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Review

Missed Monteggia fractures in children – the current state of the problem: A systematic review

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BACKGROUNG: A situation in which despite an obvious ulnar fracture, radial head dislocation is not diagnosed, resulting in a missed Monteggia fracture is not uncommon. Unsatisfactory results of the treatment of this pathology have prompted several researchers to search for an optimal treatment strategy.

AIM: This study aimed to conduct a systematic review of literature data on missed Monteggia fractures and dislocations in children by studying the main therapeutic and tactical approaches to this problem.

MATERIALS AND METHODS: A literature search was conducted in the Cochrane Database, Science Direct, Google Scholar, PubMed, and eLibrary information bases, and the search depth was 10 years. Moreover, 46 sources were selected based on the criteria. The main characteristics revealing the problem were identified, divided into four semantic groups, according to which the literature was analyzed: initial data on the condition of patients at the time of seeking medical help, status before and after treatment, and treatment methods.

RESULTS: The average age of the children was 8.4 years. The average interval from injury to the surgical treatment of missed Monteggia fracture was 15.3 months, and 883 clinical cases presented in sources with known treatment techniques were analyzed. Thus, open reduction of the radial head in combination with the restoration or reconstruction of the annular ligament and ulnar osteotomy is one of the most common methods (n = 482, 54.6%). The second most frequent application was the above-described approach, but without manipulations on the annular ligament (n = 273, 30.9%). Bone osteosynthesis and external fixation apparatus were the most widely used stabilization methods in 350 (67.8%) and 149 (28.9%), respectively. The most common complications were associated with the deterioration of the functional status after surgery.

CONCLUSIONS: Accurate diagnosis of injury and early correction of existing disorders is the key to reducing the frequency of missed Monteggia fractures. Surgical treatment is the main method of treating children with this injury, in which the restoration of the ulnar anatomy and the ratios in the brachial and proximal radiocarpal joints are the most important, providing a more physiological development of the segment with the growth of the child.

Keywords: Monteggia fracture; neglected Monteggia fracture; missed Monteggia fracture; ulnar osteotomy; radial head dislocation; children.

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Научный обзор

Застарелые повреждения Монтеджа у детей — современное состояние проблемы (систематический обзор)

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Обоснование. Нередко при очевидном переломе локтевой кости вывих головки лучевой кости не диагностируют, в результате формируется застарелое повреждение Монтеджа. Неудовлетворительные результаты лечения данной патологии стали причиной значительного количества исследований, посвященных поискам оптимальной стратегии лечения.

Цель — провести систематический обзор литературных данных по проблеме застарелых переломовывихов Монтеджа у детей и изучить основные лечебно-тактические подходы к данной проблеме.

Материалы и методы. Осуществлен поиск литературы в информационных базах Cochrane Database, Science Direct, Google Scholar, PubMed, eLibrary, глубина поиска 10 лет. На основании критериев отобрано 46 источников. Выделены основные характеристики, раскрывающие проблему, которые разделили на четыре смысловые группы, по которым анализировали публикации: исходные данные по состоянию пациентов на момент обращения за медицинской помощью, статус до и после лечения, методы лечения.

Результаты. Средний возраст детей составил 8,4 года. Средний интервал от травмы до хирургического лечения застарелого повреждения Монтеджа — 15,3 мес. Изучены 883 клинических случая, представленных в источниках с известной тактикой лечения. Открытое вправление головки лучевой кости в сочетании с восстановлением или реконструкцией кольцевидной связки и остеотомией локтевой кости оказалось одним из наиболее распространенных методов (482 — 54,6 %). Вторым по частоте применения был вышеописанный подход, но без манипуляций на кольцевидной связке (273 — 30,9 %). Наиболее широко используемыми методами стабилизации были накостный остеосинтез (350 — 67,8 %) и аппарат внешней фиксации (149 — 28,9 %). Наиболее распространенными осложнениями, с которыми сталкивались в своей работе авторы, связаны с ухудшением функционального статуса после операции.

Заключение. Точная диагностика травмы и ранняя коррекция нарушений — залог снижения частоты формирования застарелого повреждения Монтеджа. При оказании помощи детям с данным повреждением ведущее значение принадлежит хирургическому лечению, при котором наиболее важны восстановление анатомии локтевой кости и соотношений в плечелучевом и проксимальном лучелоктевом сочленениях, что обеспечивает более физиологичное развитие сегмента по мере роста ребенка.

Ключевые слова: перелом Монтеджа; застарелый перелом Монтеджа; пропущенный перелом Монтеджа; локтевая остеотомия; вывих головки лучевой кости; дети.

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BACKGROUND

In 1814, a pathologist and surgeon from Milan, Giovanni Battista Monteggia, first described a fracture of the diaphyseal ulna with radial bone head dislocation [1]. Monteggia presented the history of his mistake, namely, anterior radial bone dislocation unnoticed in time. It appears surprising; however, even after two centuries, orthopedists, being formally familiarized with the damage described by our predecessor, repeat Monteggia's diagnostic error. The dislocation of the radial head with an obvious fracture of the ulnar bone is often left out of consideration with potentially serious functional consequences. Consequently, a neglected Monteggia lesion was formed. According to most experts, the term "neglected or chronic Monteggia injury" should be used when the injury is more than 2–4 weeks old [2–5].

With the accumulation of clinical cases and their analysis, clarifying the pathological anatomy of the damage and highlighting some patterns became necessary. Thus, in 1967, Monteggia fractures were additionally classified by Jose Luis Bado; four main types and seven equivalent injuries were identified (six Monteggia equivalents to type I and one equivalent to type II) (Fig. 1; Table 1) [6]. This system, based on the direction of radial bone head displacement and angle of ulnar bone fracture, is extensively presented in clinical practice, and publications focused on this problem. According to the subsequent experience in children, a Monteggia lesion can be easily disregarded if there is a subperiosteal lesion with ulnar deformity or a green stick fracture with radial head dislocation. In 1985, Letts et al. proposed a pediatric classification subdividing Bado type I according to the fracture of the ulnar bone (i.e., plastic deformity, green stick, and complete fractures) (Fig. 2) [7].

Despite the long history of the disease and attention of specialists to it, the major problem persists, namely, undiagnosed injuries. Ulnar fusion with residual deformity and lack of reduction in the radial bone head dislocation lead to several pathological conditions, such as radioulnar instability, forearm bone deformities, impairment of the axial

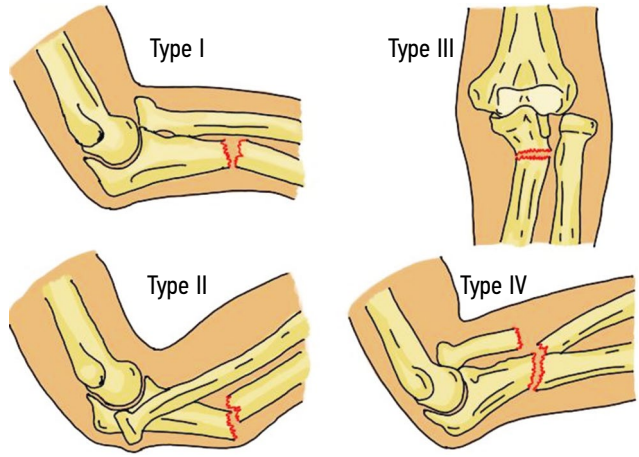

Fig. 1. Classification of Monteggia damage according to Bado: and type I, anterior radial head dislocation with associated ulnar shaft fracture and an anterior angle of inclination; type II, posterior radial head dislocation with an associated ulnar fracture with posterior angulation; type III, lateral or anterolateral radial bone head dislocation associated with an ulnar metaphyseal fracture; type IV, anterior radial head dislocation with radial and the ulnar bone fractures within the proximal third at the same level

parameters of the limb at the level of the elbow joint, elbow joint contractures, pronation–supination contractures of the forearm, and arthrosis of the humeroradial and proximal radioulnar joints [8]. The multicomponent pathomorphology of Monteggia's injuries significantly complicates the development of an approach and technical resolution of each of the elements to obtain full-fledged anatomical and functional results. Poor results for treating neglected injuries have led to a considerable amount of research on various strategies. However, no consensus on the optimal approach has been established [9]. Some authors recommend open reduction of the dislocated radial head with repair or reconstruction of the annular ligament and corrective ulnar bone osteotomy [4, 8, 10–21], whereas others recommend osteotomy without restoration of the annular ligament [5, 9, 13, 18, 21–37].

Three issues are fundamental in neglected Monteggia injuries in pediatric patients: (1) diagnostic errors; (2) an unsatisfactory result of the primary treatment in the acute period

Table 1. Monteggia lesions equivalents

Equivalent type	Description
I	Anterior radial head dislocation
	Fracture of the diaphysis of the ulnar bone and fracture of the radial bone neck
	Fracture of the radial bone neck
	Fracture of the ulnar bone diaphysis with a fracture of the proximal third of the radial bone
	Fracture of the ulnar bone diaphysis and anterior dislocation of the radial bone head
	Posterior dislocation and fracture of the ulnar bone diaphysis with or without a fracture of the proximal radial bone
II	Epiphyseal fractures of the dislocated radial bone head or fractures of the radial bone neck

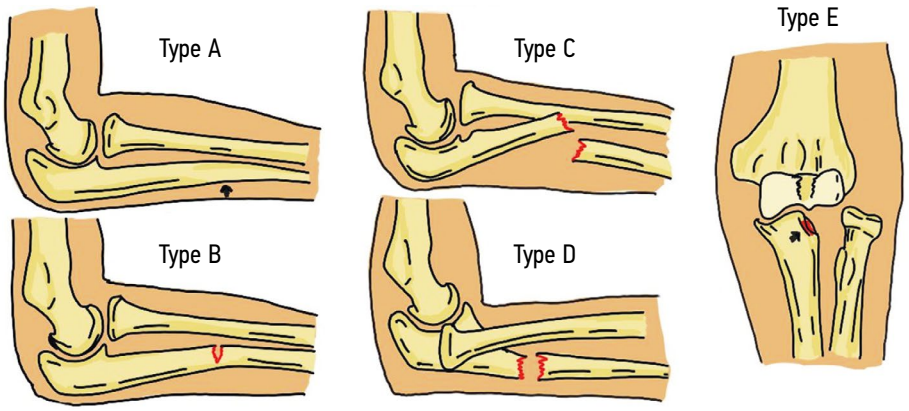

Fig. 2. Pediatric classification of Monteggia fracture dislocation according to Letts: type A, radial bone head dislocation with plastic deformity of the ulnar bone shaft; type B, anterior radial bone head dislocation with a fracture of the ulnar bone shaft; type C, complete fracture of the ulnar bone shaft and anterior radial bone head dislocation; type D, posterior radial head dislocation with associated fracture of the ulnar shaft with posterior angulation; type E, lateral, or anterolateral radial bone head dislocation associated with a fracture of the ulnar bone metaphysis

with major components, namely (a) absence of ulnar bone reposition, (b) persistent radial bone head dislocation (orienting instability in relation to the head of the humeral condyle), and (c) a combination of the options described above; and (3) absence of a modern algorithm of surgical treatment that provides an optimal anatomical and functional result, taking into account the pathological multicomponent nature of the condition.

The work conducted a systematic review of the literature data on neglected Monteggia fracture dislocations in pediatric patients and examined the main therapeutic and tactical approaches to this problem.

MATERIALS AND METHODS

A literature search and analysis was conducted in the electronic search engines Cochrane Database, Science Direct, Google Scholar, PubMed, and eLibrary, using the following keywords: "neglected Monteggia," "chronic Monteggia," "Monteggia injury," "fracture dislocation of the forearm in pediatric patients," "chronic Monteggia fracture," and "missed Monteggia fracture dislocation." The search depth was 10 years.

Inclusion criteria: (1) articles written in Russian and English, (2) full text, (3) pediatric patients (aged <18 years), and (4) analytical case–control studies, clinical series studies, and clinical cases.

Exclusion criteria: (1) acute Monteggia injuries, (2) congenital radial bone dislocations, and (3) presence of data for secondary instability of the humeroradial joint and nontraumatic deformity of the ulnar bone.

Both the structure of the publications and the clinical material presented were evaluated. Statistical data were processed using the Microsoft Excel 2019 software. Descriptive statistics was used (absolute value, minimum and maximum values, and percentage in the entire population). Between-group comparison was performed using a nonparametric method (Pearson's chi-square test with Yates correction). The $p < 0.05$ was considered statistically significant.

The study design with an analysis of quantitative data is presented in Fig. 3. Finally, 46 articles (3 analytical case–control studies, 34 with presentation of the clinical series (2–207 cases), and 9 clinical cases) were selected. In total, all publications contained data on 913 patients (543 boys and 370 girls). Additionally, 24 characteristics were identified, divided into four semantic groups, according to which the articles were analyzed. All these were included in the general summary table. Owing to the lack of data and an algorithm for presenting clinical cases in some papers, articles with insufficient data in the relevant sections were rejected (Table 2).

RESULTS

The average age of the pediatric patients was 8.4 (2–18) years. The average interval from injury to the surgical treatment of neglected Monteggia injury was 15.3 (from 2 weeks to 10 years). In the structure of damage types, according to the Bado classification, type I was predominant (Fig. 4).

Features of primary care in the acute period were analyzed for 72 patients. In more than half of the cases (37; 51%), plaster immobilization was performed for an ulnar bone fracture with a radial bone dislocation disregarded. In 23 (32%) patients, fracture dislocation was not diagnosed during the initial visit; accordingly, a treatment approach inadequate to the injury was chosen. In some patients (10; 14%), a closed reduction of the radial bone head was performed with a disregarded fracture of the ulnar bone, or reposition of its fragments was not performed, only in 2 (3%) cases, the patient's late visit was noted.

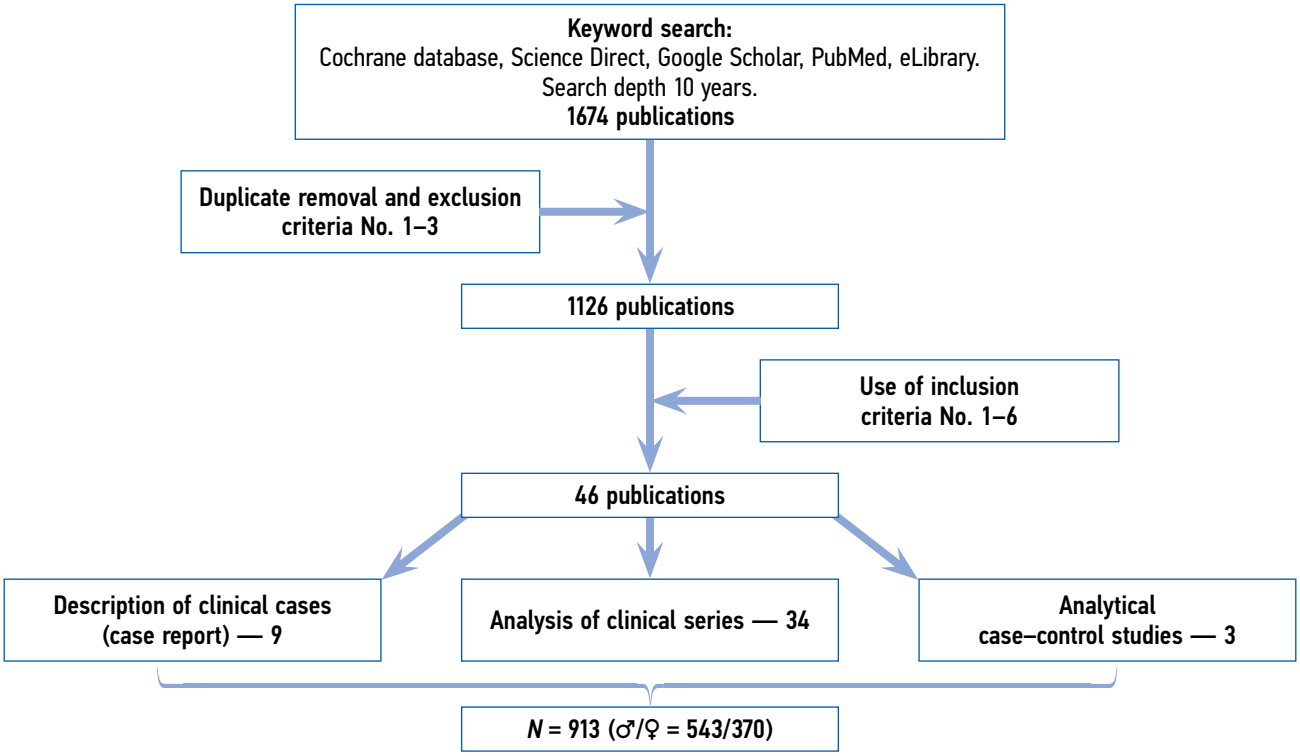

Fig. 3. Study design

Table 2. Characteristics analyzed

Groups of data analyzed	Characteristics	Number of articles with data
General characteristics	Sex	46
	Age at the time of surgery	46
	Injury type according to the Bado classification	38
Clinical anamnestic and X-ray data before treatment	Manipulations before surgery	18
	Period from injury to surgery	46
	Complaints before surgery	27
	Range of motion in the elbow joint before surgery	21
	Evaluation scale of the elbow joint function before surgery	12
	X-ray presentation before surgery	12
Methods of treatment	Manipulations performed	46
	Approach type	39
	Site of ulnar bone osteotomy	41
	Type of osteotomy site fixation	46
	Elbow osteotomy type	32
	Wire fixation of the radial bone head	43
	Reconstruction/repair of the annular ligament	46
	Bone grafting	39
	Duration of plaster immobilization	36
	Limb position during plaster immobilization	24
Results of treatment	Complaints after surgery	39
	Range of motion in the elbow joint after surgery	36
	Evaluation scale of the elbow joint function after surgery	29
	X-ray presentation after surgery	37
	Complications	46

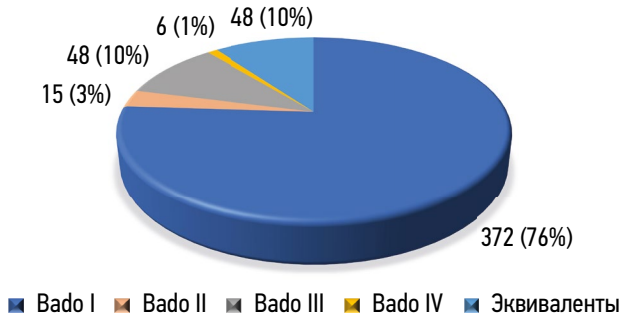

Fig. 4. Structure of patients by types of Monteggia injuries according to the Bado classification

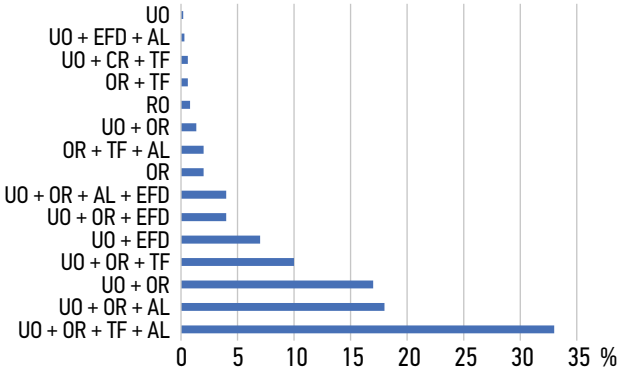

Fig. 5. Structure and frequency of implementation of the surgical approach (%). CR, closed reduction of the radial bone head; OR, open reduction of the radial bone head; UO, ulnar bone osteotomy; RO, radial bone osteotomy; TF, transcapitellar fixation; AL, restoration/reconstruction/excision of the annular ligament; EFD, external fixation device

Treatment strategies for neglected Monteggia lesions

In this study, we analyzed 883 clinical cases with a detailed description of the treatment approach of injuries and revealed that the open reduction of the radial bone head in combination with the restoration or reconstruction of the annular ligament and ulnar bone osteotomy is one of the most common methods (482; 54.6%). The second most commonly used approach was the one described above but without annular ligament reconstruction (273; 30.9%). None of the sources mention the possibility of conservative treatment or monitoring of such injuries. In all cases, the indications for surgical treatment were a dislocation of the radial bone head and deformity of the ulnar bone. Over time, in the growth of the bones of the limb, radial bone head dislocation is aggravated, its deformity is formed, the ulnar bone shortens, radioulnar biomechanics are impaired, and contracture and pain in the elbow joint emerge [11]. Moreover, Ngoc Hung et al. believe that the surgical indications should be determined individually, and the decision to perform the surgery should be made by the patient, parents, and surgeon, taking into account preoperative expectations, potential complications, and postoperative rehabilitation [19]. The structure and frequency of the implementation of the surgical approach according to the literature are presented in Fig. 5.

Surgical approach

In 141 (28.8%) cases, the surgery was performed through the lateral Kocher's approach, extended Kocher's approach in 53 (10.8%) cases, posterolateral Boyd's approach in 142 (29%) cases, and Boyd's extended approach in 45 (9.2%) cases. The anterior Henry approach (89; 18.2%) and Kaplan approach (19; 4%) were used less frequently. The authors considered the possibility of combining ulnar bone osteotomy, open reduction of the radial bone head, and use of the triceps tendon for ligament reconstruction as an advantage of Boyd's extended posterolateral approach [38]. However, with this approach, there is a high risk of damage to the radial nerve. Anterior Henry and posterior approaches for osteotomy have the advantages of better exposure, more comfortable intraoperative procedures, and easier examination of the radial nerve [39].

According to our data, the relationship between the type of approach and the occurrence of neurological and infectious complications is not statistically significant ($p > 0.05$) (Table 3).

Ulnar bone osteotomy

Simple reduction of radial bone head dislocation without ulnar bone osteotomy, even with the use of stable fixation with hardware, does not provide a beneficial outcome. This is why the ulnar bone is the key to repositioning the radial bone

Table 3. Type of approach and complications

Type of approach	Neurological complications Yes/No (*n*)	Statistical criteria	Infectious complications Yes/No (*n*)	Statistical criteria
Lateral Kocher	5/136	$\chi^2 = 4.337$ $p > 0.05$	0/141	$\chi^2 = 17.452$ $p > 0.05$
Extended Kocher	1/52		1/52	
Boyd posterolateral	1/141		2/140	
Extended Boyd	1/44		2/43	
Anterior Henry	4/85		0/89	
Kaplan	1/18		2/17	

Table 4. Type of osteotomy and subsequent recurrence of dislocation

Type of osteotomy	Recurrence	No recurrence	Statistical criteria
Wedge	14	139	$\chi^2 = 0.092$ $p > 0.05$
Transverse	10	111	
Oblique	9	100	

Table 5. Dependence of the stability of correction and infectious complications on the fixation method

Метод фиксации	Потеря коррекции Да/Нет (абс.)	Статистические критерии	Инфекционные осложнения Да/Нет (абс.)	Статистические критерии	
Extracortical osteosynthesis	29/321	$\chi^2 = 2.064$ $p > 0.05$	4/346	$\chi^2 = 10.762$ $p < 0.05$	$\chi^2 = 5.728$ $p < 0.05$
Wire and rod fixation	0/17		2/15		
External fixation device	15/134		3/146		

head [19, 26, 28, 34]. According to one study, in some cases, after ulnar osteotomy, open reduction of the radial head and/or its transcapitellar fixation was not required [5]. Corrective ulnar bone osteotomy can be considered to have two aims: (1) to stretch the interosseous membrane to maintain the radial bone head in the correct anatomical position and (2) to eliminate the pressure of the ulna on the radial bone, leading to the anterior dystopia of the radial bone when the arm is in pronation [12, 23].

In 32 (73%) studies, the authors performed proximal (metaphyseal) ulnar bone osteotomy, including at the deformity apex, in 17 (39%) cases. Numerous arguments have been put forward in favor of proximal osteotomy, for example, the altered bone shape and the resulting scar will disturb and disrupt less the interosseous membrane, while reducing the risk of nonunion [10, 23, 40].

The results of the literature data analysis did not reveal any significant dependence of the subsequent recurrence of dislocation on the osteotomy type (oblique, wedge-shaped, transverse, and Z-shaped) ($p > 0.05$) (Table 4).

Fixation of the osteotomy site

Most researchers favor ulnar bone angulation and lengthening. The only question is how to perform the required correction: simultaneously or with the use of an external fixation device. Extracortical osteosynthesis and external fixation apparatus are the most widely used for stabilization (350 (67.8%) and 149 (28.9%), respectively) [17, 33, 36, 41, 42]. Wire cross-fixation or intramedullary fixation is performed much less frequently (17; 3.3%) [5, 20, 37, 38, 43, 44]. Extracortical osteosynthesis provides greater stability and lower loss of correction than alternative fixation [28].

The results of a comparative analysis of instrumental treatment and one-stage correction with extracortical osteosynthesis showed no difference in the frequency of delayed consolidation [11]. Moreover, results of a comparative analysis of the techniques presented in the literature showed that the fixation method does not affect the reduced head stability ($p > 0.05$); however, the frequency of infectious complications depended significantly on the technique, namely, when comparing intramedullary fixation with extracortical osteosynthesis ($p < 0.05$) (Table 5).

Transarticular fixation

Transarticular pin stabilization of the radial head is controversial. Thus, 27 (63%) researchers prefer to perform this manipulation, and 16 (37%) researchers are against it [8, 10, 23, 29, 38]. In the analyzed studies, an insignificant relationship was found between transcapitellar fixation and arthritic changes ($p > 0.05$); however, the average strength of the relationship was identified between the fixation type and dislocation recurrence, and the presence of a transcapitellar pin increases the probability of dislocation recurrence ($p < 0.05$).

Manipulations of the annular ligament

The manipulation of the annular ligament has been a topic of various discussions. The main tactical approaches are presented in Fig. 6.

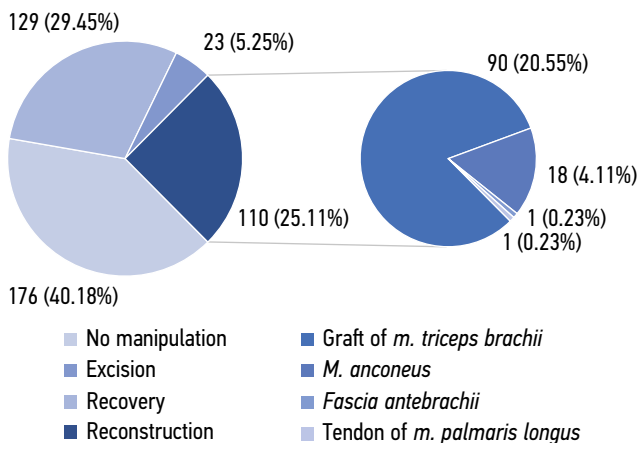

Fig. 6. Approach in relation to the annular ligament in the surgical treatment of neglected Monteggia injuries

Opponents of ligament grafting argue that it does not provide radial head stability and causes a risk of radioulnar synostosis [8]. Stragier et al. refused the reconstruction procedure because of conflicting evidence of the positive effect on surgical outcomes and potential risk of complications, such as avascular necrosis, impaired growth and development of the proximal metaepiphysis of the radial bone, growth of the radial neck, heterotopic ossification, radioulnar synostosis, and limited forearm pronation. Ulnar osteotomy and its angulation are of key importance, whereas grafting of the annular ligament is not crucial in maintaining the correct humeroradial ratio [10, 31, 39]. According to the statistical calculation, manipulations on the annular ligament did not affect the development of recurrent dislocation, subluxation, and osteoarthritic changes ($p > 0.05$).

In the case of radial bone head reluxation following surgical treatment, formation of contractures, and pain syndrome, some authors tend to proximal resection of the radial bone. Osteotomy of the proximal radial bone was performed in three studies [11, 21, 29].

An almost equal number of authors, namely, 11 (46%) and 12 (54%), consider immobilization in the neutral position of rotation and in the position of complete supination to be correct, respectively. The fixation period ranges from 2 to 6 weeks [12, 13, 16, 21, 29, 38, 40, 43, 45–47].

Evaluation of treatment outcomes

In the literature analyzed, the authors evaluated treatment results in different ways, from the common measurement of the range of motion in the elbow joint to scoring according to the scales (Table 6). In particular,

Table 6. Range of motion and assessment of other functions of the elbow joint

Scale	Authors	Number of cases	Manipulations performed	Score	
				Before surgery	After surgery
Mayo Elbow Performance Index	M. Delpont [8]	28	OR + UO	84	94
	Sh. Liao [39]	33	OR + UO + TF	79.4	97.7
	P. Eamsobhana [12]	10	OR + UO (Z-shaped) + ALR	ND	99.5
	T. Datta [45]	21	Subperiosteal oblique UO + OR + ALR + TF	ND	Increase by 30
	H.-Y. Chen [29]	20	1) OR + UO (TF) (18); 2) OR + UO + RO (TF) (2)	80	94
	H. Park [48]	22	1) OR (5); 2) OR + UO (17)	81.1	89.5
	E.G. Mohan Kumar [14]	17	OR + UO + ALR	76.76	91.11
Kim's Elbow Performance Score	M. Baydar [37]	14	OR + UO	69.6	92.9
	E.G. Mohan Kumar [14]	17	OR + UO + ALR	76.91	91.35
	X. Lu, K. Wang [40]	33	OR + UO + EFD	85	90
	G. Di Gennaro [11]	22	1) OR + RAL (7) / ALR (2) + TF 2) UO + EFD (9) (OR (8) + ALR (8) + TF (8) at the time of EFD removal) 3) UO + elongation of the ulnar bone in EFD + OR + RO + ALR + TF (1) 4) OR + UO + ALR (2); 5) RO (1)	ND	91
	M. Take [41]	5	OR + UO	65	94
	X. Lu [35]	23	1) OR (5); 2) OR + UO (18)	85	90
	H. Park [48]	22	1) OR (5); 2) OR + UO (17)	80	86.6
	N. Hung [19]	13	OR + UO + ALR / RAL (+TF)	75.38	93.07
Oxford Elbow Score	H. Çevik [43]	18	1) OR + UO + TF + ALR (6) 2) CR + UO + TF (5) 3) OR + UO + TF (2); 4) UO + CR (5)	ND	90
	Ol. Rahbek [51]	16	1) OR + UO (6); 2) OR + UO + RAL /ALR (10)	92	ND
Quick DASH	Ot. Junko [27]	1	UO + free grafting with vascularized fibula graft with plate fixation	9.1	ND

Note: ALR, annular ligament reconstruction; CR, closed reduction of the radial bone head; EFD, external fixation device; ND, no data; OR, open reduction of the radial bone head; RAL, repair of the annular ligament; RO, radial bone osteotomy; TF, transcapitellar fixation; UO, ulnar bone osteotomy.

the Mayo Elbow Performance Score scale was widely used, which took into account several parameters, such as pain, range of motion, stability, and function [8, 12, 14, 15, 22, 29, 39, 45, 48, 49]. The Kim elbow performance test is another frequently used scale, which is based on four parameters (deformity, pain, age, and function) that patients most often considered problems that need to be addressed [50]. Each parameter was assigned 25 points for an ideal score of 100 points. The overall assessment of treatment efficiency was accepted as excellent (⩾90), good (89–75 points), satisfactory (74–60 points), or poor (<60 points) [4, 11, 13, 14, 16–20, 23, 30, 34–37, 40, 41, 48]. The Oxford Elbow Score questionnaire, which includes an assessment of the elbow joint function, pain syndrome, and sociopsychological status, was used less frequently [43, 51, 52].

Two studies used the Quick DASH scale [27, 42]. I.Yu. Khodzhanov et al. used the modified Mattis–Luboshits–Schwarzberg scale [47]. In the main group, the number of positive treatment results reached 100%. There were no poor results. Satisfactory treatment results in the main group (12.1%) were mainly associated with elbow joint function. There was a limitation of flexion–extension and rotational movements in the elbow joint in patients with a disease duration of >1 year, when the radial bone head was deformed and expanded.

In addition to assessing the range of motion, Stragier et al. used the standard visual analog scale for pain in the elbow joint to determine potential subjective improvement and satisfaction caused by treatment. All 18 patients stated that they would not change the decision to perform the surgery [10]. Nearly all patients with damage < 6 months old had a score of 0 out of 10 on the pain scale (none), except for one patient (score 1 out of 10). All patients with trauma of >6 months old reported some pain. The overall mean range of motion increased by nearly 15% after surgery.

In general, most authors have achieved an increase in the range of motion after surgical treatment up to equalization with a healthy contralateral limb [5, 8–10, 12, 21, 23, 24, 28, 34, 37–39, 43, 44]. However, some have noted that with an increase in mean supination, the pronation volume is often lost compared with preoperative values [10, 29, 39]. Some authors have reported no statistically significant difference between pre- and postoperative measurements [13, 40]. A positive treatment result in most cases was the relief of elbow joint pain after the intervention [31, 53].

X-ray data

The post-treatment radiological presentation was assessed in most studies by dividing the results into three categories, namely, good (complete reduction of the radial head without degenerative changes in the ulnar bone), satisfactory (subluxation and/or arthrosis and deformities), and poor (radial head dislocation) [8].

Before surgical treatment, in addition to neglected damage, certain radiographic features were noted (n = 94), namely, ectopic ossification in 10 (11%) patients, hypertrophied radial bone head in 8 (9%), another deformity of the head in 3 (3%), short neck of the radial bone in 4 (4%), radial synostosis, and hypoplasia of the lateral condyle of the humerus, and osteoarthritic changes in one patient. In general, good radiological results were achieved in 380 out of 472 cases (81%). Satisfactory results were obtained in 53 (11%) cases, and poor results were registered in 23 (5%). Among the latter, one patient subsequently underwent radial head resection. Radial head hypertrophy was registered in 29 (6%) cases. The average period of radiographic consolidation of the osteotomy site was 8 weeks.

Complications

The most common complications are associated with deterioration in functional status, in particular the loss of rotational movements, and subluxation or recurrence of radial bone head dislocation. In the long term, degenerative changes were recorded in the humeroradial, proximal, and distal radioulnar joints and a deformity formed at the level of the elbow joint. Moreover, nonspecific complications were inherent in corrective interventions, such as impaired consolidation of the osteotomy site and infectious complications [4, 8, 10–13, 15, 17–19, 21, 24, 26–29, 36, 37, 39–43, 45, 47, 48]. The structure and incidence of complications of surgical treatment are presented in Fig. 7.

DISCUSSION

Monteggia fracture dislocations in pediatric patients remain a problem despite being a well-known and common injury [54]. The main cause of the transition of an acute condition to neglected damage involves a "human factor," namely, the result of a defect in diagnostics and incorrect subsequent treatment approach. According to I.Yu. Khodzhanov et al., the clinical aspects of recent radial bone head dislocations in pediatric patients include insufficiently pronounced dysfunction of the elbow joint, absence of a forced position of the hand, and pain syndrome. This circumstance often contributed to late-seeking medical help [47]. The correction of neglected damage is complex and is associated with several anatomical and biomechanical disorders, the correction of which is not always possible within the surgical strategy. In this regard, several surgical approaches and interventions have been proposed. Most authors prefer open one-stage surgical intervention, including ulnar correction (this component is of greatest importance), and open reduction of the radial bone head.

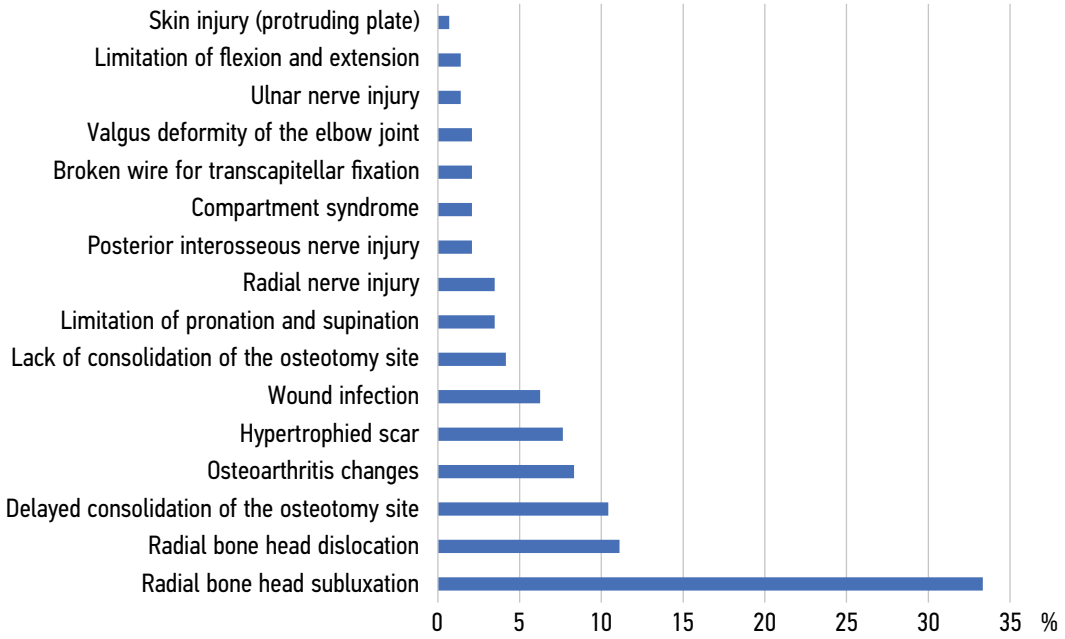

Fig. 7. The structure of complications of the surgical treatment of neglected Monteggia injuries

The issue of grafting the annular ligament remains debatable. Some authors tend to believe in the lack of a clear static relationship between the results of the surgical approach and the Bado classification [43]. Orthopedists converge on the opinion that a surgical delay in neglected Monteggia injuries and the patient's age affect both the clinical [10, 13, 37, 40, 43, 45] and radiological results [51]. Reconstructive efforts should be undertaken urgently to limit the deformity during radial head growth [26]. Open reduction is advisable before the occurrence of secondary deformity of the head and humeroradial arthrosis [37]. With a significant age of injury, in older patients, the wrist joint stability must be assessed [9]. The main problem in treatment results is the recurrence of the radial head dislocation. Despite this, surgery is recommended even for asymptomatic cases or those with minimal clinical manifestations [11]. The best results are noted when performing a reconstructive and corrective intervention up to six months after the injury. The patient's age is of great importance. Significantly better X-ray anatomical results of surgical treatment were noted in patients aged < 6 years than in older patients [32].

CONCLUSION

Accurate diagnostics of injury and early correction of disorders are the most significant in reducing the incidence of complex disorders such as neglected Monteggia injury. When providing treatment to pediatric patients with neglected Monteggia injury, surgical treatment plays the principal role, in which the restoration of the ulnar bone anatomy and ratios in the humeroradial and proximal radioulnar joints is the most important, which ensures a more physiological development of the segment as the child grows.

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Author contributions. *A.R. Gubaeva* conceived the study, data selection, and processing, and wrote the article. *V.I. Zorin* conceived and designed the study and wrote and edited the article.

All authors made a significant contribution to the study and preparation of the article, read, and approved the final version before its publication.

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