Surgical treatment of chronic anterior radial head dislocations in missed Monteggia lesions in children: A rationale for treatment and pearls and pitfalls of surgery

LC Langenberg[1,2], ACH Beumer[3], B The[3], KLM Koenraadt[4] and D Eygendaal[2,3]

Abstract

Introduction: The treatment of chronic radial head dislocations after Monteggia lesions in children can be challenging. This article provides a detailed description of the most frequently performed surgical technique: an ulna osteotomy followed by annular ligament reconstruction. Accordingly, we present the clinical and radiological results of 10 paediatric cases.

Material and methods: All paediatric patients that had a corrective osteotomy of the ulna for a missed Monteggia lesion between 2008 and 2014 were evaluated with standard radiographs and clinical examination. A literature search was performed to identify the relevant pearls and pitfalls of surgery. Primary outcome was range of motion.

Results: We included 10 patients, with a mean follow-up of 2.5 years. Postoperative range of motion generally improved 30.7°. Even in a patient with obvious deformity of the radial head, range of motion improved after surgery, without residual dislocation of the radial head.

Conclusion: Corrective proximal ulna osteotomy with rigid plate fixation and annular ligament reconstruction yields good results in patients with chronic radial head dislocation following a Monteggia lesion. Surgery should be considered regardless of patient age or time since trauma. Given substantial arguments in literature, we discourage surgery if a CT scan shows dome-shaped radial head dysmorphic features in work-up to surgery.

Introduction

Although most children with a radial head dislocation are at first asymptomatic, complaints may arise over the course of years. Pain, loss of range of motion (ROM) and neurologic complaints can occur, primarily because of scarring, chronic compressive changes, or due to nerve entrapment in the (sub)luxating joint.[1,2] In the growing child, long-standing radial head dislocation may therefore cause deformity of the radial head, overgrowth of the proximal radius, instability and early osteoarthritic changes of the elbow joint.[3–7]

[1]Department of Orthopaedic Surgery, Amsterdam University Medical Center, Amsterdam, The Netherlands
[2]Department of Orthopaedic Surgery, Amsterdam University Medical Center, The Netherlands
[3]Department of Orthopaedic Surgery, Upper Limb Unit, Amphia, Breda, The Netherlands
[4]Foundation for Orthopedic Research, Care & Education (FORCE), Amphia, Breda, The Netherlands

Corresponding author:
LC Langenberg, Department of Orthopaedic Surgery, Amsterdam University Medical Center, Boelelaan 1117, Amsterdam 1081HV, the Netherlands.
Email: lisette.langenberg@gmail.com

Furthermore, the ulna is relatively shortened, which may lead to complaints at the level of the wrist. Therefore, reduction of the radial head should take place as soon as possible to prevent these long-term harmful effects.[1,4]

Mechanism of injury and the effect of growth

If a Monteggia fracture occurs, the interosseous membrane ruptures. Consequently, tension on the radial shaft and radial head reduces, allowing it to dislocate. This mechanism explains why over 70% of radial head dislocations are in an anterior direction (Bado type I). Several articles that describe the trauma mechanism for a Bado type I Monteggia fracture have been published, which render different explanations.[8–10] Secondly, the annular ligament may rupture or dislocate from the radial head, and migrate into the proximal radioulnar joint, interfering with reduction of the radial head.[3,6,11,12] Finally, during growth, ulnar angulation may develop,[4,13,14] which may result in a persisting dislocation of the radial head. Treatment ideally should address all components of the injury, providing reduction of the radial head, correction of ulnar length and angulation and reconstruction of the annular ligament.[11,15,16]

Surgery for posttraumatic chronic radial head dislocation may include an ulna osteotomy, for which there are several ways of fixation, and/or annular ligament reconstruction (ALR). Reduction of the radial head can be achieved by an open approach or without opening the joint.[17–20] No consensus has yet been reached regarding the necessity for the several steps in this surgical procedure. Therefore, work-up to surgery is also still unclear; it is unknown whether dysmorphic features of the radial head are a contraindication for surgery or whether time between trauma and surgery is of influence on surgical outcome. In this article, we will therefore outline the work-up, treatment rationale and several pearls and pitfalls of the surgical technique. We will therefore describe the clinical and radiological outcome for ROM in 10 paediatric cases.

Materials and methods

We composed a patient cohort consisting of all consecutive patients undergoing a corrective osteotomy of the ulna between 2008 and 2014, for chronic radial head malalignment following a Monteggia lesion. A radial head dislocation was considered a chronic lesion four weeks after sustaining a trauma.[4,6,21,22] Congenital dislocations were excluded.

Patient follow-up consisted of a physical examination and a radiological assessment. Radiological check-ups performed conform to local protocols.

Work-up to surgery

Ideal timing of surgery has been widely discussed in literature, and opinions vary. We decided to use each patient's amount of radial head deformity as a guideline. Several authors regard the chances of successful surgery low, if the concavity of the radial head has been completely lost.[3,16,23] These studies identified that the amount loss of concavity of the radial head directly determines surgery outcome more so than patient age or time since trauma.

Prior to surgery, a CT scan is deemed essential to assess the degree of radial head deformity. Dysplastic changes of the radiocapitellar joint (RCJ) are identifiable on a CT scan, and the process enables the construction of a 3D model.[14,24] In cases where the patient is a young child with considerable residual growth and potential for remodeling,[15,25] an MRI may be preferable.

In two patients that were seen in our hospital, radial head deformation had developed to such extent that the radial head had lost its concavity, and as such, we decided not to perform surgery. In both patients, an exceptionally prominent dome-shaped radial head was noted, with a slender radial neck (Figure 1(a) to (c)).

Alternatives for surgery in these cases consist of follow-up and planning of radial head excision if elbow complaints persist after bone maturity has been reached. However, this procedure is considered as salvage surgery.[7] In a patient seen at our hospital, follow-up of a dome-shaped radial head lasted seven years (Figure 1). The patient had fallen of a slide at the age of seven years, and the elbow had initially been immobilised in a cast without recognition of the radial head dislocation. Four years following trauma, complaints of pain and restrained elbow flexion arose. Upon presentation in our hospital, six years after trauma, there was a prominent, palpable radial head and a restriction of elbow ROM with a positive anterior impingement test were noted (flexion 100, extension +10, pronation 30 and supination 45°). On examination at last follow-up, no pain was present, but the patient experienced crepitations in the joint. An evident cubitus valgus was seen (estimated 25°), and ROM, mostly supination, was impaired (flexion 110, extension +10, pronation 70 and supination 45°). A 'watchful waiting' policy is now initiated, to evaluate the patients' complaints while the skeleton matures.

In cases of deformation with preserved concavity, to date, no tool has been installed to relate radial head deformation to surgery success rates. Kim et al. described a head–neck ratio[14] (Figure 2(a) to (c)). However, they were not able to identify the consequences of a higher ratio, other than that the surgeon had to be aware of a more difficult reposition of the radial head due to anatomical anomalies.
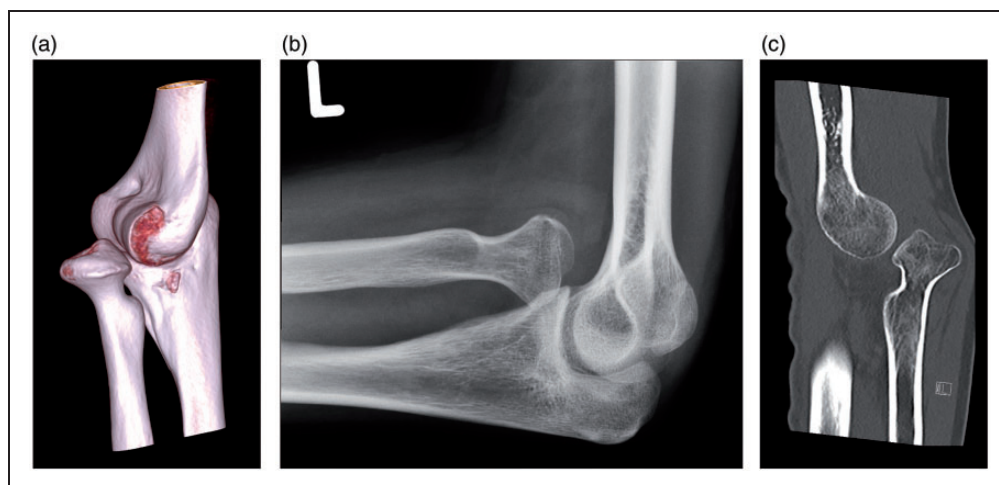
Figure 1. (a to c) Persistent radial head dislocation seven years following Monteggia lesion (head–neck ratio 2.2).
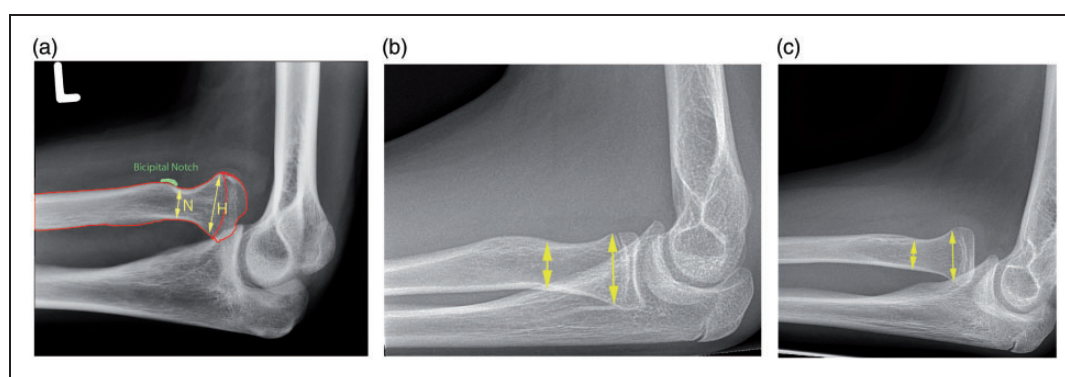
Figure 2. (a) Head/neck ratio. H/N; H = metaphyseal diameter measured at the widest part adjacent to the physis, N = neck diameter measured at the narrowest past proximal of the bicipital notch. (b) non-affected side (head/neck ratio 1.6); (c) affected side 2C (head/neck ratio 1.9).

Surgical technique

All operations were performed by two orthopaedic surgeons (DE and BT). Patients were operated under general anaesthesia, in a supine position. First, the proximal radioulnar joint (PRUJ) was opened using a lateral incision (Kaplan incision). The joint space of the PRUJ was debrided, and annular ligament remnants were identified and preserved where possible.

The ulna was approached using the same incision that gave access to the PRUJ. A wedge osteotomy of the ulna at the most proximal site possible was performed, adapting ulna length and angulation under radiologic guidance until radial head reduction was achieved. After radial head reduction, rigid plate fixation of the osteotomy of the ulna was performed with a locking compression plate (LCP). The plate was bent if necessary. We used 3.5-mm locking head screws for fixation. Fluoroscopy was used to determine the level of the osteotomy and the optimal placement of the plate and screws, avoiding interference of the screws with the growth plate of the proximal ulna. No bone grafts were used. Thereafter, an ALR was performed, using annular ligament remnants when possible. Alternatively, reconstruction was performed by using a piece of triceps fascia, that was attached with transosseous sutures.

Finally, elbow ROM and radial head stability were assessed postoperatively, while the patient was still under general anaesthesia. A radioulnar K-wire was placed to secure the radial head reduction, if the surgeon preferred to support radial head stability. This K-wire was placed distally to the PRUJ to prevent damage to the cartilage and was then removed after four weeks.

Patients were immobilised for six weeks in an above elbow cast in 90° flexion, with the forearm in a neutral position following surgery. Active forearm rotation, elbow flexion and extension were allowed at six weeks postoperatively. Plate and screws were removed routinely 6–12 months after surgery. Figure 3(a) shows a
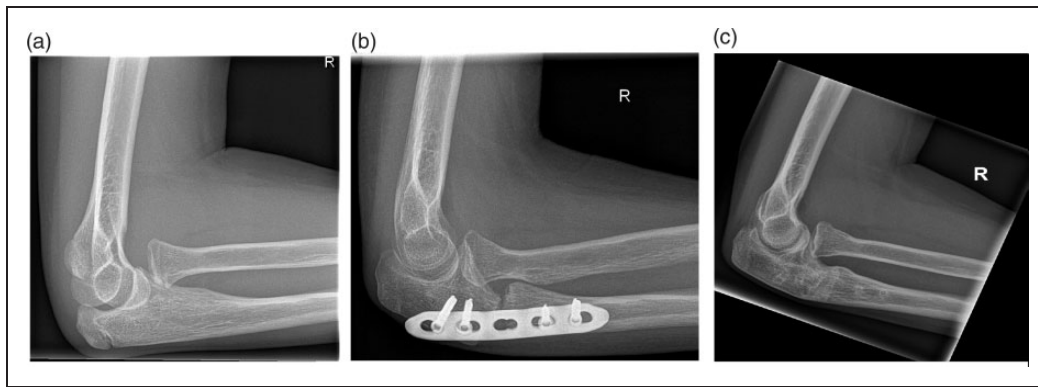
Figure 3. (a) Preoperative X-ray of the elbow in a patient that had sustained a Monteggia injury two years earlier; (b) X-ray of the elbow six weeks after ulna osteotomy and annular ligament reconstruction; (c) outcome 1.5 years after surgery.

preoperative X-ray of the elbow in a patient that had sustained a Monteggia injury two years prior to presentation at our hospital. Figure 3(b) depicts the X-ray of the situation directly after ulna osteotomy and ALR, and Figure 3(c) shows the outcome 1.5 years after surgery.

Results

Mean age at surgery was 8.2 years (range 5.3–12.7 years). Mean interval between injury and surgery was 1.8 years (range 0–4 years). All dislocations were of Bado type I (anterior). In four patients, the initial diagnosis had been missed on presentation. Detailed patient characteristics are described in Table 1.

Intraoperative findings

Preoperative testing of the ROM under general anaesthesia did not notably differ from preoperative clinical findings. In four patients, we noted that the severity of radial head deformation on X-ray (head–neck ratio calculated following Kim et al.[14]) and on intraoperative inspection did not correlate. No relationship was identified between the time since trauma and surgery, patient age or previous surgery. For example, the patient that had the longest time to surgery (four years), had a head–neck ratio of 1.8 and only mild deformation of the radial head on intraoperative inspection.

Postoperative ROM

In all cases, the radial head was stable on direct postoperative stability testing under general anaesthesia. Follow-up was 30.4 months on average (median 59 months (707 days); range 2.3–94.1 months). One patient was lost to follow-up (Table 1: patient nr. 7).

All osteotomies had healed within six months, which was demonstrated by standard radiographs. One child, that had experienced complaints of a transient

dropping hand after previous surgery around the proximal radius, reported a transient recurrence of the radial nerve palsy following surgery (patient 5). No other evident complications were reported.

Postoperative ROM (Table 2) increased overall with 30.7°. No explanation was identified for differences in outcome between patients. No relationship was established between ROM outcome and radioulnar pinning, previous surgery, time between trauma and surgery, or age at time of surgery. Similarly, preoperative parameters such as radiological deformation or dysmorphic features of the radial head on preoperative inspection had no influence on ROM outcome.

Discussion

Postoperatively, ROM generally increased in our case series. Three patients noted a decrease in either pronation, flexion or extension. The majority of other studies found an occasional decrease in pronation,[3,5,6,7,11,22,26–30] and flexion generally increased. However, no explanations formerly noted in literature, such as time to surgery or amount of radial head dysplasia, seemed to be of any influence for the patients in our cohort.

We note that if the radial head is found to be dome-shaped, and has lost all its concavity, surgery tends to be unsuccessful. This is supported by convincing arguments.[3,7,12,15,31,32] Even though we did not find that radial head deformation influenced the outcome, we maintain that a CT scan is mandatory in preparation for surgery.

Unfortunately, our cohort was too small to perform a statistical analysis. Questions regarding preoperative patient characteristics and their influence on outcome may be answered by performing a literature review with pooled data.

For each step in surgery, a number of 'pearls and pitfalls' were identified following our literature search

Table 1. Patient characteristics.

Pt nr	Lesion	Preoperative radial head description	Head–neck ratio	Previous surgery	Age at time of trauma	Time trauma-surgery[a]	Affected side
1	Missed Monteggia	Mild deformation, caput magnum	1.8	2; no details short after trauma	5	4 Years	Dominant
2	pers. RHD	Mild deformation, Reduction impossible	1.5	None	11	1 Year	Non-dominant
3	Re-RHD following ulna osteotomy	Mild deformation, Reduction possible	1.5	Ulna osteotomy, pen fixation 1 year after trauma	5	2 Years	Non-dominant
4	Missed RHD	Obvious deformation Reduction unstable	1.5	None	6	1.5 Month	Dominant
5	Monteggia	Mild deformation Reduction possible	1.6	None	4	1 Year	Non-dominant
6	Missed Monteggia	Mild deformation Reduction possible	3.2	Ulna osteotomy External fixation 1.5 year after trauma	3	3 Years	Non-dominant
7	Monteggia	Obvious deformation, Diameter discrepancy in pronation		Ulna osteotomy plate fixation	8	2 Years	Dominant
8	Missed RHD	Mild deformation (30–40% caput) Reduction possible		Open reduction Percutaneous fixation Six months after trauma	8	2 Years	Dominant
9	pers. RHD	Mild deformation Reduction possible	2.1	None	No trauma recalled	No trauma recalled	Dominant
10	pers. RHD	No information	1.8	None	11	2 Years	Dominant

RHD: radial head dislocation.
[a]Time between trauma and surgery in our hospital.

(Table 3). These are elaborated in the following paragraphs.

Open versus closed reduction

Open reduction of the radial head has several advantages; even in repositioned radial heads, annular ligament remnants may interpose in the radiohumeral joint.[33] In our series, we also noticed that radial head reduction may be hindered by interpositioning remnants of the annular ligament or fibrosis.

Another argument for an open reduction is that the posterior interosseus nerve (PIN) may be incarcerated in the PRUJ or RCJ.[3,6,12,22] On the contrary, successful closed radial head repositioning has been documented by some authors.[17–20]

Ulna osteotomy

Many authors described a stable situation following ulna osteotomy, in which subsequent ALR was not always necessary.[3,4,11–13,15,16,22,29,34–36] We aim for an

Table 2. Range of motion.

Pt nr	K-wire	Pronation			Supination			Flexion			Extension			Overall ΔROM
		Preop	Postop	Difference	Preop	Postop	Difference	Preop	Postop	Difference	Preop	Postop	Difference	
1	RU	45			45	60	15	120	145	25	10	0	10	
2	RU	70	75	5	80	80	0	125	145	20	3	10	−7	18
3	RU	60	60	0	45	60	15	130	120	−10	0	20	−20	−15
4	None	45	70	25	20	80	60	95	130	35	−45	−15	30	62
5	None		60			70		120	110	−10	10	0	10	
6	None	'Full'	'Full'	0	'Full'	'Full'	0	'Full'	'Full'	0	'Full'	0	0	0
7	None	70			70			125			−10			
8	None	60	70	10	50	90	40	100	145	45	0	0	0	95
9	RU	'Full'	'Perfect'	0	'Full'	'Perfect'	0	150	'Perfect'	0	5	'Perfect'	5	5
10	None	80	70	−10	30	60	30	120	140	20	−10	0	10	50
			Mean	+4.3		Mean	+20		Mean	+13.89		Mean	+4.22	+30.7

K-wire RU = radioulnar fixation; ΔROM = overall number of degrees increase in motion.

Table 3. Pearls and pitfalls.

	Pearls	Pitfalls
Ulna osteotomy position and technique *We suggest a closing wedge osteotomy, placed as proximal in the ulna as possible*	Several authors described a stable situation following ulna osteotomy and fixation only. Osteotomy as proximal as possible: – potentially increases grip due to wider metaphysis in proximal ulna – interosseous ligament pulling forces are increased – Metaphyseal bone healing is overall better Angulation at the metaphyseal level has less effect on reduction, but it permits a finer adjustment. Lengthening of the ulna is necessary to avoid excessive pressure on the radial head	Closed wedge osteotomy may lead to neurological impingement Transverse osteotomy (not bending/elongating) may be associated with a higher risk of radial head redislocation An osteotomy at the centre of rotation and angulation may predispose to non-union
Ulna osteotomy fixation *We suggest rigid fixation (LCP plate and locking screws)*	Rigid plate fixation: – facilitates early mobilisation – no need for interposition graft According to the tension band principle, a posterior plate may be preferred. External fixation with multidirectional clamps simplifies the attainment of the most satisfactory position of the ulna, since the system can be easily adjusted until a stable reduction has been achieved Intramedullary/radiocapitellar nailing (e.g. Steinman pins): – relatively easy pin removal	Plate removal will be necessary in young patients A lateral location of the plate for ulna fixation may be associated with non-union. An external fixator: – may result in soft tissue contractures – may be less sufficient in a young child – requires multiple frame adaptation under general anaesthesia – may be associated with a higher risk of infection Osteosynthesis materials may break Unfixed ulna osteotomies are associated with high risk of radial head redislocation Pins may migrate or break. Pin infections are rare.
Annular ligament reconstruction (ALR) *We suggest to use remnants if possible, or a triceps graft when not available*	ALR may contribute to radial head stability Inspection and debridement of the proximal radioulnar joint are possible A triceps graft may be harvested via the incision that had been used for ulna osteotomy	ALR only cannot stabilise the radial head if the forearm is malaligned The use of drill holes may lead to heterotopic ossifications Use of forearm fascia for ALR may lead to a reconstruction that is too weak. ALR has been associated with postoperative loss of pronation Osteolytic changes may be seen; too much tension in ALR may cause hourglass deformation of the radial neck
Transcapittellar K-wire	K-wire fixation may contribute to radial head stability	Radioulnar K-wire fixation may cause heterotopic ossifications interfering with pro-/supination
We suggest that no transcapittellar K-wires should be required following a stable reconstruction. When in doubt, we prefer the use of a radioulnar K-wire.	Radioulnar K-wire fixation: – prevents damage to joint surfaces	Migrating material Material fracture

ALR: annular ligament reconstruction.

osteotomy location approximately 1 cm distally of the coronoid process, so the osteotomy location is as proximal as possible without opening the joint.[4,11,16] This enforces the downward pull of the interosseous membrane, which contributes to repositioning of the radial head.[11,16,23,37] In our experience, planning the osteotomy as proximal as possible also provides the advantage of a wider bone diameter in the proximal part of the ulna, resulting in a firmer grip and a larger contact surface. Therefore, metaphyseal bone has a higher potency for bone healing than diaphyseal bone. Angulation at the metaphyseal level has less effect on reduction, but it permits a finer adjustment.[38] Several authors state that the risk for radial head redislocation is higher in osteotomies that were performed at the middle of the ulnar shaft.[4] An osteotomy at the centre of rotation and angulation may predispose to non-union.[38]

Ulnar lengthening may be considered a key part of surgery.[31] Restoring ulnar length avoids excessive pressure on the radial head[4] and corrects the proximal shift of the radial head.[7] The osteotomy may be planned either straight, oblique or as a Z-lengthening ulna osteotomy.[37] Several authors conclude that the risk for postoperative redislocation of the radial head is lower following bending and lengthening ulna osteotomy than in a simple transverse osteotomy of the ulna, intended to only straighten the ulna.[4,25] This slight overcorrection is considered to result in extra tension on the interosseous membrane, facilitating reduction of the radial head.[26,32]

Acute ulna lengthening of up to 1 cm has been supported by others despite the risk of delayed union and failure of fixation.[23,31] In most cases, acute ulnar lengthening of 2 to 3 mm is sufficient and does not delay osseous union. One of the pitfalls when lengthening the ulna is that osteotomy site distraction may lead to ulnar nerve palsy in a high percentage of cases.[21] We affirm that the ulna should be lengthened and bent to a slight overcorrection, until the radial head repositions.

Ulna fixation techniques

We favour rigid fixation using a plate and locking head screws. One of the advantages of rigid fixation is that mobilisation is facilitated and postoperative contractures prevented.[4,22] Note that a lateral location of the plate for ulna fixation may lead to non-union of the osteotomy. According to the tension band principle, a posterior plate may be preferred.[38]

ALR

Some authors state that ALR has no effect on radial head stability at all.[2] Others emphasise that ALR may

contribute to stability of radial head reduction, but it cannot stabilise the radial head when the forearm is malaligned[13,29] and some even claim that ALR is the primary stabiliser in radial head reduction.[4,31,39] Most authors agree that reconstruction of the annular ligament may contribute to radial head stability. Especially if there is persistent radial head instability when the forearm is brought to pronation after ulna osteotomy, ALR may be considered.[15,20,28,30,40,41] Redislocations may occur more frequently if a patient only had an ulna osteotomy compared to patients that had an ulna osteotomy and a reconstruction of the annular ligament.[5,6,12]

ALR has been associated with postoperative loss of pronation,[5,26,28,30,42–44] especially if the ALR is not properly tensioned. In a study performed by Rodgers et al., 2/6 ALR patients developed an hourglass deformation of the radial neck, which may occur if the ligament has been reconstructed with too much tension. Therefore, 1/6 had ossification of a portion of the reconstructed annular ligament.[5,21] Also, osteolytic changes may be seen following ALR,[4,21,23,45–47] of which the clinical impact is still uncertain. Possibly adapted tension on the pronator teres muscle plays a role. We conclude that ALR may contribute to radial head stability, and therefore we either sutured the AL remnants or used triceps tendon for reconstruction of the ligament.

Transcapitellar/radioulnar Kirschner wires

Most authors state that a transcapitellar K-wire may be considered if persisting instability is suspected after completing ulna osteotomy and ALR.[5,7,15,21,25,26,35,36,39,42–44,47–51] However, we favour radioulnar K-wire fixation, because it has the advantage that no joint surfaces are damaged. In our case series, we did not find any influence of this extra immobilisation on ROM outcome. It should be taken into account that heterotopic ossifications may occur, influencing pro- and supination; material may break, migrate, or on rare occasions material may infect.[21,26,29,30]

In our cohort, one patient experienced a redislocation of the radial head following a reposition that had been previously fixated elsewhere with a radioulnar K-wire. If the radial head is prone to redislocate directly after surgery, this may mean that the initial reduction is not stable enough. No research has been performed to date to demonstrate that redislocation occurs more frequently, if radiocapitellar pinning was necessary, but we state that in persistent instability, ulnar osteotomy should be reassessed and improved.[29,52] As such, we would recommend radioulnar pinning in such case, as explained above.

Postoperative immobilisation varies greatly between several international studies. In a recent cadaver study, supination in the forearm increases tension on the central band of the interosseous membrane. Thus, forces pulling the radial head towards a repositioned state may be increased by applying a cast in supination.[10] We, however, decided to apply an upper arm cast in 90°, with the forearm a neutral position for patient comfort.

Conclusion

Our series show good results of an open radioulnar debridement, followed by corrective ulnar osteotomy, rigid plate fixation and ALR. We note that adequate ulnar correction and fixation are the key to reducing the radial head, lengthening and bending the ulna until the radial head falls into place. An ALR or a radioulnar K-wire may contribute to stability.

Surgery should be considered regardless of patient age or time since trauma. Within the ranges in our study, no influence of age nor interval since trauma could be found. However, future research should revisit this statement in a larger patient cohort that facilitates adequate statistical analysis. The extent of radial head deformation is concluded as a reliable guideline when deciding whether to operate on a patient in combination with a CT scan as a mandatory part of work-up to surgery.

We emphasise that research is needed to establish preoperative tools in the work-up to surgery. Patients and their families should be well informed about possible postoperative decrease in pronation, given the frequent reports of pronation impairment following surgery. We therefore recommend that the indication for surgery should be established in consultation with the patient and his parents, regardless of patient age or time since trauma.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

References

1. Li H, Cai Q-X, Shen P-Q, et al. Posterior interosseous nerve entrapment after Monteggia fracture-dislocation in children. *Chin J Traumatol* 2013; 16: 131–135.
2. Ruchelsman DE, Pasqualetto M, Price AE, et al. Persistent posterior interosseous nerve palsy associated with a chronic type I Monteggia fracture-dislocation in a child: a case report and review of the literature. *Hand* 2009; 4: 167–172.
3. Seel MJ and Peterson HA. Management of chronic posttraumatic radial head dislocation in children. *J Pediatr Orthop* 1999; 19: 306–312.
4. Horii E, Nakamura R, Koh S, et al. Surgical treatment for chronic radial head dislocation. *Orthopedics* 2008; 83-A: 1183–1188.
5. Gyr B, Stevens P and Smith J. Chronic Monteggia fractures in children: outcome after treatment with the Bell–Tawse procedure. *J Pediatr Orthop* 2004; 13: 402–406.
6. Hui JHP, Sulaiman AR, Lee HC, et al. Open reduction and annular ligament reconstruction with fascia of the forearm in chronic Monteggia lesions in children. *J Pediatr Orthop* 2005; 25: 501–506.
7. Stoll TM, Willis RB and Paterson DC. Treatment of the missed Monteggia fracture in the child. *J Bone Joint Surg Br* 1992; 74: 436–440.
8. Josten C and Freitag S. Monteggia and Monteggia-like-lesions: classification, indication and techniques in operative treatment. *Eur J Trauma Emerg Surg* 2009; 35: 296–304.
9. Ring D, Jupiter JB and Waters PM. Monteggia Fractures in children and adults. *J Am Acad Orthop Surg* 1998; 6: 215–224.
10. Farr LD, Werner FW, Mcgrattan ML, et al. Anatomy and biomechanics of the forearm interosseous membrane. *J Hand Surg Am* 2015; 40: 1145–1151.
11. Nakamura K, Hirachi K, Uchiyama S, et al. Long-Term clinical and radiographic outcomes after open reduction for missed monteggia fracture-dislocations in children. *J Bone Joint Surg Am* 2009; 91: 1394–1404.
12. Wang MN and Chang W-N. Chronic posttraumatic anterior dislocation of the radial head in children. *J Orthop Trauma* 2006; 20: 1–5.
13. Jupiter JB, Fernandez DL, Levin LS, et al. Reconstruction of posttraumatic disorders of the forearm. *J Bone Joint Surg Am* 2009; 91: 2730–2739.
14. Kim HT, Conjares JNV, Suh JT, et al. Chronic radial head dislocation in children, Part 1: Pathologic changes preventing stable reduction and surgical correction. *J Pediatr Orthop* 2002; 22: 583–590.
15. Di Gennaro GL, Martinelli A, Bettuzzi C, et al. Outcomes after surgical treatment of missed Monteggia fractures in children. *Musculoskelet Surg* 2015; 99: 75–82.
16. Goyal T, Arora SS, Banerjee S, et al. Neglected Monteggia fracture dislocations in children: a systematic review. *J Pediatr Orthop* 2015; 24: 191–199.
17. Rajasekaran S and Venkatadass K. "Sliding angulation osteotomy": preliminary report of a novel technique of treatment for chronic radial head dislocation following missed Monteggia injuries. *Int Orthop* 2014; 38: 2519–2524.
18. Chauhan P. Surgical treatment in children missed Monteggia lesions at Bhuj, Kutch, Gujarat: a retrospective study. *Int J Res Orthop* 2017; 3: 30–34.
19. Exner GU. Missed chronic anterior Monteggia lesion. Closed reduction by gradual lengthening and angulation of the ulna. *J Bone Joint Surg Br* 2001; 83: 547–550.
20. Song KS, Ramnani K, Bae KC, et al. Indirect reduction of the radial head in children with chronic monteggia lesions. *J Orthop Trauma* 2012; 26: 597–601.

21. Rodgers WB, Waters PM and Hall JE. Chronic monteggia lesions in children. *J Bone Joint Surg Am* 1996; 78: 1322–1329.

22. Eygendaal D and Hillen RJ. Open reduction and corrective ulnar osteotomy for missed radial head dislocations in children. *Strateg Trauma Limb Reconstr* 2007; 2: 31–34.

23. Hirayama T, Takemitsu Y and Yagihara K. Operation for chronic dislocation of the radial head in children. Reduction by the osteotomy of the ulna. *J Bone Joint Surg Br* 1987; 69: 639–642.

24. Oka K, Murase T, Moritomo H, et al. Morphologic evaluation of chronic radial head dislocation: three-dimensional and quantitative analyses. *Clin Orthop Relat Res* 2010; 468: 2410–2418.

25. Garg P, Baid P, Sinha S, et al. Outcome of radial head preserving operations in missed Monteggia fracture in children. *Indian J Orthop* 2011; 45: 404–409.

26. David-West KS, Wilson NIL, Sherlock DA and Bennet GC. Missed Monteggia injuries. *Injury* 2005; 36: 1206–1209.

27. Inoue G and Shionoya K. Corrective ulnar osteotomy for malunited anterior Monteggia lesions in children. *Acta Orthop Scand* 1998; 69: 73–76.

28. Kim HT, Park BG, Suh JT and Yoo CI. Chronic Radial Head Dislocation in Children, Part 2: Results of Open Treatment and Factors Affecting Final Outcome. *J Pediatr Orthop* 2002; 22: 591–597.

29. Rahbek O, Deutch SR, Kold S, Søjbjerg JO and Møller-Madsen B. Long-term outcome after ulnar osteotomy for missed Monteggia fracture dislocation in children. *J Child Orthop* 2011; 5: 449–457.

30. Bhaskar A. Missed Monteggia fracture in children: Is annular ligament reconstruction always required? *J Child Orthop* 2010; 4: 479.

31. Hasler CC, Von Laer L and Hell AK. Open reduction, ulnar osteotomy and external fixation for chronic anterior dislocation of the head of the radius. *J Bone Joint Surg Br* 2005; 87: 88–94.

32. Kalamchi A. Monteggia fracture-dislocation in children. Late treatment in two cases. *J Bone Jt Surg - Ser A* 1986; 68: 615–619.

33. Tan JW, Mu MZ, Liao GJ, et al. Pathology of the annular ligament in paediatric Monteggia fractures. *Injury* 2008; 39: 451–455.

34. Ray R and Gaston M. Treatment of late-presenting Monteggia variant with an isolated, simple flexion ulnar osteotomy. *J Pediatr Orthop Part B* 2014; 23: 472–476.

35. Kemnitz S, De Schrijver F and De Smet L. Radial head dislocation with plastic deformation of the ulna in children. A rare and frequently missed condition. *Acta Orthop Belg* 2000; 359–362.

36. Belangero WD, Livani B and Zogaib RK. Treatment of chronic radial head dislocations in children. *Int Orthop* 2007; 31: 151–154.

37. Eamsobhana P and Kaewpornsawan K. Chronic Monteggia lesions treatment with open reduction and Z-lengthening technique with annular ligament reconstruction. *J Med Assoc Thai* 2012; 95(Suppl 9): 47–53.

38. Lädermann A, Ceroni D, Lefèvre Y, et al. Surgical treatment of missed Monteggia lesions in children. *J Child Orthop* 2007; 1: 237–242.

39. Schülitz KP. Die operative Behandlung der veralteten Radiusköpfchenluxationen im Kindesaher. *Arch orthop Unfall-Chir* 1975; 81: 225–237.

40. Lu X, Wang YK, Zhang J, et al. Management of missed monteggia fractures with ulnar osteotomy, open reduction, and dual-socket external fixation. *J Pediatr Orthop* 2013; 33: 398–402.

41. Shinohara T, Horii E, Koh S, et al. Mid- to long-term outcomes after surgical treatment of chronic anterior dislocation of the radial head in children. *J Orthop Sci* 2016; 21: 759–765.

42. Datta T, Chatterjee ND, Pal AK, et al. Evaluation of outcome of corrective ulnar osteotomy with bone grafting and annular ligament reconstruction in neglected Monteggia fracture dislocation in children. *J Clin Diagnostic Res* 2014; 8: 1–4.

43. Cappellino A, Wolfe SW and Marsh JS. Use of a modified bell tawse procedure for chronic acquired dislocation of the radial head. *J Pediatr Orthop* 1998; 18: 410–414.

44. Đapić T, Antičević D, Bilić R, et al. Reconstruction of chronic Monteggia's lesions in children. *Acta Clin Croat* 2004; 43: 371–377.

45. Kosev P and Valentinov B. Chronic Radial Head Dislocation in Children. Treatment By Open Reduction and Ulnar Osteotomy. *J IMAB* 2015; 21: 757–762.

46. Stragier B, De Smet L and Degreef I. Long-term follow-up of corrective ulnar osteotomy for missed Monteggia fractures in children. *J Shoulder Elb Surg* 2018; 27: e337–343.

47. Fowles JV, Sliman N and Kassab MT. The Monteggia lesion in children. Fracture of the ulna and dislocation of the radial head. *J Bone Jt Surg* 1983; 65: 1276–1282.

48. Best TN. Management of Old Unreduced Monteggia Fracture Dislocations of the Elbow in Children. *J Pediatr Orthop* 1994; 14: 193–199.

49. Degreef I and De Smet L. Missed radial head dislocations in children associated with ulnar deformation: Treatment by open reduction and ulnar osteotomy. *J Orthop Trauma* 2004; 18: 375–378.

50. Mukhopadhyay KK, Kumar S, Bhattacharjya B and Mukhopadhyay K. Neglected montegia lesion - is full recovery expected? *J Indian Med Assoc* 2012; 110: 779–780.

51. Strahm PL. FD, P L. Monteggia-Verletzung im Kindesalter: eine häufige Ursache der chronischen Radiusköpfchenluxation. *Helv chir acta* 1993; 60: 225–230.

52. Delpont M, Jouve JL, Sales de Gauzy J, et al. Proximal ulnar osteotomy in the treatment of neglected childhood Monteggia lesion. *Orthop Traumatol Surg Res* 2014; 100: 803–807.