ANALYSIS OF THE RESULTS OF SURGICAL TREATMENT OF CORONOID FRACTURES USING A SPECIAL REHABILITATION PROGRAM

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Abstract: The article aims to determine the main factors influencing the treatment of injuries associated with fractures of the coronoid process, optimization of surgical techniques, and postoperative rehabilitation of patients. Surgical treatment of 52 patients with a coronoid fracture was analyzed, including 35 patients with injuries up to 3 weeks and 17 patients with chronic trauma. There were 32 men and 20 women aged 44.1 ± 13.0 years. In 17 cases of fractures of the coronoid process, a transosseous suture of the anterior capsule was performed. In 15 cases, osteosynthesis with a support plate was used, in 13 patients, fixation with screws was carried out, and in 1 – wires were applied. Concomitant fractures of the radial head were treated by plate osteosynthesis in 19 cases and prosthetics in 18 cases. External collateral ligaments were restored in 23 cases. After surgery, patients underwent a special rehabilitation program. The average MEPS function in type I, II and III fracture of the coronal process according to Regan and Morrey, respectively, were as follows - 86.3 ± 4.1; 90.0 ± 7.3; 85.9 ± 13.1. The best functional results were obtained in the coronoid process's osteosynthesis by the support plate (93.0 ± 4.4). A negative effect of collateral ligament damage and an increased time after the injury on the treatment results has been proven. Early rehabilitation is important in restoring the function of the elbow joint.

Keywords: Coronoid fractures, Injuries, Osteosynthesis, Rehabilitation program, Surgical treatment.

1 Introduction

Coronoid fractures account for approximately 1-2% of all elbow fractures, and in 2-15% of patients are accompanied by dislocation of the forearm bones [8]. The coronoid, as the main component of the elbow-shoulder joint, together with the medial and lateral collateral ligaments, represents one of the main static stabilizers of the elbow joint [5, 11, 19, 26]. Numerous clinical observations show that untreated coronary fractures lead to chronic instability and severe anatomical and functional disorders [1, 6, 9, 22].

Ambiguous attitude to the technical aspects of coronoid fractures osteosynthesis raises the issue of indications for conservative or surgical treatment, especially for Regan fractures of I and II degrees [6, 8]. There is also a discussion about the methods of coronoid osteosynthesis: it is proposed to use retrograde threaded wires, screws [5, 7, 24], support plates [12, 21], use the lasso technique of transosseous fixation [6, 27].

An important element in the treatment of these injuries is the restoration of the radial head as a secondary stabilizer of the elbow joint [17]. Most authors agree that removing a broken radial head in the case of a "terrible triad" is contraindicated. To restore the radial head, it is offered to apply either osteosynthesis or prosthetics; treatment by both methods gives approximately the same results [16, 21].

The results of treatment of injuries accompanied by a fracture of the coronoid cannot be considered very encouraging. Thus, after surgical treatment of the "terrible triad", in 76% of cases, the elbow joints remained unstable, all patients had early osteoarthritis, and only four of the thirteen patients had a satisfactory result [17].

No less important component of the treatment of these injuries is postoperative rehabilitation. This issue is given undeservedly little attention, and many unresolved issues remain [16].

Thus, this study aimed to determine the main factors influencing the outcome of treatment of injuries associated with fractures of the coronoid process, optimization of surgical techniques, and postoperative rehabilitation of patients.

2 Materials and Methods

Surgical treatment of 52 patients with coronary fracture, including 32 men (61.5%) and 20 women (38.5%), the average age was 44.1 ± 13.0 years.

According to the injury duration, patients were divided into two groups – acute injury (less than three weeks) and long term injuries – more than three weeks. The group with new injuries consisted of 35 patients (67.3%), the average period after the injury before surgery was 45.0 ± 20.1 days.

Seventeen patients (32.7%) with long term injuries were observed. These patients' treatment time ranged from 25 days to 1.5 years from the primary injury and averaged 112 ± 100.2 days. In the group with the consequences of injuries, 12 patients underwent preliminary surgical treatment. The diagnosis of a coronoid fracture has not been established in almost any case. In general, previous surgical treatment is difficult to characterize as sufficient; namely, removal of the radial head (6 cases) and synthesis of the ulnar process in 2 cases without coronoid osteosynthesis led to chronic persistent instability, severe contractures, and significant limitation of elbow function.

Among 52 cases of coronal fracture, only 3 (5.7%) were observed in isolation, while in all other patients, the coronoid fracture was accompanied by a concomitant fracture of the bones in the elbow joint. In particular, the concomitant fracture of the distal humerus was observed in 4 cases, and in 48 (92.3%) cases, the fracture of coronoid was accompanied by a fracture of the radial head; among them, there are 15 (28.8%) cases of simultaneous fracture of the radial head and olecranon.

Only in 8 cases (15.4%) fractures of the coronoid, data were not reported for elbow dislocation; in another 44 (84.6%) cases, coronoid fractures and other concomitant injuries caused elbow dislocation.

Coronal fractures were classified according to Regan and Morrey. Among the presented patients, type I fracture was observed in 18 (34.6%) cases, type II – in 22 patients (42.3%), and 12 patients (23.1%) had type III fracture. The percentage of forearm bone dislocations in groups I, II, and III constituted 88.9%, 81.8%, and 83.3%, respectively.

Different approaches were used during the interventions. The most frequently used ones were the following: lateral, posterior, and anterior accesses in 45.9%, 25.7%, and 18.9%, respectively. In 20 patients, a combination of anterior and posterior approaches (8 cases), lateral and medial – 6 cases, and lateral and posterior – 6 cases were used.

The choice of access depended on the combination of injuries and the severity of the injury. Thus, in relatively mild injuries, such as fractures of the radial head and coronoid of type I, according to Regan, usually lateral access was used. In more severe trauma with multi-fragment fractures of other bones, posterior access or two accesses were used. Anterior access was used independently in multi-fragment fractures of the radial head and coronoid of II-III degrees, as well as in the consequences of such injuries in 25% of cases. This made it possible to perform osteosynthesis with a plate and screws within one access, and, if necessary, bone grafting, coronoid process, as well as osteosynthesis or the radial head replacement.

In 9 cases, due to the absence of the coronoid process (which was removed in the previous stages of treatment), bone-grafting reconstruction of the coronoid was performed with fixation of the graft with a plate and screws, mobilization, and transosseous fixation of the anterior capsule to the formed coronoid.

In 13 cases of the detachment of the anterior capsule from the coronoid or fractures of the coronoid belonging to type I, a

transosseous suture of the capsule of the ulnar joint of the coronoid was performed with anchor clamps or through pass-through holes through the ulna (the thread is tied from the back) (Table 1).

Table 1: Methods of fixing the coronoid depending on the degree of fracture

Type of the coronoid fracture	Quantity	%	Method of fixation	Quantity
I	18	34,6%	Capsule seam	13
II	22	42,3%	Plate	8
			Screws	8
			Wire	1
			Capsule seam	4
III	12	23,1%	Screws	5
			Plate	7
Total	52		Total	46

In type II fractures, as a rule, a plate and screws were used for osteosynthesis of the coronoid; in type III fractures either a plate with screws or two screws were used.

Interventions for fractures of the radial head were performed in 47 (88.7%) patients. Osteosynthesis with a plate and screws was used in 19 (36.5%) cases, and prosthetics in 18 (34.6%), osteosynthesis with screws in 7, and the radial head were removed in 1 case.

Eleven patients underwent elbow osteosynthesis using a plate and screws, and 6 of them underwent bone grafting of bone defects. Osteosynthesis of the distal humerus was performed in three patients.

In 30 cases, the lateral ligaments of the elbow joint were restored. The external collateral ligament was most often restored - 23 (76.7%) cases; the medial collateral ligament was restored in 7 patients, and both ligaments were restored in 5.

2.1 Rehabilitation

After surgery, a special rehabilitation program was used in all presented patients with coronoid fractures or their consequences, which began on the first day after surgery. After the operation, a posterior plaster splint was applied in the position of extension of the elbow joint in 20-30 degrees. Depending on the concomitant damage to the ligament, pronation, supination, or neutral installation was used. Dosed active flexion with a braid bandage was started from the first day after surgery. The patient makes one cycle of movements per day: in the morning dosed flexion from 20-30° to 100-120°, keeping the elbow joint in the flexion position 100-120° during the day, and in the evening – slow extension and fixation in a plaster cast in the extension position 20-30°. Over time, the extension angle decreased. Such rehabilitation lasts 2-2.5 months. In cases of restoration of the ligament in the first four weeks, instead of a square bandage, a plaster splint is used in the position of bending the elbow joint at an angle of 110-120 degrees. In 1.5 months after the operation, the load's intensity on the limb is increased, and massage and physiotherapy are started.

3 Results

Long-term outcomes were assessed by us in 39 of 52 patients (75%) for MEPS at 2 years or more (55.9 ± 8.5 months).

When analyzing the results of treatment, taking into account the type of fracture of the coronoid – I, II, and III types by Regan and Morrey, the average function (MEPS), respectively, were as follows: 86.3 ± 4.1; 90.0 ± 7.3; 85.9 ± 13.1. The results of 90.0 ± 7.3 MEPS of type II fractures are statistically better ($p < 0.05$) than the results of 86.3 ± 4.1 fractures of the coronoid with type I. The results of treatment for fractures type II and III by Regan and Morrey did not differ statistically.

In 9 patients with a fracture of the coronoid of the degree I, who had a transosseous suture of the anterior part of the capsule, the result of MEPS was 84.4 ± 5.3, and in 4 patients, also with a fracture of the coronal process of the 1st degree, and without suturing the anterior capsules, the result for MEPS was better 87.5 ± 10.2, but these differences were statistically insignificant. The explanation for the difference in the results was that in those 9 patients in whom the anterior capsule was sutured, in 7 cases (78%) rupture of the lateral ligaments was diagnosed and their suturing was performed, while in 4 patients in whom restoring of the anterior part capsules of the elbow joint was not carried out, only one needed to suture the external collateral ligament.

The MEPS results were also analyzed depending on the nature of the intervention on the coronoid. The best functional results for MEPS were obtained with osteosynthesis of the coronoid with plate 93.0 ± 4.4, while with the suture of the anterior capsule in the case of type I fractures, the results were 88.8 ± 4.4; when using purely screws 82.2 ± 14.2 respectively, and in patients for whom interventions on the coronoid were not performed, the results were the worst 80.0 ± 21.0. The results after the MOS with plate were significantly better ($p<0.05$) than after the suture of the anterior capsule and the use of screws.

Similar differences in treatment outcomes were because in the groups with capsule suture and use of screws, there were 3 patients in whom these interventions were not sufficiently justified, and in these three cases, it would be appropriate to use MOS plate and screws. Due to the insufficiently stable fixation when using sutures and screws, there was a need to increase the period of immobilization, which led to worse results, contributing to a decrease in the average function in each of these groups.

Coronoid fusion in 2 cases of osteosynthesis of the coronoid process in type II fracture consolidation did not occur. In one case, due to scar adhesions, the stability of the joint was preserved, and, after the mobilizing operation, a satisfactory amount of movement was achieved. Another elderly female patient developed flexion contracture of the elbow joint and significant restriction of pronation-supination movements. One female patient replacement of the radial head was performed but a fractured coronoid of type II not fixated. Despite the stability achieved in the elbow joint during surgery, instability of the elbow joint and pain developed over time.

The results of treatment of patients with simultaneous fractures of the coronoid process and the radial head were also analyzed. The best results were obtained in the osteosynthesis of the radial head with screws - 95.0 ± 6.9 and osteosynthesis with the use of plates and screws (90.7 ± 4.1). In the case of the radial head replacement, the result of MEPS was 81.4 ± 10.6.

Figure 1 shows a case of coronoid fracture of degree II, according to Regan. Three-fragmentary fracture of the radial head, fracture of the ulna's diaphysis with displacement. Osteosynthesis of the ulna was performed from the posterior approach, then osteosynthesis of the coronoid process and the radial head was performed from the anterior approach (Figure 1).

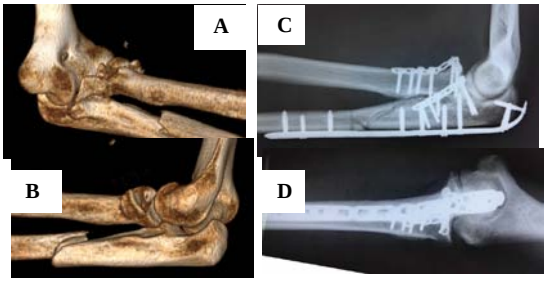

Figure 1 – Fragmentary coronoid fracture of the degree II according to Regan. Three-fragment fracture of the radial head

with displacement, fracture of the diaphysis of the ulna (A, B). Condition after repositioning and osteosynthesis (C, D)

The patient underwent the above rehabilitation course. Within 4.5 months, the full amount of flexion-extension in the elbow joint and almost the total amount of supination-pronation movements were obtained (Figure 2).

Figure 2 – The result is 4.5 months after surgery. The result for MEPS 100

In the group of patients with a coronoid fracture who underwent olecranon osteosynthesis, the MEPS result was 92.5 ± 5.3, which was significantly better ($p<0.05$) than the MEPS index in all other patients without olecranon osteosynthesis 86.49 ± 5.5. More likely, the results were since in the subgroup with osteosynthesis of olecranon and coronoid, the percentage of LCL or MCL damage was 25%; on the other hand, in the subgroup of 30 patients (who had no fracture of the olecranon but the coronoid fracture was accompanied by radial head fractures), damage to the lateral ligaments was observed in 70% of cases. That is, the results of treatment in these two subgroups, in our opinion, were influenced by the different proportions of LCL and MCL damage.

A comparative evaluation of the results was performed in the group of patients in whom no damage to the ligament was found, or there were minor manifestations of lateral instability and, accordingly, they were not restored (23, 44.2%); and patients (28, 53.8%) who underwent a restoration of one or two lateral and medial collateral ligaments. In the first of these groups, the elbow dislocation at the time of injury was in 17 (73.9%) patients; in the second group, where ligaments were restored, the elbow dislocation was in 26 (92.9%) patients.

The mean MEPS function in the group without significant clinical signs of lateral ligament damage was 91.7 ± 3.9, in the group with the recovery of one lateral ligament (LCL) – 87.8 ± 6.6, and in the group with LCL and MCL recovery – 72.0 ± 24.3. There was a statistically significant difference ($p<0.05$) between these averages. These data indicate that ligament damage (LCL and MCL), despite their recovery, has a significant adverse effect on the result of treatment.

When analyzing the results of treatment depending on the delay of injury, it was determined that the average value of MEPS function in the group operated before 21 days after injury was within 90.0 ± 5.4, while when performing the surgical treatment in term of more than 21 days, the average function was 80.5 ± 15.9. A statistically significant difference was observed between the mean values ($p<0.05$). The treatment of previously unoperated patients was 89.5 ± 4.9 and was statistically better ($p<0.05$) than in the group of patients who underwent surgery in the previous stages – 78.8 ± 22.2.

4 Discussion

Regan and Morrey, introducing a 3-stage classification of the coronoid process in 1989, found that the results of conservative treatment of patients with an increased degree of coronoid fracture deteriorate [22]. O'Driscoll [17] emphasized that in the "terrible triad" with grade II and III coronoid fractures, the results remain unpredictable and have a high percentage of negative results. In our study, there are some differences between the treatment results of patients with varying degrees of coronoid fracture, but in fractures of the first and third type, the results were almost the same. The best results were achieved in patients with coronoid fracture of type II. The obtained data show that the degree of coronoid fracture, with the full recovery of the elbow joint's main stabilizers, did not have a significant impact on the final result.

The most commonly used approach to restoring the coronoid process is lateral, which allows carrying out osteosynthesis of the coronal process and the radial head [2, 5, 6, 7]. This access is convenient for suturing the anterior part of the capsule in fractures of degree I, the lasso technique, and the coronoid's retrograde fixation. For osteosynthesis of the coronoid process by the support plate, this approach is extremely inconvenient. Therefore, it is often suggested to perform medial or posterior-medial accesses, which are also suitable for fixing large fragments of the coronoid with either screws or a plate [5, 8].

An anterior-medial approach is also used, which involves mobilizing and cutting off a portion or all of the round pronator from the humerus and mobilizing the shoulder muscle [10]. Anterior access is also offered for grade II fractures [23, 26]. It is technically more complex but allows performing high-quality osteosynthesis of the coronoid process, even with fragmentary fractures. In the presented series of studies, we used an anterior approach in 25% of patients with stage II coronoid fractures.

Indications for the coronoid process's osteosynthesis, especially in type I and II fractures, are still the subject of constant debate. Experimental studies confirm that the stability of the elbow joint is significantly impaired in fractures of more than 50% of the coronoid [3]. A significant number of publications emphasize that fractures of the degree I and II do not require surgery [4, 13, 14, 19]. On the other hand, in a biomechanical study by Pollock et al., it has been established that the first signs of instability appear with a fracture of the coronoid process of 30% or 5 mm [6, 20]. Thus, with fractures of the coronoid of 2 degrees combined with a fracture of the head, severe instability often arises, which requires stabilization of damaged elements of the joint [25].

We are also in favour of trying to repair most coronoid fractures, even of grade II. Grade II fractures represent the most complex fractures group from a technical point of view because these fractures are often fragmented and often inconvenient for fixation with screws. However, the main argument in favour of the restoration of the coronoid process is a significant increase in joint stability, which allows for an earlier and more effective rehabilitation program, which, in turn, affects the final results of treatment [1].

As for the attitude to the methods of synthesis of the coronoid process, in our series of observations, the support plate turned out to be a more stable method of fixation than screws, which coincides with the data of Rausch et al. [21] and Kiene [12].

Many experts in this field emphasize the need to restore lateral collateral ligaments [17, 18, 25], and their restoration is included in the treatment protocol of the "terrible triad" [14]. However, we did not find a study of the effect of lateral ligament damage on treatment outcome. Our study showed that despite the restoration of LCL and MCL, the functional results in these observations were worse than coronoid fractures, which did not require restoration of the lateral ligaments.

A long-term injury to the coronoid process can lead to chronic dislocation of the forearm bones or chronic instability, the treatment of which is a very difficult task. We did not find any references to a comparative study of the results of treatment of acute and long-term fractures of the coronoid process (including cases of chronic posterior instability).

According to our data, it is proved that operating in terms of up to 3 weeks gives significantly better results, but in the group with long-term coronoid fractures, which were accompanied by chronic posterior dislocation, contractures, good results can be

achieved. Thus, out of 15 patients with chronic trauma, in whom long-term treatment results were evaluated, in 7 cases, the results were better than 95 points for MEPS, and only one unsatisfactory result was stated.

It is difficult to overestimate the importance of postoperative rehabilitation of coronoid fractures and related injuries to improve outcomes. As a rule, published rehabilitation protocols provide postoperative immobilization of the elbow joint in the flexion position of 70-90° [8, 6, 16, 17]. The onset of the active load varies from 2 days to 1-2 weeks, and the nature of the load, intensity, and frequency are determined by the feeling of comfort for the patient. Rehabilitation under such conditions can last quite a long time – 6-12 months, despite the use of various orthoses and devices [15].

5 Conclusion

Our study presents a different approach to rehabilitation for elbow injuries associated with a fracture of the coronoid process. We suggest fixing the elbow joint in extreme positions during the day.

A combination of early onset of movements in the functional range with immobilization of the elbow joint to the extreme positions – full extension and flexion of 110-130 degrees – is achieved. A more intense load in the future, as a rule, makes it possible to achieve bending up to 130 degrees or more without losing almost complete extension. Under such conditions, contractures do not occur, and there is no need to eliminate them in the future; it is only necessary to maintain the required amount of movement.

Thus, the fracture of the coronoid process, in most cases, is a manifestation of severe trauma, requiring precise and stable osteosynthesis of fractured joint fragments, restoration of the ligament, and a specialized rehabilitation program. The most effective treatment for such patients is up to 3 weeks after injury.

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