J Shoulder Elbow Surg (2016) 25, 276-282

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ELBOW

Outcomes using the extensor digitorum communis splitting approach for the treatment of radial head fractures

Fucai Han, MRCS[a,*], Alex Quok An Teo, MRCS[a], Jia Chen Lim, MBBS[a], Manohara Ruben, FRCS[a], Bryan Hsi Ming Tan, FRCS[a], V. Prem Kumar, FRCS[a,b]

[a]*Department of Orthopaedic Surgery, University Orthopaedics, Hand & Reconstructive Microsurgery Cluster, National University Hospital, National University Health System, Singapore*
[b]*Department of Orthopaedic Surgery, Yong Loo Lin School of Medicine, National University of Singapore, Singapore*

Background: Surgery on the radial head is usually performed via the Kocher interval. Iatrogenic injury to the posterior interosseous nerve (PIN) and lateral ligamentous complex are known complications of lateral elbow approaches. The extensor digitorum communis (EDC) splitting approach for lateral elbow exposure is known to provide better access to the anterior half of the radial head while reducing the risk of injury to the lateral ligaments. The aim of this study was to provide clinical outcome data for the EDC splitting approach.

Methods: Thirteen patients with closed radial head fractures underwent internal fixation or replacement via the EDC splitting approach. Patients were evaluated using the Mayo Elbow Performance, American Shoulder and Elbow Surgeons (ASES), and Disabilities of Arm, Shoulder and Hand scores. Clinical assessments of the elbows were also performed.

Results: Ten patients underwent open reduction and internal fixation of their radial heads, and 3 underwent radial head replacements. At final follow-up, all patients achieved good to excellent Mayo Elbow Performance scores, with a mean score of 90 (range 80-100). They had a mean ASES elbow score of 89.6 (range 77-97) and a mean Disabilities of Arm, Shoulder and Hand score of 12.8 (range 6.67-25.8). Patients reported a mean overall ASES satisfaction score of 8.5 (range 6-10). There were no significant surgical complications, including iatrogenic damage to the PIN or the lateral ligaments.

Conclusion: The EDC splitting approach is a feasible method of exposing the lateral elbow, providing safe and reliable access to the radial head.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Direct lateral approach to elbow; radial head fracture; extensor digitorum communis splitting approach; posterior interosseous nerve; clinical outcomes

This study was approved by the National Healthcare Group Domain Specific Review Board.

*Reprint requests: Fucai Han, MRCS, Department of Orthopaedic Surgery, University Orthopaedics, Hand & Reconstructive Microsurgery Cluster, National University Hospital, National University Health System, NUHS Tower Block, Level 11, 1E Kent Ridge Rd, Singapore 119228.
E-mail address: fucai_han@nuhs.edu.sg (F. Han).

1058-2746/$ - see front matter © 2016 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2015.09.030

Fractures of the radial head account for approximately 20% of all elbow fractures.[13] Surgical treatment of radial head fractures—whether by open reduction and internal fixation (ORIF) or by radial head replacement—results in satisfactory outcomes.[9,15,18,28,29] There are several possible approaches when performing surgery for radial head fractures, with the choice ultimately dependent on surgeon preference and the injury-specific fracture configuration. Because radial head fractures most commonly involve the anterolateral aspect of the radius,[12,27] the Kocher approach to the radial head is frequently used. This approach uses an interval between the anconeus and extensor carpi ulnaris (ECU). Alternatively, an approach using the Kaplan interval—between extensor carpi radialis brevis and extensor digitorum communis (EDC)—has also been described for access to the radial head.

Surgery of the radial head entails risk of injury to the posterior interosseous nerve (PIN), due to its proximity to the PIN, anatomic variation of the nerve, and the lack of clear intermuscular planes.[26] Furthermore, there is also the risk of injury to the lateral ulnar collateral ligament (LUCL), particularly with the Kocher approach, which could lead to elbow instability.[4] Proximal extension of the Kocher approach involves detachment of the common extensor origin, which further destabilizes the elbow. Radial head fractures have a relatively low incidence, accounting for only 1.5% to 4% of all fractures in adults, and not all need to be treated surgically.[8,13] The potential lack of familiarity with lateral elbow approaches among orthopedic trainees may further increase the risk of iatrogenic damage to the elbow.

The EDC splitting approach for lateral elbow exposure was first described by Hotchkiss[17] and could provide more reliable access to the anterior aspect of the radial head.[6,24] The approach is more anterior and reduces the risk of injury to the LUCL. To date, all previous studies related to this approach have been anatomic cadaveric studies, which have reported promising results in terms of better access to the radial head with potentially reduced injury to the LUCL[6] while maintaining a similar safe distance to the PIN compared with the Kocher approach.[24] No clinical studies have assessed the feasibility of this surgical approach in the treatment of patients with radial head fractures.

To the best of our knowledge, our study is the first to report clinical outcomes with the use of this approach in the surgical treatment of radial head fractures. Our aim was to determine if this approach could be used to provide adequate access for internal fixation or replacement of the radial head, while avoiding iatrogenic damage to the elbow, in particular, PIN palsy and LUCL damage leading to elbow instability. Outcome data were obtained in objective postoperative clinical examination findings as well as subjective patient-reported scores.

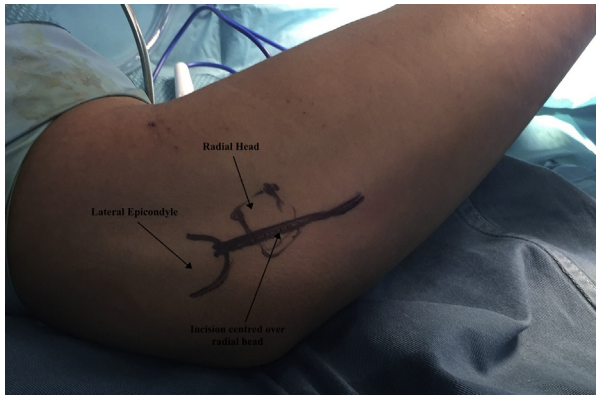

Figure 1 Skin incision with the arm pronated.

Methods

This retrospective case series reviewed patients with closed isolated radial head fracture who underwent ORIF or radial head arthroplasty via the EDC splitting approach between 2011 and 2014. The study excluded patients for whom postoperative clinical evaluation data were not available (ie, lost to follow-up) or those with a follow-up period of less than 12 months. Thirteen patients were eligible and included in the final analysis.

Indications for ORIF of radial head fractures in our cohort included patients with Mason type II radial head fractures with a block to motion, when anatomic reduction and restoration of articular congruity with stable fixation could be achieved, and in younger patients whenever possible. Radial head replacement was performed in patients with comminuted intra-articular fractures for which stable fixation could not be performed.

Operative technique

Surgery was performed under general anesthesia in all cases with the administration of prophylactic perioperative intravenous antibiotics at induction and for a further 24 hours postoperatively. All surgeries were performed using the EDC splitting approach. Patients were positioned supine with their elbow flexed and fully pronated on a hand table to increase the distance between the site of incision and the PIN.[26,28] A proximal arm pneumatic tourniquet was applied and used in all patients.

A longitudinal skin incision was made directly over the radial head, palpating it through the substance of the EDC, extending from the central portion of the origin of the EDC at the lateral epicondyle down along the EDC muscle belly (Fig. 1). Dissection was continued down to the level of fascia to expose the EDC origin. The fibers of the EDC were split over the radial head, not more than 5 cm distal to the radiocapitellar joint along length of proximal radius (Fig. 2), and the capsule and annular ligament were incised to visualize the radial head and neck (Figs. 3 and 4). A conscious effort was made to ensure retractors were not placed with excessive force to avoid injury to the PIN. If visualized, the PIN was protected. In all cases using this approach, the LUCL was not encountered or injured. At the end of the procedure, the capsule was repaired and the skin closed in layers.

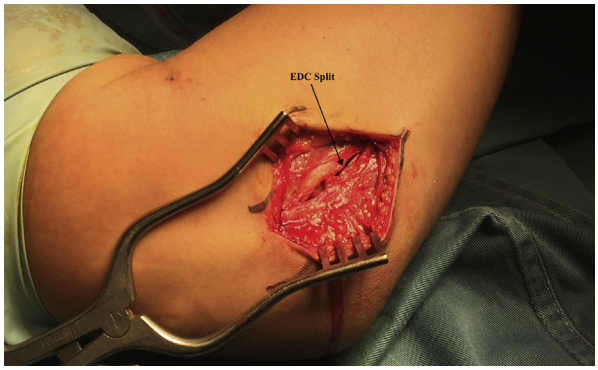

Figure 2 Split made in extensor digitorum communis.

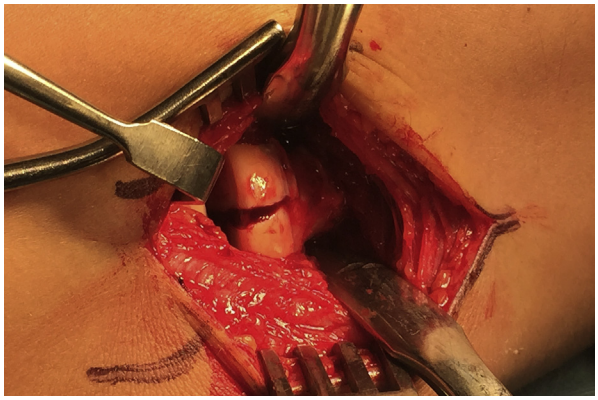

Figure 3 Visualization of the exposed fractured radial head.

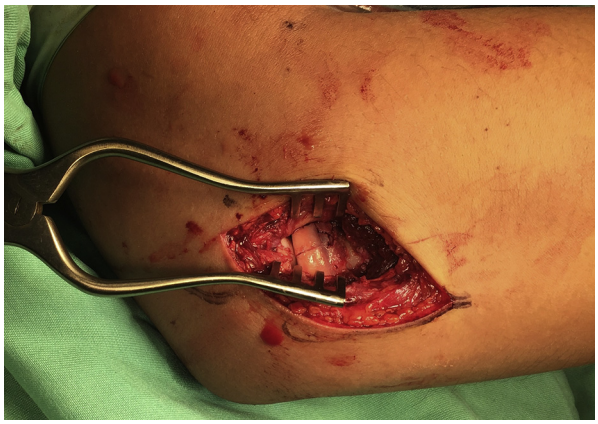

Figure 4 After fixation of the radial head.

Radial head replacements were performed using a radial head prosthesis system (Small Bone Innovations, New York, NY, USA). ORIF was performed using headless screws.

Postoperative rehabilitation

Immediate postoperative rehabilitation aimed to allow early mobilization to regain elbow range of motion. Subsequent rehabilitation sessions focused on exercises to strengthen the elbow and optimize elbow function to allow return to work. Patients were started on gentle elbow flexion-extension exercises, as tolerated, with shoulder and wrist range of motion exercises immediately postoperatively. Gentle pronation and supination elbow exercises were started after 2 to 3 weeks. Progressive strengthening and weight-bearing exercises were commenced after 6 to 8 weeks.

Evaluation of outcomes

All patients had a minimum follow-up period of 12 months postoperatively. Two independent authors (F.H., J.C.L.) who were not involved in the initial surgical management, performed the final postoperative clinical evaluation. The clinical assessments consisted of the Mayo Elbow Performance Score (MEPS),[21] Disabilities of the Arm, Shoulder and Hand (DASH) outcome measure,[14] and the American Shoulder and Elbow Surgeons (ASES) elbow score.[16] In addition, patients' satisfaction of the surgery, motion (assessed using a goniometer and compared with the contralateral limb), stability, and strength of the elbows were evaluated with the modified ASES elbow score. A MEPS score of 90 and above is considered excellent, 75 to 89 good, 60 to 74 fair, and any score below 60 is considered a poor outcome.

Results

The demographics of our patient cohort are illustrated in Table I. The mean age at the time of surgery was 40.6 years, (range, 25-61 years). The final evaluation was performed at an average of 22.5 months (range, 12-36 months) postoperatively. The dominant upper limb was injured in 84.6% of the patients. The mechanism of injury in the 13 patients consisted of 10 mechanical falls (76.9%), 2 as a result of a sports injury (15.4%) and 1 minor road traffic accident (7.7%). None of the patients had any neurologic or vascular deficit at the time of the initial assessment. All were closed fractures.

The fractures were classified according to the Mason classification. Three radial head replacements and 10 ORIFs were performed for these fractures, as reported in Table I. The mean time to complete ORIF of the radial head was 85.4 minutes (range 54-121 minutes), and the time for radial head arthroplasty was 71.8 minutes (range 51-92 minutes).

The results of the objective clinical assessments at follow-up are summarized in Table II. At the final clinical follow-up, all patients had returned to work. There was no instability in external rotation or with varus and valgus stress of the affected elbow. The mean range of motion was 110° (range, 100°-140°) of flexion/extension and 136° (range, 105°-180°) of pronation/supination.

Table I Demographics of the patient cohort

Patient	Follow-up (mon)	Age (y)	Gender	Arm	Occupation	Mason classification	Surgery performed
1	16	28	M	D	Student	III	Fixation
2	36	56	F	ND	Desk-based	III	Replacement
3	24	60	F	D	Laborer	II	Fixation
4	30	30	M	D	Laborer	II	Fixation
5	36	61	F	D	Laborer	II	Fixation
6	12	26	M	D	Desk-based	II	Fixation
7	22	47	F	D	Desk-based	II	Fixation
8	20	37	M	D	Laborer	II	Fixation
9	26	51	F	D	Homemaker	III	Replacement
10	32	27	M	D	Desk-based	II	Fixation
11	12	53	F	D	Desk-based	III	Replacement
12	12	32	M	ND	Laborer	II	Fixation
13	14	47	F	D	Desk-based	II	Fixation

D, dominant; *F*, female; *M*, male; *ND*, nondominant.

Table II Results of the clinical evaluations performed at last follow-up

Patient	Range of motion (°)		Stable	Power	
	Extension/flexion	Pronation/supination		Extension/flexion	Pronation/supination
1	10/140	55/50	Yes	5/5	4/4
2	0/140	80/80	Yes	4/4	4/5
3	5/120	70/70	Yes	5/5	4/4
4	10/140	55/50	Yes	5/5	4/5
5	15/120	70/70	Yes	5/5	4/5
6	5/120	70/70	Yes	5/5	5/5
7	0/130	90/90	Yes	5/5	4/5
8	10/120	60/50	Yes	5/5	4/4
9	10/140	70/70	Yes	5/5	4/4
10	10/120	60/60	Yes	5/5	5/5
11	10/140	90/90	Yes	5/5	5/5
12	10/120	60/60	Yes	4/4	4/4
13	20/120	70/70	Yes	5/5	4/4

Intraoperative image intensifier images and postoperative radiographs were obtained in all patients and assessed for adequacy of treatment. The 3 radial head replacements were well positioned and appropriately sized, with no overstuffing. Satisfactory articular reduction and fixation were achieved in the 10 ORIF patients. No patients required revision surgery or encountered complications.

Outcome scores

The outcome scores are summarized in Table III. The mean MEP score was 90 (range, 80-100), with 6 of the 13 patients being scored ''excellent,'' and the remaining 7 scored ''good.'' The mean ASES elbow score was 89.6 (range, 77-97), and the mean DASH score was 12.8 (range, 6.67-25.8). Patients reported a mean overall ASES satisfaction score of 8.5 (range, 6-10). There were no cases of deep infection, nonunion, radial nerve injury, instability, dislocation, fixation, or implant failure at the last follow-up assessment.

Patients 2, 9, and 11, who underwent radial head replacement, had a mean MEPS of 95 (range, 85-100), a mean ASES elbow score of 94.7 (range, 92-97), a mean DASH score of 7.5 (range, 6.7-8.3) and a mean overall ASES satisfaction rating of 9.3 (range, 9-10). The remaining patients, who underwent ORIF, had a mean MEPS of 91.1 (range, 80-100), a mean ASES elbow score of 88.1 (range, 77-93), a mean DASH score of 14.4 (range, 6.7-25.8), and a mean overall ASES satisfaction score of 8.3 (range, 6-10).

Discussion

Our results have shown that the EDC splitting approach can be safely used for surgery on the radial head, whether

Table III Patient-reported outcome scores

Patient	MEPS	ASES score		DASH
		Elbow	Satisfaction	
1	85	88	7	19.2
2	100	97	9	7.5
3	95	93	10	11.7
4	85	86	9	19.2
5	100	93	10	6.7
6	85	89	9	8.3
7	100	91	9	8.3
8	80	86	7	6.7
9	85	92	9	8.3
10	95	90	8	19.2
11	100	95	10	6.7
12	80	77	6	25.8
13	80	88	8	19.2

ASES, American Shoulder and Elbow Surgeons; *DASH*, Disabilities of the Arm, Shoulder and Hand; *MEPS*, Modified Elbow Performance Score.

internal fixation or replacement. All patients regained functional range of motion,[22] with no incidences of instability or nerve palsy. Good results were also obtained in patient satisfaction and outcome scores postoperatively.

The Kocher approach is a familiar, commonly performed lateral approach that avoids exposure of the PIN, with protection provided by the surrounding muscle bellies. Using the Kocher approach on the pronated forearm also provides a safe working surgical field away from the PIN. The advantages of the EDC splitting approach, however, are being increasingly recognized: it involves less soft tissue dissection than the Kocher approach, provides superior exposure to the anterior aspect of the radial head, and may reduce the risk of iatrogenic elbow instability. In isolated radial head fractures, the EDC splitting approach may thus be the more reliable technique.

The current literature on the EDC splitting approach consists predominantly of descriptive cadaveric studies. Desloges et al[6] compared the surface area exposure obtained with the EDC splitting approach to the Kocher approach in fresh frozen cadavers, finding that the former consistently provided a greater degree of exposure to the anterior aspect of the radial head. This came primarily from better exposure of the anteromedial radial head, a vital feature given that a recent study showed that 79% of Mason type II fractures extended to the anteromedial quadrant.[27] They further found that although greater visualization was achieved with extension of the Kocher approach, this necessitated detachment of the common extensor origin—an important secondary stabilizer of the elbow[5]—with postulated consequent instability.[5,20] If the Kocher approach is not extended, adequate visualization of the anterior radial head often requires anterior retraction of the ECU and EDC muscle bellies, and aggressive retraction in this manner puts the PIN at risk of traction injury.

Moreover, they theorized that the proximity of the Kocher interval to the LUCL indicates that use of the EDC splitting approach should reduce the risk of iatrogenic LUCL damage. Iatrogenic injury to the LCL complex may lead to chronic posterolateral rotatory instability,[4,5,23] which involves external rotation at the ulnohumeral articulation and resultant posterolateral subluxation of the radial head. The LCL is a constraint to external rotation, with the LUCL considered to be the main constraint to varus and rotatory laxity.[5,23] In our study, the LUCL was not violated during the surgical approach. We did not incise and repair the LCL complex as in the Kocher approach. None of our patients reported instability in external rotation.

The EDC splitting approach was performed in all patients in our series with the forearms in pronation, which is predicated on an anatomic study by Strachan and Ellis,[25] who described the position of the PIN in the cadaveric forearm. They showed that pronation moved the PIN by approximately 1 cm more medially from the elbow joint to the radial tubercle. Diliberti et al[7] have also demonstrated that full pronation places the PIN further from the plane of dissection, thus minimizing risk of injury to the nerve. More specifically, a cadaveric study by Schimizzi et al[24] recommended minimum safe dissection distances of up to 29 mm from the radiocapitellar joint and up to 42 mm from the lateral epicondyle with the forearm in pronation. The average distances from the radiocapitellar joint and lateral epicondyle in the Schimizzi et al study were 48.2 mm and 68.7 mm, respectively.

Importantly, all patients had regained functional range of motion at 1-year follow-up. A study by Giannicola et al[10] showed that after surgery to the radial head, the critical time period for recovery of range of motion was the first 6 months. The mean MEPS of 90 obtained in our cohort is comparable to those reported for both ORIF[18] and radial head replacement[2] performed via the Kocher approach. Similarly comparable ASES[15] and DASH[18,28] scores were obtained in this study. Several studies have been performed to delineate patients who require ORIF from those who require radial head replacements[9,29] as well as the comparative clinical outcomes after these surgeries,[1,29] and it is not our intent in this study to address either of these issues. We simply propose that the use of the EDC splitting approach in performing either type of surgery does not result in poorer outcomes objectively and subjectively.

The PIN provides motor innervation to the extensor compartment of the forearm, and damage to the PIN potentially results in significant functional deficit. Although the exact incidence of iatrogenic PIN damage has never been reported, it is not an uncommon occurrence, particularly with surgeons inexperienced in approaching the proximal radius. In attempts to minimize the risk of

iatrogenic PIN injury, myriad cadaveric dissection studies have been performed to assess the anatomic variation of the nerve.[3,11] We do not recommend an incision into the EDC beyond 5 cm distal to radiocapitellar joint along length of proximal radius because the EDC is shown to receive branches from the PIN after the PIN has sent branches to the supinator.[19] The PIN exits the supinator approximately 5.8 cm from the radiocapitellar joint.[3] With an EDC incision of not more than 5 cm, as described in our case series, denervation of the EDC by splitting it as described in this report is therefore unlikely.

After a prerequisite learning curve, the EDC splitting approach should not take any longer to perform than the current standard approaches. Although we did not have operative times using the Kocher approach from our local center for comparison, the mean operative time in our cohort was comparable to those reported in other studies. Al-Burdeni et al[1] reported mean operative times of 129.2 minutes for ORIF and 96.8 minutes for arthroplasty.

The strengths of this study include that all patients were followed up and that the clinical examination findings and postoperative outcome scores were studied by the authors who were not involved in the initial surgical management and were blinded to the surgical approach used in these patients, thus minimizing bias.

There are recognized limitations of this study. The small sample size and the retrospective nature of this study limit the strength of the conclusions we can draw from our results. As mentioned, the overall incidence of elbow fractures is relatively low, and often, the presence of other concurrent injuries necessitates greater exposure of the elbow than can be provided from lateral approaches. Our study did not have a control group or preoperative scores for comparison. We have, however, shown the good functional outcomes obtained via this approach to be at least equivalent to those obtained via the Kocher approach. We believe this preliminary study is an important first step in the clinical translation of cadaveric studies performed thus far. Future multicenter studies with a larger number of patients could clarify some of the issues raised in this study.

Conclusion

The EDC splitting approach was successfully used to perform ORIF and radial head arthroplasty in our case series of 13 patients with no adverse events. All patients had good functional outcomes at a minimum follow-up period of 1 year postoperatively, with no iatrogenic injury to the PIN or LUCL. This approach is a viable alternative for surgical exposure of the radial head and should be more commonly used for surgical treatment of isolated radial head fractures. Larger-scale studies are required to further identify the limitations of this approach.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Al-Burdeni S, Abuodeh Y, Ibrahim T, Ahmed G. Open reduction and internal fixation versus radial head arthroplasty in the treatment of adult closed comminuted radial head fractures (modified Mason type III and IV). Int Orthop 2015;39:1659-64. http://dx.doi.org/10.1007/s00264-015-2755-1
2. Ashwood N, Bain GI, Unni R. Management of Mason type-III radial head fractures with a titanium prosthesis, ligament repair, and early mobilization. J Bone Joint Surg Am 2004;86:274-80.
3. Calfee RP, Wilson JM, Wong AH. Variations in the anatomic relations of the posterior interosseous nerve associated with proximal forearm trauma. J Bone Joint Surg Am 2011;93:81-90. http://dx.doi.org/10.2106/JBJS.I.01242
4. Charalambous CP, Stanley JK, Siddique I, Aster A, Gagey O. Posterolateral rotatory laxity following surgery to the head of the radius: biomechanical comparison of two approaches. J Bone Joint Surg Br 2009;91:82-7. http://dx.doi.org/10.1302/0301-620X.91B1.21039
5. Cohen MS, Hastings H. Rotatory instability of the elbow. The anatomy and role of the lateral stabilizers. J Bone Joint Surg Am 1997;79:225-33.
6. Desloges W, Louati H, Papp SR, Pollock JW. Objective analysis of lateral elbow exposure with the extensor digitorum communis split compared with the Kocher interval. J Bone Joint Surg Am 2014;96:387-93. http://dx.doi.org/10.2106/JBJS.M.00001
7. Diliberti T, Botte MJ, Abrams RA. Anatomical considerations regarding the posterior interosseous nerve during posterolateral approaches to the proximal part of the radius. J Bone Joint Surg Am 2000;82:809-13.
8. Ditsios KT, Stavridis SI, Christodoulou AG. The effect of haematoma aspiration on intra-articular pressure and pain relief following Mason I radial head fractures. Injury 2011;42:362-5. http://dx.doi.org/10.1016/j.injury.2010.09.003
9. Furry KL, Clinkscales CM. Comminuted fractures of the radial head: arthroplasty versus internal fixation. Clin Orthop Relat Res 1998;353:40-52.
10. Giannicola G, Polimanti D, Bullitta G, Sacchetti FM, Cinotti G. Critical time period for recovery of functional range of motion after surgical treatment of complex elbow instability: prospective study on 76 patients. Injury 2014;45:540-5. http://dx.doi.org/10.1016/j.injury.2013.11.033
11. Hackl M, Wegmann K, Lappen S, Helf C, Burkhart KJ, Müller LP. The course of the posterior interosseous nerve in relation to the proximal radius: is there a reliable landmark? Injury 2015;46:687-92. http://dx.doi.org/10.1016/j.injury.2015.01.028
12. Haverstock JP, Katchky RN, Lalone EA, Faber KJ, King GJ, Athwal GS. Regional variations in radial head bone volume and density: implications for fracture patterns and fixation. J Shoulder Elbow Surg 2012;2:1669-73. http://dx.doi.org/10.1016/j.jse.2012.07.002
13. Herbertsson P, Josefsson PO, Hasserius R, Karlsson C, Besjakov J, Karlsson M. Uncomplicated Mason type-II and III fractures of the

radial head and neck in adults. A long-term follow-up study. J Bone Joint Surg Am 2004;86-A:569-74.
14. 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;29:602-8. Erratum in: Am J Ind Med. 1996;30:372.
15. Ikeda M, Sugiyama K, Kang C, Takagaki T, Oka Y. Comminuted fractures of the radial head. Comparison of resection and internal fixation. J Bone Joint Surg Am 2005;87:76-84. http://dx.doi.org/10.2106/JBJS.C.01323
16. King GJ, Richards RR, Zuckerman JD, Blasier R, Dillman C, Friedman RJ, et al. A standardized method for assessment of elbow function. Research Committee, American Shoulder and Elbow Surgeons. J Shoulder Elbow Surg 1999;8:351-4.
17. King GJW. Fractures of the head of the radius. In: Green DP, Hotchkiss RN, Pedersen WC, Wolfe SW, editors. Green's operative hand surgery. 5th ed. Philadelphia: Elsevier; 2005. p. 847-8.
18. Lindenhovius AL, Felsch Q, Ring D, Kloen P. The long-term outcome of open reduction and internal fixation of stable displaced isolated partial articular fractures of the radial head. J Trauma 2009;67:143-6. http://dx.doi.org/10.1097/TA.0b013e31818234d6
19. Liu J, Pho RW, Pereira BP, Lau HK, Kumar VP. Distribution of primary motor nerve branches and terminal nerve entry points to the forearm muscles. Anat Rec 1997;248:456-63.
20. McKee MD, Schemitsch EH, Sala MJ, O'Driscoll SW. The pathoanatomy of lateral ligamentous disruption in complex elbow instability. J Shoulder Elbow Surg 2003;12:391-6. http://dx.doi.org/10.1016/S1058-2746(03)00027-2
21. Morrey BF, An KN. The Mayo elbow performance score (MEPS). Functional evaluation of the elbow. In: Morrey BF, editor. The elbow and its disorders. 3rd ed. Philadelphia: WB Saunders; 2000. p. 82.
22. Morrey BF, Askew LJ, Chao EY. A biomechanical study of normal functional elbow motion. J Bone Joint Surg Am 1981;63:872-7.
23. Nestor BJ, O'Driscoll SW, Morrey BF. Ligamentous reconstruction for posterolateral rotatory instability of the elbow. J Bone Joint Surg Am 1992;74:1235-41.
24. Schimizzi A, MacLennan A, Meier KM, Chia B, Catalano LW 3rd, Glickel SZ. Defining a safe zone of dissection during the extensor digitorum communis splitting approach to the proximal radius and forearm: an anatomic study. J Hand Surg Am 2009;34:1252-5. http://dx.doi.org/10.1016/j.jhsa.2009.04.026
25. Strachan JC, Ellis BW. Vulnerability of the posterior interosseous nerve during radial head resection. J Bone Joint Surg Br 1971;53:320-3.
26. Thomas SJ, Yakin DE, Parry BR, Lubahn JD. The anatomical relationship between the posterior interosseous nerve and the supinator muscle. J Hand Surg Am 2000;25:936-41.
27. van Leeuwen DH, Guitton TG, Lambers K, Ring D. Quantitative measurement of radial head fracture location. J Shoulder Elbow Surg 2012;21:1013-7. http://dx.doi.org/10.1016/j.jse.2011.08.056
28. Watters TS, Garrigues GE, Ring D, Ruch DS. Fixation versus replacement of radial head in terrible triad: is there a difference in elbow stability and prognosis? Clin Orthop Relat Res 2014;472:2128-35. http://dx.doi.org/10.1007/s11999-013-3331-x
29. Zwingmann J, Welzel M, Dovi-Akue D, Schmal H, Südkamp NP, Strohm PC. Clinical results after different operative treatment methods of radial head and neck fractures: a systematic review and meta-analysis of clinical outcome. Injury 2013;44:1540-50. http://dx.doi.org/10.1016/j.injury.2013.04.003