 78° , supination 61°).

Other techniques include performing a radial resection distal to the synostosis to restore pronation-supination, which resulted in a rotational arc improvement of 98° at 2 years in a series of 7 patients reported by Kamineni et al.⁶ In a similar fashion, Kamrani et al managed a cohort of 15 patients with post-traumatic proximal radioulnar synostosis with a proximal radial diaphyseal segment resection and noted an improvement of 101° after an average of 31 months.⁷

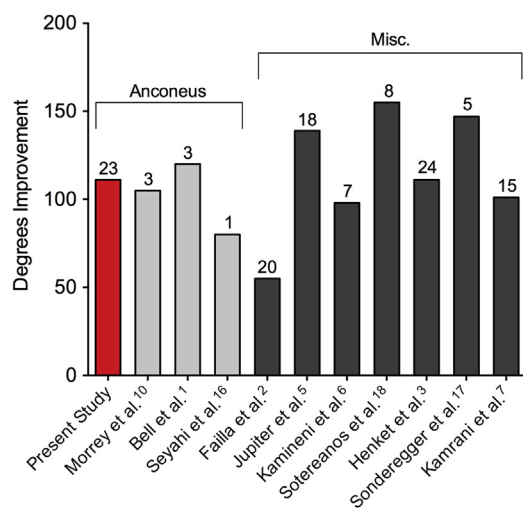


Figure 5 Comparison of postoperative improvements in forearm rotation among published case series on proximal radioulnar synostosis treatment. The size of the cohort is indicated above each respective column. The 4 studies on the left used an anconeus interposition technique; the remaining 7 studies used various other techniques (see [discussion](#)).

Sonderregger et al used a pedicled adipofascial flap in 5 cases of proximal radioulnar synostosis in an attempt to prevent recurrence after surgical excision and had 72° of pronation and 75° of supination after an average of 28 months.¹⁷

There are few reports of use of an anconeus interposition flap to improve motion after radioulnar synostosis ([Fig. 5](#)).^{1,10,16} In the largest series to date, Morrey and Schneeberger described 3 techniques for using an anconeus flap at the radioulnar and radiocapitellar joints.¹⁰ Their pooled outcomes in 14 patients with various indications (minimum follow-up of 2 years) were a forearm pronosupination arc improvement of 46°. Of note, the 3 patients treated for radioulnar synostosis showed a mean forearm rotation arc improvement of 105°.

Our findings showed that patients with a biceps tendon rupture etiology had greater motion improvements than did those with a traumatic etiology. This is consistent with a report by Henket et al,³ who compared the results of isolated resection of proximal radioulnar synostosis complicating biceps tendon reattachment ($n = 11$, rotational arc improvement of 131°) and elbow trauma ($n = 13$, improvement of 94°). Whereas some have found success with resection alone for treatment of synostosis after biceps tendon repair,^{3,18} others have found it to be unsuccessful with a high recurrence rate.²⁰

In the present series, we observed significantly greater improvements in pronation in the biceps cohort. The total rotational arc did not reach statistical difference in our series, but we believe that the 30° difference in pronosupination between etiologic cohorts may be clinically significant. Possible explanations for these differences include significantly more extensive heterotopic bone formation (i.e., more grade IIIB synostoses) along with

significantly more prior procedures in the trauma cohort ([Table I](#)). Four patients failed to achieve 100° of forearm rotation, 3 in the trauma cohort and 1 in the biceps cohort. Whereas the reasons for inferior results are not entirely clear, they had more extensive initial injuries and a higher number of previous procedures.

This study is limited by its single-center retrospective nature, which may limit its external validity. However, our results closely approximate those of previous reports employing a similar technique ([Fig. 5](#)).^{1,10,16} Strengths of this study include the large size of the cohort as the 2 previous largest outcome studies using anconeus interposition for management of synostosis were limited to 3 patients.^{1,10}

The importance of forearm rotation in performing activities of daily living has been well documented.^{4,8,9,13-15} The synostosis observed in our cohort would have impaired the ability to perform everyday tasks of eating with silverware, washing one's face and hair, opening a door, and using a keyboard and mouse.^{4,8,9,13-15} The mean postoperative pronation and supination after interposition of an anconeus flap would restore the ability to perform all of these tasks. The reliability of outcomes and the low incidence of complications make it an ideal treatment strategy for restoration of forearm rotation after various proximal radioulnar synostosis-producing events.

Conclusion

Managing patients with proximal radioulnar synostosis by excision of the heterotopic bone and use of an anconeus interposition flap produces significant and reliable clinical improvement in elbow pronosupination. Regardless of etiology (after biceps tendon repair or proximal forearm trauma), both of the indicated cohorts demonstrated significant improvements in pronation, supination, and total arc of motion. Patients in the biceps tendon rupture cohort had less involved synostosis radiographically and displayed significantly greater gains in pronation and a trend toward greater overall rotational arc improvement. The mean degree of forearm rotation seen postoperatively would provide nearly full restoration of functional motion, resulting in minimal limitations in activities of daily living.

Disclaimer

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