Open surgical treatment of post-traumatic elbow contractures in adolescent patients

Nickolaos A. Darlis, MD, Robert W. Kaufmann, MD, Dean G. Sotereanos, MD, *Pittsburgh, PA*

The results of surgical treatment of post-traumatic elbow contractures in adolescence have been conflicting in the literature. Twelve adolescent patients (mean age 16.7 years, range 13-21) that had open release of post-traumatic elbow contractures were followed-up for a mean of 18.9 months (range 10-42 months). All releases were performed through a lateral approach (sparing the lateral ulnar collateral ligament) with anterior joint release (in twelve) supplemented by posterior release (in four patients). An additional medial approach was used in three patients. In three patients the radial head was excised. A mean gain of 54° in the flexion-extension arc was observed at final follow-up and all patients achieved a functional ROM of at least 100°. The patients maintained 93% of the motion that was achieved intraoperatively. No patient lost motion. Open release in adolescent patients with post-traumatic elbow contractures and no intarticular incongruence or erosion, yielded satisfactory results, similar to those achieved in adults. (J Shoulder Elbow Surg 2006;15:709-715.)

Post-traumatic elbow contractures are not uncommon. Most are initially treated with physical therapy and static and/or dynamic splinting. If these modalities fail, operative release is indicated to restore function. The efficacy of operative treatment of post-traumatic elbow contractures in adults is well documented. Open releases through anterior,[1,8,24] lateral,[6,11,14,25] medial[18,26,27] and combined[15] approaches have been used. More recently arthroscopic elbow release[3,5,12,19,20,22] has been introduced with satisfactory results and low complication rates. For adult patients with advanced arthritic changes distraction-interposition arthroplasty[4,7,23] and total elbow arthroplasty[17] are salvage options.

Experience with surgical release of post-traumatic elbow contractures in pediatric and adolescent patients has been limited[2,17,21] and in one report[21] results were shown to be less favorable and less predictable, compared to adults. In an effort to better clarify the outcome following post-traumatic elbow contracture releases in adolescents we present our experience from twelve open contracture releases using a consistent surgical protocol.

From the Department of Orthopaedic Surgery, Allegheny General Hospital, Pittsburgh, PA and the Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA

Reprint requests: Dean G. Sotereanos, MD, Allegheny General Hospital, Department of Orthopaedic Surgery, 1307 Federal Street, Pittsburgh, PA 15212. (E-mail: *nickdarlis@medscape.com, dsoterea@hotmail.com*).

1058-2746/2006/$32.00
doi:10.1016/j.jse.2006.01.006

MATERIALS AND METHODS

A retrospective review of the senior author's (DGS) records produced sixteen patients under the age of 21 with posttraumatic elbow contracture releases. Three patients with arthroscopic releases and one patient lost to follow up were excluded from this study. Twelve adolescent patients (mean age 16.7 years, range 13 to 21 years) with post-traumatic elbow contracture releases are included in this study. Ten male and two female patients were treated for contractures of their dominant elbow in nine and the non-dominant in three. All patients developed contractures after trauma (Table 1) and had persistent functional limitations of the elbow despite initial conservative treatment with physical therapy, static and dynamic splinting. Turnbuckle splints were initially used in four of the patients. The average interval between the original injury and surgical treatment was 21.3 months (range 6 to 60 months).

The indication for surgical release was significant functional limitation in the flexion-extension arc. More over, four patients presented with severe limitations in the pronation-supination arc as well. With regards to symptoms, four patients presented with pain at the extremes of flexion or extension, one with pain in supination and one with pain over prominent hardware. In addition, three patients presented with cubital tunnel symptoms including medial elbow pain, ulnar nerve distribution sensory symptoms and one of them with mild motor weakness. Two of the patients with cubital tunnel symptoms had medial epicondyle non-unions. Three of the patients were completely pain free and none of the twelve patients reported pain through the entire range of motion.

Preoperative evaluation included plain radiographs in all patients and CT scans to further determine the precise location of heterotopic bone in three patients. All releases were performed utilizing a lateral approach to the elbow

Table I Demographic data, etiology, and Procedures

Patient No.	Age (y)	Etiology	Time from injury to capsular release (mo)	Approach	Procedure
1	16	RH fracture	60	Lateral	Anterior capsular release, RH excision
2	13	Supracondylar humerus fracture	6	Lateral	Anterior capsular release, plate removal
3	15	RH dislocation	42	Lateral	Anterior capsular release, RH excision
4	19	Elbow fracture-dislocation, radius malunion, cubital tunnel syndrome	20	Lateral, medial	Ulnar nerve transposition, anterior capsular release, olecranon osteophyte excision, RU synostosis excision, posterior capsular release, plate removal, medial epicondylectomy
5	18	Floating elbow, compartment syndrome (fasciotomy)	10	Lateral	Anterior capsular release, posterior capsular release, olecranon osteophyte excision
6	14	Distal radius fracture, non-displaced RH fracture	50	Lateral	Anterior capsular release, posterior capsular release, olecranon osteophyte excision
7	17	Elbow dislocation, medial epicondyle fracture, cubital tunnel syndrome	6	Lateral, medial	Anterior capsular release, ulnar nerve transposition, resection nonunion of medial epicondyle, MCL repair
8	20	RH fracture	14	Lateral	Anterior capsular release, RH excision
9	21	Distal humerus fracture, elbow dislocation, RH subluxation	28	Lateral	Anterior capsular release, coronoid osteophyte excision
10	15	Elbow dislocation, medial epicondyle fracture, cubital tunnel syndrome	6	Lateral, medial	Anterior capsular release, ulnar nerve transposition, resection nonunion of medial epicondyle, MCL imbrication
11	20	Diaphyseal humerus fracture	8	Lateral	Anterior capsular release, posterior capsular release, olecranon osteophyte excision, olecranon fossa HO excision
12	13	Elbow dislocation	6	Lateral	Anterior capsular release, triceps release

RH, Radial head; *RU,* radioulnar; *MCL,* medial collateral ligament.

that was sparing the lateral collateral ligament. Posterior contracture release through the same skin incision was performed in four patients and a separate medial approach to address medial sided pathology was performed in three patients. Radial head excision was necessary in three patients (Table I).

Surgical Technique

The procedure is performed under general anesthesia supplemented by a brachial plexus block for post-operative analgesia. Both anterior and posterior constraints to the elbow range of motion can be addressed through the lateral approach. The procedure can be performed through a lateral or a more extensile posterior skin incision.

In uncomplicated cases a lateral skin incision is preferred. Release of the anterior elbow is performed first. The position of the radial head is verified by palpation with the forearm in pronation and supination. The extensor musculature is incised along the line that connects the tip of the lateral epicondyle to a point bisecting the width of the radial head (Figure 1*A*, 2). This incision spares the lateral ulnar collateral ligament (Figure 1*A* insert). The extensor muscles are then partially reflected from the anterior surface of the supracondylar ridge to expose the anterior capsule (Figure 3). The brachialis muscle fibers covering the anterior capsule are carefully reflected using a Codman elevator. A long right-angle retractor is used to retract the brachialis (and the neurovascular structures anterior to it) off of the capsule (Figure 1*B*). Under direct vision the anterior capsule is excised from lateral to medial. Care should be taken to incise the capsule under direct vision on its medial aspect where the ulnar nerve is in jeopardy. After the anterior capsular release, the entire anterior part of the elbow joint is visible (Figure 4). Depending on the pathology, there may be a need to perform osteophyte excision from the coronoid process or the margin of the anterior distal humeral articular surface which impacts a coronoid osteophyte. Loose body removal is also performed as necessary. The articular surfaces are carefully inspected. In cases of symptomatic radiocapitellar arthritis or significant painful restrictions in pronation/supination secondary to old radial head fractures, radial head excision may be necessary to improve function.

If the desired range of motion is not achieved through the anterior release, attention is then turned to the posterior part of the joint. Through the same skin incision, the interval between the triceps and anconeus is developed (Figure 1*A*, 1*B*, 5). The posterior capsule is released and olecranon tip and olecranon fossa osteophytes are removed as necessary (Figure 6). Again, caution is exercised not to injure the ulnar nerve coursing over the medial gutter. In cases with limitations of flexion, release of adhesions between the triceps and the posterior surface of the humerus, using a Codman elevator may be beneficial. This release should not extend

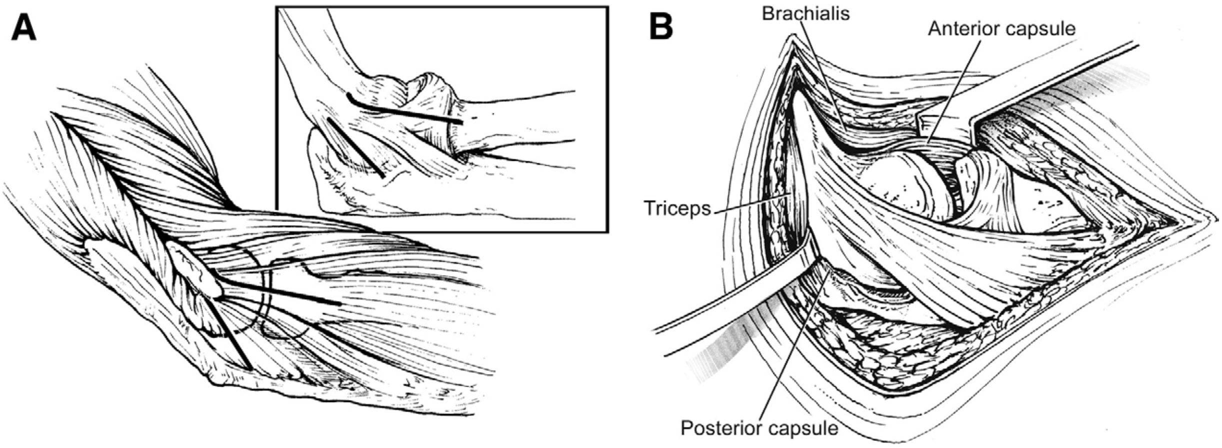

Figure 1 Schematic of the lateral ulnar collateral ligaments-sparing lateral approach that was used in this study. **A**, To expose the anterior capsule, the extensor musculature is incised along the line that connects the tip of the lateral epicondyle to a point bisecting the width of the radial head and is partially reflected from the anterior surface of the supracondylar ridge. Access to the posterior elbow joint is obtained trough the interval between the anconeus and the triceps. The position of the two incisions relative to the lateral ulnar collateral ligament is demonstrated in the insert. **B**, By reflecting the brachialis off of the anterior capsule and the triceps off of the posterior capsule, anterior and posterior release of the elbow joint can be performed and intraarticular obstructs to the range of motion can be addressed.

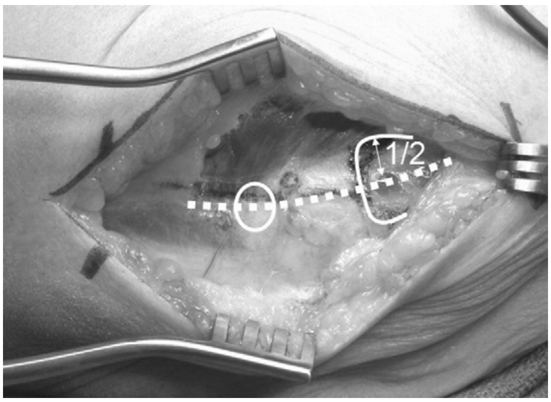

Figure 2 Intaroperative image of the lateral approach to the elbow demonstrating the landmarks for the anterior incision through the extensor musculature along the line that connects the tip of the lateral epicondyle to a point bisecting the width of the radial head.

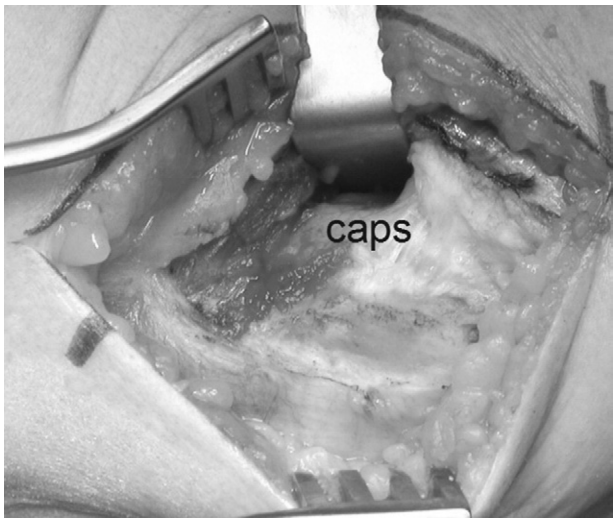

Figure 3 After partial reflection of the extensor musculature from the anterior surface of the supracondylar ridge, the brachialis muscle(and the neurovascular structures anterior to it) is retracted from the anterior capsule (caps) with a long right-angle retractor, thus allowing safe anterior capsular release.

to the spiral groove of the humerus to avoid radial nerve injury.

Medial-sided pathology necessitated an additional medial approach in three of our patients. This could also be addressed with an extensile posterior approach depending on surgeon preference. Indications for a medial approach included ulnar nerve entrapment symptoms and non-union of medial epicondyle fractures. Severe valgus instability of the elbow necessitating medial collateral ligament reconstruction could be another indication. The ulnar nerve is carefully dissected and transposed anteriorly. Medial epicondylar pathology can be addressed through this incision and the stability of the elbow in valgus is examined. If medial collateral ligament laxity is encountered the ligament can be imbricated. In cases of complete detachment, it can be reattached though drill holes or suture anchors to the medial epicondyle. Formal reconstruction with the use of a tendon graft can be performed if necessary. In this study medial collateral ligament imbrication was performed in one patient and reattachment in another.

After surgically releasing all of the potential sites of contracture and impingement, the elbow is gently manipulated under anesthesia using a short level arm. The authors

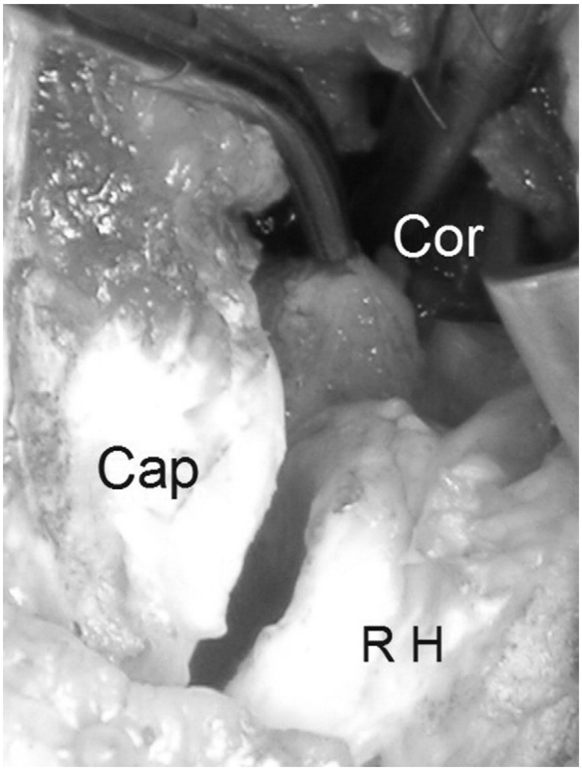

Figure 4 After the anterior capsular release, the entire anterior part of the elbow joint is visible. Depending on the pathology, there may be a need to remove loose bodies, excise osteophytes from the coronoid process (Cor) and the articular margins of the trochlea or the capitelum (Cap) and in more rare occasions to perform radial head (RH) excision.

find this useful in regaining the last few degrees of motion by breaking intraarticular adhesions. The intraoperative range of motion is then documented and serves as a useful reference during the first weeks of rehabilitation. A long arm splint with the elbow in extension is applied.

Physical therapy is initiated within the first postoperative week. Continuous passive motion was used in six of the patients in this series for a period of four weeks. The remaining patients underwent a supervised active and passive range of motion physical therapy program. An orthoplast long arm extension splint was used during the night for a period of four weeks.

Oral NSAIDs were not used in this study for heterotopic ossification prophylaxis. In a 19-year-old patient with extensive bone removal due to heterotopic ossification, postoperative radiotherapy of 700 cGy divided in two doses was used. The authors do not routinely use radiation in children and adolescents.

At the last follow-up visit the elbow range of motion was recorded in all patients. A long arm goniometer is routinely used to record the range of motion in flexion and extension arc. Postoperative elbow radiographs were reviewed on all patients. In patients with radial head excision, postoperative radiographs of the wrist were also obtained and postoperative ulnar variance was measured. Statistical analysis was performed using Student's *t*-test to compare preoperative, intraoperative, and postoperative values; *P* values less than .05 were considered of statistical significance.

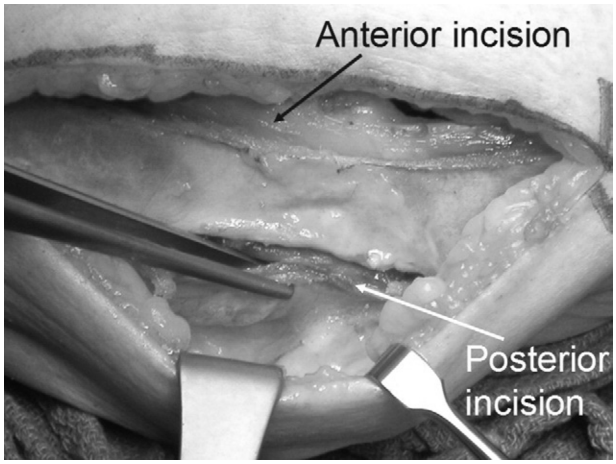

Figure 5 Intraoperative image of a lateral approach to the elbow demonstrating the position of the posterior incision at the triceps-anconeus interval relative to the anterior incision described in Figure 2. Note that a strip of tissue (that includes the lateral ulnar collateral ligament of the elbow) remains intact between the two incisions thus maintaining the stability of the joint. Both incisions have to be closed with interrupted sutures at the end of the procedure.

RESULTS

The mean follow-up was 18.9 months (range 10 to 42 months). A detailed presentation of the results is included in Table II. Flexion was increased from mean of 113° preoperatively to 129° at the final follow-up ($P < .01$). Extension improved from a mean −51° to −15° ($P < .001$). In total, the flexion-extension arc improved from 62° to 116° for a mean total gain of 54° ($P < .01$). All of our patients achieved a func-

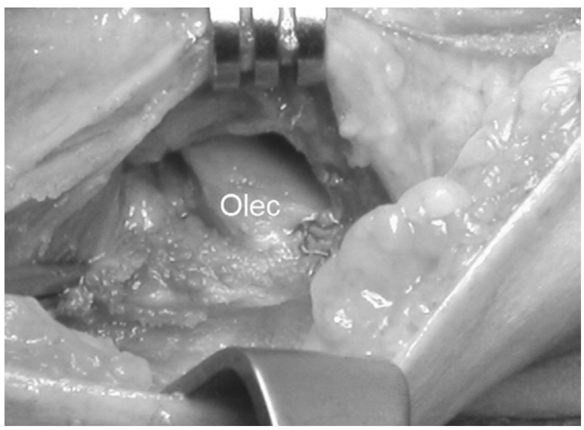

Figure 6 After posterior capsular release is performed through the anconeus-triceps interval, the posterior elbow joint is visible and loose body removal and osteophyte excision from the olecranon (Olec) tip or the olecranon fossa of the elbow can be performed.

Table II Range-of-motion data

Patient No.	Follow-up (mo)	Flexion (°)			Extension (°)			Pronation (°)			Supination (°)			Flexion-extension arc (°)			Total increase in flexion-extension arc (°)	% Intraop motion maintained at final follow-up
		Preop	Intraop	Postop	Preop	Intraop	Postop	Preop	Intraop	Postop	Preop	Intraop	Postop	Preop	Intraop	Postop		
1	15	130	130	130	−30	−15	−30	40	70	80	20	60	60	100	115	100	0	87
2	10	110	145	140	−80	−25	−30	70	70	80	80	80	80	30	120	110	80	92
3	25	110	140	130	−90	−20	−30	70	70	70	−70	0	0	20	120	100	80	83
4	10	90	140	130	−30	0	−15	60	70	70	10	10	10	60	140	115	55	82
5	16	80	125	115	−10	0	−10	70	70	70	70	70	70	70	125	105	35	84
6	10	130	130	130	−30	−5	−15	80	80	80	70	70	70	100	125	115	15	92
7	18	120	130	130	−50	−5	0	80	80	80	80	80	80	70	125	130	60	104
8	42	130	130	130	−45	0	−5	−80	80	80	90	90	90	85	130	125	40	96
9	10	90	125	125	−60	−5	−10	80	80	80	70	70	70	30	120	115	85	96
10	44	120	130	130	−75	−5	0	80	80	80	80	80	80	45	125	130	85	104
11	15	140	140	140	−60	−10	−10	80	80	80	90	90	90	80	130	130	50	100
12	12	100	130	120	−50	0	0	70	70	70	80	80	80	50	130	120	70	92
Mean	19	113	133	129	−51	−8	−13	58	75	77	56	65	65	62	125	116	54	93

tional range of motion of at least 100 degrees in the flexion extension arc. No patient lost motion. Pronation was improved from 58° to 77° and supination from 56° to 62°, but these improvements did not reach statistical significance. All three patients in which the radial head was excised improved their pronation and supination, but one failed to achieve supination past neutral. Comparing the range of motion that was achieved intraoperatively with the one recorded at final follow up, a mean of 9° of motion was lost (from a mean of 125° in the flexion-extension arc intraoperatively to 116° at final follow-up). Ninety-three percent of the motion achieved intraoperatively was maintained at the final follow up.

One complication was encountered amongst these twelve patients. A superficial wound infection developed at the incision site in one patient. It was successfully treated with suture removal and and oral antibiotics on an outpatient basis.

Ulnar nerve symptoms completely resolved in two of the three patients with preoperative cubital tunnel syndrome. The third patient complained of mild intermittent pain without sensory deficits and declined any further treatment. Persistent pain with extreme extension was observed in one patient. The remaining patients were symptom free. No patient complained of instability, including the two patients in which the medial collateral ligament was either imbricated or repaired during the procedure.

Postoperative radiographs were available for all patients after a mean of 16 months (range 4 to 24 months) from the procedure. In one patient, clinically insignificant heterotopic ossification (Hastings and Graham[9] class I) was observed at the anterior proximal humerus. No signs of elbow arthritis were observed. Regarding the three patients with radial head excision, overgrowth of the stump of the radius was observed in one patient without any functional limitation. Proximal radial migration was observed in two of the patients with radial head excision (ulnar positive variance of 2 and 3 mm, respectively) but both remained asymptomatic at the final follow-up.

DISCUSSION

Children and adolescents are not immune to posttraumatic elbow contracture. If elbow contractures eventually develop in children and adolescents, an initial period of conservative treatment using static, dynamic, or turnbuckle splints is recommended, provided there are no bony restraints to the range of motion. In cases refractory to conservative treatment, operative release is an option. Results of operative treatment in the pediatric population have been infrequently reported. Mih and Wolf[17]reported nine pediatric patients with elbow contractures (secondary to trauma in six) treated with a lateral approach and supplemented by a medial approach. At an average of 17 months follow-up, a mean improvement of the total range of motion of 53° was observed. A functional range of motion of 100° was achieved in 8 out of 9 patients. Lengthening of the biceps, triceps or medial collateral ligament was mentioned as part of the treatment in an undisclosed number of patients. Bae[2] followed eleven adolescent patients with post-traumatic elbow contractures treated through an extensile medial approach for an average of 29 months. The mean improvement of the total arc of motion was 54° and 9 out of 11 patients achieved a functional range of motion of 100°. Aldridge, et al[1] reviewed the outcomes of 106 patients treated with an anterior approach for a flexion contracture. The results in twelve patients under age 19 were not found to be significantly different than the results of other age groups. Our experience with adolescent patients is similar to the above mentioned studies. The mean improvement in the elbow flexion extension arc was 54° with all our patients achieving final arc of motion of at least 100°.

The results of a study by Stans et al[21] were less optimistic. Thirty-seven patients under the age of 21 years with open surgical release of elbow contractures were evaluated. Contractures were secondary to trauma in 28° of those patients. The preoperative range of motion was similar to this study, yet only 28° of mean improvement in the flexion-extension arc were observed and only 17 out of 37 patients achieved a functional arc of motion of 100°. The authors of that study found the results in the traumatic and non-traumatic groups to be similar. The discrepancy in the results between this and previous studies may be explained by the inclusion of more severe elbow contractures in the study by Stans et al. Four of their patients needed contouring of the distal humerus to reconstruct a congruent joint. An external fixator was applied after the release in six patients (in three in conjuction with a fascial interposition arthroplasty) It is evident that patients with severe ulnohumeral joint erosions were included in that study and pooling of the data with the patients with simple contractures could account for the inferior results. Elbow distraction arthroplasty or elbow interposition arthroplasty are salvage procedures in young patients and results following these two procedures have been suboptimal in the literature.[4,7,23]

The presence of intraarticular incongruence and cartilage erosions of the ulno-humeral joint can negatively affect the outcome of elbow contracture releases. Radiographs and even CT scans may be inconclusive as to the presence of ulno-humeral cartilage erosions as accurate positioning of patients with elbow contractures for those imaging studies can be very difficult. It is important for the surgeon to assess preoperative pain. Pain presenting at the extremes of flexion or extension is usually caused by impingement of osteophytes. In contrast, pain throughout the range of motion is indicative of arthrosis and may adversely affect prognosis for these patients. The results of elbow releases in patients without significant ulnohumeral erosions presented in our study and in the studies by Mih[17] and Bae[2] seem to be more favorable and comparable to the ones achieved in adults.

The follow up in this study, although similar to previous studies, is rather short (mean 19 months, minimum 10 months). In two longer-term studies[1,21] no significant changes in the range of motion were recorded after the six and twelve months follow up point, respectively. Nevertheless, the possibility of arthritic progression in the long term remains.

The lateral collateral ligament sparing lateral approach that was used in this series presents some differences with the ones described in the literature. In the original "lateral column" procedure[6,14] the interval between extensor carpi radialis longus (ECRL) and the extensor digitorum communis (EDC) is used to expose the anterior capsule. In our technique, anterior exposure is obtained with an incision extending from the tip of lateral epicondyle to a point bisecting the width of the radial head. This exposure is simpler, using more stable anatomic landmarks. The intramuscular plane described above is often difficult to discern. Moreover, this incision provides easier access to the radial head, should radial head resection be necessary. Keeping the forearm in full pronation and avoiding overjealous anterior retraction help in protecting the posterior interosseous nerve. No neurapraxias were observed in this study.

Radial head excision to improve restricted pronation and supination secondary to radial head fractures was used in this and other[2,21] studies. Radial head excision alone without anterior capsular release can offer only a modest increase in flexion/extension and was complicated with appositional overgrowth in 50% of post-traumatic patients in one study of adolescent patients.[10] Proximal radial migration was observed in most patients in that study, but no symptoms were recorded at the mean follow-up of 7.8 years.

Experience from arthroscopic contracture release in pediatric and adolescent patients is very limited at this point. Micheli et al[16] reported arthroscopic releases in nine patients with post-traumatic arthrofibrosis and elbow contractures. Six of those patients were followed and a mean gain of 63° in the arc of motion was reported. However, one of these patients had a fair and one a poor functional result. Arthroscopic release of pediatric elbow contractures is promising, but needs to be further evaluated.

In conclusion, based on our series, the results of open release of post-traumatic elbow contractures refractory to conservative treatment in adolescent patients can be satisfying. In patients presenting without pain through the range of motion or other evidence of ulno-humeral joint incongruence or erosions the prognosis is favorable, similar to the adult population. The available literature, although small in numbers, further supports this conclusion.[13]

REFERENCES

1. Aldridge JM 3rd, Atkins TA, Gunneson EE, Urbaniak JR. Anterior release of the elbow for extension loss. J Bone Joint Surg Am 2004;86A:1955-60.
2. Bae DS, Waters PM. Surgical treatment of posttraumatic elbow contracture in adolescents. J Pediatr Orthop 2001;21:580-4.
3. Ball CM, Meunier M, Galatz LM, Calfee R, Yamaguchi K. Arthroscopic treatment of post-traumatic elbow contracture. J Shoulder Elbow Surg 2002;11:624-9.
4. Cheng SL, Morrey BF. Treatment of the mobile, painful arthritic elbow by distraction interposition arthroplasty. J Bone Joint Surg Br 2000;82B:233-8.
5. Cohen AP, Redden JF, Stanley D. Treatment of osteoarthritis of the elbow: a comparison of open and arthroscopic debridement. Arthroscopy 2000;16:701-6.
6. Cohen MS, Hastings H 2nd. Post-traumatic contracture of the elbow. Operative release using a lateral collateral ligament sparing approach. J Bone Joint Surg Br 1998;80B:805-12.
7. Fox RJ, Varitimidis SE, Plakseychuk A, Vardakas DG, Tomaino MM, Sotereanos DG. The Compass Elbow Hinge: indications and initial results. J Hand Surg Br 2000;25B:568-72.
8. Gates HS 3rd, Sullivan FL, Urbaniak JR. Anterior capsulotomy and continuous passive motion in the treatment of post-traumatic flexion contracture of the elbow. A prospective study. J Bone Joint Surg Am 1992;74A:1229-34.
9. Hastings H 2nd, Graham TJ. The classification and treatment of heterotopic ossification about the elbow and forearm. Hand Clin 1994;10:417-37.
10. Hresko MT, Rosenberg BN, Pappas AM. Excision of the radial head in patients younger than 18 years. J Pediatr Orthop 1999; 19:106-13.
11. Husband JB, Hastings H 2nd. The lateral approach for operative release of post-traumatic contracture of the elbow. J Bone Joint Surg Am 1990;72A:1353-8.
12. Kim SJ, Shin SJ. Arthroscopic treatment for limitation of motion of the elbow. Clin Orthop Relat Res 2000;375:140-8.
13. Mansat P, Morrey BF. Semiconstrained total elbow arthroplasty for ankylosed and stiff elbows .J Bone Joint Surg Am 2000;82A: 1260-8.
14. Mansat P, Morrey BF. The column procedure: a limited lateral approach for extrinsic contracture of the elbow. J Bone Joint Surg Am 1998;80A:1603-15.
15. Marti RK, Kerkhoffs GM, Maas M, Blankevoort L. Progressive surgical release of a posttraumatic stiff elbow. Technique and outcome after 2-18 years in 46 patients. Acta Orthop Scand 2002;73:144-50.
16. Micheli LJ, Luke AC, Mintzer CM, Waters PM. Elbow arthroscopy in the pediatric and adolescent population. Arthroscopy 2001; 17:694-9.
17. Mih AD, Wolf FG. Surgical release of elbow-capsular contracture in pediatric patients. J Pediatr Orthop 1994;14:458-61.
18. Moritomo H, Tada K, Yoshida T. Early, wide excision of heterotopic ossification in the medial elbow. J Shoulder Elbow Surg 2001;10:164-8.
19. Phillips BB, Strasburger S. Arthroscopic treatment of arthrofibrosis of the elbow joint. Arthroscopy 1998;14:38-44.
20. Savoie FH 3rd, Nunley PD, Field LD. Arthroscopic management of the arthritic elbow: indications, technique, and results. J Shoulder Elbow Surg 1999;8:214-9.
21. Stans AA, Maritz NG, O'Driscoll SW, Morrey BF. Operative treatment of elbow contracture in patients twenty-one years of age or younger. J Bone Joint Surg Am 2002;84A:382-7.
22. Timmerman LA, Andrews JR. Arthroscopic treatment of posttraumatic elbow pain and stiffness. Am J Sports Med 1994;22: 230-5.
23. Tsuge K, Murakami T, Yasunaga Y, Kanaujia RR. Arthroplasty of the elbow. Twenty years' experience of a new approach. J Bone Joint Surg Br 1987;69B:116-20.
24. Urbaniak JR, Hansen PE, Beissinger SF, Aitken MS. Correction of post-traumatic flexion contracture of the elbow by anterior capsulotomy. J Bone Joint Surg Am 1985;67A:1160-4.
25. Vardakas DG, Varitimidis SE, Goebel F, Vogt MT, Sotereanos DG. Evaluating and treating the stiff elbow. Hand Clin 2002; 18:77-85
26. Wada T, Ishii S, Usui M, Miyano S. The medial approach for operative release of post-traumatic contracture of the elbow. J Bone Joint Surg Br 2000;82B:68-73.
27. Weiss AP, Sachar K. Soft tissue contractures about the elbow. Hand Clin 1994;10:439-51.