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## Current trends in the treatment of acetabular fractures (literature review)

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*Acetabular fractures are known for their disabling outcomes, so the search for optimal treatment tactics is an actual problem for modern orthopedics and traumatology. Materials and methods. Randomized trials that reflect the results of acetabular fractures treatment depending on the method of treatment were analyzed. The literature was searched in the PubMed Central database. Hip joint is a complex two-component articulated system. Traumatic lesion of all elements of the joint creates the conditions for the development of a wide range of complications and secondary changes that must be taken into account at preoperative treatment. Acetabular fracture is an intra-articular injury, where the visualization methods have the prominent significance. Nowadays the treatment can be conservative and surgical. Surgical treatment can be divided into two areas: osteosynthesis and arthroplasty. Anatomical reposition and stable fixation of fragments, in the most of cases, is the key to a satisfactory functional result, but the development of post-traumatic changes in the joint nullifies the results of even perfect osteosynthesis, encourages repeated surgery and, finally, hip replacement. In recent years, primary arthroplasty has been successfully used to treat acetabular fractures, reducing inpatient and rehabilitation period, compared with osteosynthesis, preventing the possible development of secondary degenerative changes in the joint. Conclusions. Acute hip replacement is an effective treatment, however, the technical aspects of reliable fixation of the acetabular component of the implant are insufficiently substantiated and highlighted in actual literature and constitute significant research interest. Key words. Acetabular fractures, acute hip replacement, posttraumatic hip arthritis.*

*Переломи кульшової западини відомі своїми наслідками, що порушують функцію кульшового суглоба та призводять до інвалідизації в 73–88 % випадків. Саме тому вибір оптимальної лікувальної тактики залишається відкритим питанням. Мета огляду. Виділити основні клініко-анатомічні характеристики травматичних ушкоджень кульшового суглоба, особливості діагностики, які впливають на вибір лікувальної тактики, оцінити ефективність відомих способів лікування переломів кульшової западини та перспективи подальших досліджень. Методи. Проаналізовано рандомізовані дослідження, які відображають результати лікування пацієнтів із переломами кульшової западини залежно від його способу. Пошук літератури здійснено в базі даних PubMed Central. Результати. Кульшовий суглоб — складна двокомпонентна шарнірна система. Ураження всіх елементів суглоба під час травми створює умови для розвитку широкого спектра ускладнень і вторинних змін, урахувати які необхідно під час планування лікування. Перелом кульшової западини є внутрішньосуглобовим ушкодженням, під час діагностики якого вирішальну роль відіграють методи візуалізації. Лікування на сьогодні здійснюють консервативним і хірургічним способами. Останній можна поділити на два напрями — остеосинтез та ендопротезування. Анатомічна репозиція та стабільна фіксація фрагментів здебільшого є запорукою задовільного функціонального результату, проте розвиток післятравматичних змін у суглобі може призвести до повторних хірургічних втручань і, урешті, тотального ендопротезування. Останніми роками первинне ендопротезування успішно застосовують для лікування переломів кульшової западини, що дає змогу скоротити час перебування хворого в стаціонарі та період реабілітації, уникнути вторинних дегенеративних змін у суглобі. Висновки. Первинне ендопротезування — ефективний лікувальний захід, проте, технічні аспекти надійної фіксації ацетабулярного компонента ендопротеза недостатньо обґрунтовані та висвітлені в сучасній літературі й становлять значний дослідницький інтерес.*

**Key words.** Acetabular fractures, acute hip replacement, posttraumatic hip arthritis

## Introduction

The incidence of fractures of the acetabulum increases in direct proportion to the industrialization of society. In the general structure of injuries about 3 % of the total number of fractures are fractures of the pelvic ring, of which 20 % are isolated fractures of the acetabulum and 6 % of pelvic ring, combined with damage to the acetabulum. More often, fractures of the acetabulum are the result of high-energy trauma resulting from an accident, cata-trauma and, as a rule, are part of polytrauma [1, 2]. Over the past 30 years, there has been a tendency to a sharp increase in low-energy isolated fractures of the acetabulum secondary to systemic osteoporosis among the elderly [3].

Hip fractures are known for their consequences, which disrupt the function of the hip joint and, despite the whole modern arsenal of treatment measures, lead to disability in 73–88 % of cases [4]. That is why the choice of optimal treatment tactics remains an open question.

*The aim of the review:* to identify the main clinical and anatomical characteristics of traumatic hip injuries, diagnostic features that influence the choice of treatment tactics, to analyze the effectiveness of known methods of treatment of hip fractures, in particular, to determine the location of primary arthroplasty, and prospects for further research.

## Material and methods

Randomized trials were selected for the assessment, which reflect the results of treatment of patients with fractures of the acetabulum, depending on its method. The literature was searched in the PubMed Central database by keywords «acetabular fracture», «acute hip replacement», «acetabular fracture, outcome», «revision hip arthroplasty», «combined hip procedure». Additionally, a search of publications from bibliographic lists of selected sources of literature, monographies and clinical recommendations on this topic. A total of 44 sources were selected for the assessment.

## Results and their discussion

Identifying the basic anatomical units that make up the hip joint and understanding the anatomical and physiological key to their effective, coordinated functioning is necessary to restore joint function after injury.

The hip joint is a two-component articulated system consisting of the acetabulum and the femoral head. The bony base of the acetabulum provides shelter for the femoral head just under half (170°).

The fibrous ring adds approximately 33 % to the total volume of the joint, increasing stability, which is one of the keys to its normal function and the main indication for surgical treatment in case of its violation [5]. It is proved that the stability of the hip joint depends on the integrity of the posterior wall of the acetabulum and to a lesser extent the capsule of the joint. It was found that in the case of fracture of the posterior wall of the acetabulum with a fragment of 33 % of its total area and intact joint capsule 75 % of the joints remained stable and only 14 % in the case of a similar fracture with damaged posterior capsule [8, 10].

The intersection of the anterior and posterior columns, located at the level of the apex of the large sciatic notch, is the strongest part of the iliac bone, which creates support for the upper wall of the acetabulum and is practically not injured in case of pelvic fractures [6]. The organization of the bone base of the acetabulum allows its dynamic deformation depending on the load. At its insignificant values (up to 30 % of body weight) the distribution of forces is carried out only between the front and rear walls, and the vault of the depression is loaded in case of increasing load. The posterior wall is much more elastic than the anterior one. The transverse ligament together with the quadrilateral plate act as stabilizers of excessive deformation [7].

The articulating surface of the acetabulum is covered with hyaline cartilage and has a crescent shape with a greater thickness of the coating of the anterior, upper and posterior walls and a minimum medial and section of the acetabular notch [8]. Mathematical studies prove that this shape of the cartilaginous surface of the acetabulum provides optimal contact of the articulating surfaces and prevents the appearance of zones of critical load in the joint [9].

The blood supply to the acetabulum depends on a wide, extensive network of blood vessels and is occasionally compromised. The blood supply to the femoral head is extremely limited anatomically and can easily be compromised due to injury or poor surgical access [11]. The prognosis after injury largely depends on the condition of the articular cartilage of the femoral head, the damage of which can vary from associated with contusion of the subchondral bone and circulatory disorders to total detachment.

The morphology of the tissues that form the hip joint, spatial orientation of its elements, presence of cartilage of the articulating surfaces, abundant, efficient blood supply system determine its impressive range of motion with significant stability. The complex structure and elegant interconnection of the ele-

ments of the joint cause significant difficulties in the reconstruction of its damage.

*Classification of fractures of the acetabulum*

Since the publication of information on the first successful cases of surgical treatment of fractures of the acetabulum, the authors emphasize the need for differentiated use depending on the type of fracture. The morphological classification of fractures available at that time (1948) was descriptive and could not serve as a basis for possible treatment tactics [12]. Therefore, as early as 1964, R. Judet and E. Letournel [6] proposed a system for classifying fractures of the acetabulum, based on the concept of its anatomical construction of two columns. This system includes five elementary fractures: 14–24 % of fracture types are fractures of the posterior wall (in the general structure of fractures of the acetabulum), 2 % of anterior and 1–3 % of posterior column, 4–13 % of anterior, 7–17 % transverse and five combined: 1–5 % of transverse and posterior wall, 3–5 % of posterior wall and posterior column, 7–8 % T-shaped, 3–7 % of anterior column and semi-transverse, 20–23 % of two columns [13]. It is quite reliable and universal, so it is widely used today. Moreover, this system became the basis of a detailed Muller AO classification [14] (see the Table), which is also based on the concept of two-column structure of the acetabulum, but additionally takes into account the degree of damage to the articular surface.

In this classification, there are 27 subtypes of fractures, which are isolated cases, but have their own characteristics, which must be taken into account in a differentiated approach to diagnosis and treatment [15].

*Diagnosis of fractures of the acetabulum*

Since fractures of the acetabulum are usually the result of high-energy trauma and are often accompanied by impaired integrity of the pelvic ring, long bones, spinal and craniocerebral injuries, pelvic

and abdominal injuries, the detection of concomitant injuries requires special attention during primary care. Bruises and hematomas of the acetabulum may be a sign of Morel-Lavalle damage, which is a peeling skin with fluctuations due to the presence of hematoma and necrosis of adipose tissue. Such damage, although formally closed, is often complicated by secondary bacterial contamination and requires careful debridement and drainage before planning surgical treatment of the fracture.

A thorough neurological examination is mandatory. Damage to the sciatic nerve, according to G. J. Haidukewych et al. [17], was detected before surgery for fracture of the acetabulum in 12–38 % of all cases, respectively, the rest was regarded as iatrogenic.

For all patients who have suffered a high-energy injury, it is mandatory to perform a radiography of the skull in two projections, the chest and the pelvis in the anteroposterior projection.

If a hip fracture is suspected, three additional Judet projections are indispensable:

1. Anterior-posterior image of the injured hip joint;
2. Oblique iliac projection to assess the condition of the posterior column and anterior wall. The patient rotates 45° in the direction of the injury, and the beam is centered on the symphysis;
3. Oblique back projection: used to assess the back hole, anterior column and posterior wall. The pelvis is rotated 45° to the healthy side, and the beam is centered on the damaged joint [15].

The condition of the femoral head as part of the hip joint must be assessed. Today, computed tomography (CT) has become the «gold standard» in the diagnosis of intra-articular injuries, and the acetabulum is no exception. Multiplane, layered, three-dimensional visualization provides comprehensive information on

**Classification of acetabular fractures by AO ([14])**

*Table*

Type of fracture	Characteristic	Subtype
A	Incomplete intra-articular fracture affecting only one of the two columns	A1 — posterior wall
		A2 — posterior column
		A3 — anterior column or wall
B	Incomplete intra-articular fracture with transverse component	B1 — simple transverse
		B2 — T-shaped
		B3 — anterior column and posterior half-transverse
C	Complete intra-articular fracture (both columns)	C1 — high variant, extends to the iliac wing
		C2 — low variant, extends to the anterior edge of the iliac bone
		C3 — extends to the sacroiliac joint

the nature of the damage and allows for preoperative planning [18]. In some cases, magnetic resonance imaging (MRI) of the pelvis is performed as a predictor of treatment outcome to clarify the condition of the articular cartilage, to detect early signs of aseptic necrosis of the femoral head (ANFH).

#### *Treatment of fractures of the acetabulum*

The requirements of modern orthopedics-traumatology for the treatment of traumatic injuries include reducing the patient's stay in the hospital and return to normal activities as soon as possible. The answer to this is to some extent the rapid evolution of surgical treatments. Despite this trend, conservative treatment of acetabular fractures remains widespread. According to modern standards [15], it can be recommended in the case of some stable fractures without displacement, while maintaining the concentricity of the acetabulum [13]. Such fractures include:

- not extended to the vault of the loaded joint;
- low anterior columns;
- posterior wall with a small fragment, which are not accompanied by dislocation of the thigh and do not extend to the posterior upper part of the cavity;
- low transverse, at which the «angle of coverage of the roof of the depression» (Matta angle) remains greater than  $45^\circ$  in all three X-ray projections;
- both columns with satisfactory secondary congruence in patients with low functional requirements.

According to the literature of the first half of the 20<sup>th</sup> century, a satisfactory result after conservative treatment of fractures of the acetabulum was achieved in a minority of cases (13–30 %). At the same time, traction was performed along the thigh axis, early mobilization of the joint with a gradual increase in load [19]. Today there is a tendency to abandon permanent skeletal traction as a therapeutic measure. The best functional results were determined in patients for whom skeletal traction was used only to eliminate hip dislocation in its presence. It is also emphasized that the key to a satisfactory result is the rational control of the pain syndrome and the fastest mobilization of the patient with the help of additional support [20].

Surgical methods of treatment of hip fractures are divided into osteosynthesis, hip arthroplasty and their combination.

In 1943, M. A. Levine was one of the first to report the successful outcome of open repositioning with metal osteosynthesis for a fracture of the acetabulum [21]. In 1964, a fundamental article was published providing a system of classification and surgical access for the treatment of fractures of the acetabulum [6]. Subsequently, as indicated in the literature

review [22], a series of observations were performed involving 492 and 816 patients who underwent open repositioning and metal osteosynthesis for the treatment of hip fractures. In the first group, 80 % were good and excellent (according to the modified Merle d'Aubigné and Postel scale), in the second twenty-year survival of the hip joint was found in 79 % of patients, which proves the decisive influence of repositioning quality on clinical outcome.

An important component for achieving a positive result of the operation is the choice of optimal surgical access, which will provide the best opportunities for anatomical reposition and stabilization of the joint surface in the least traumatic conditions. In 1990, K. A. Mayo formulated five main factors that influence the choice of access: 1) fracture configuration; 2) the condition of soft tissues in the area of operation; 3) the presence of concomitant injuries and diseases; 4) the patient's age and the expected functional outcome of treatment; 5) the duration of the injury [23]. The AO/ASIF team identifies the five most commonly used approaches: Kocher-Langenbeck, inguinal-inguinal, Stoppa, advanced femoral-femoral, surgical hip dislocation (Berne access) [15, 24]. In modern surgery, there has long been a tendency to reduce the invasiveness of interventions. This fully applies to fractures of the acetabulum.

D. L. Helfet, G. J. Schmeling [25], analyzing the results of surgical treatment of 84 complex two-column fractures of the acetabulum, reported 91 % of good functional results in the case of infectious complications 0 %, and 2 % of clinically significant heterotopic ossification using closed, indirect repositioning methods and single restricted operational access. Despite the well-known disadvantages of extended and combined surgical approaches, such as excessive duration of surgery, blood loss, risk of infection, iatrogenic neurovascular damage, weakness of the hip abductors, limitation of movement and heterotopic ossification, they become necessary due to the need for reoperation. V. Trikha and R. Tornetta noted that traumatic accesses become especially indispensable for adequate repositioning and fixation of complex fractures in the case of surgery 3 weeks or more after injury [26].

A group of AO authors based on a unified classification of AO/ASIF fractures developed a clear treatment algorithm for each type of fracture [15]. This algorithm involves the implementation of a set of measures from diagnosis to rehabilitation. Single, anterior or posterior access is preferably sufficient for adequate repositioning and stable fixation of most fractures, with the exception of cases

where simultaneous stabilization of both columns of the acetabulum, or, for example, intrapelvic fixation of the anterior column and revision of the hip joint is required. For such complex fractures, extended access or a combination of standard ones is forced. Reposition of the fragments of the acetabulum often cannot be performed by direct manual manipulation, which requires the use of intraoperative extraction or distraction of the hip joint and a set of specially designed tools and intraoperative imaging. Fixation of fragments is carried out by means of reconstructive plates and screws in various combinations. The use of individual metal structures made taking into account the anatomical features and the nature of the fracture by 3D-printing from titanium is becoming relevant [27].

Traditional osteosynthesis, regardless of the type of fracture, requires anatomical repositioning of the articular surface, stable fixation of fragments, extra-articular conduction of fixing elements, sufficient access and arsenal of tools for repositioning maneuvers. Surgery should be performed in the conventional period after injury. It is known that after 10 days from the moment of injury, all indirect repositioning maneuvers become ineffective, require more traumatic approaches and significant skeletalization of fragments with a violation of their vascularization [28].

According to the meta-analysis, timely surgery in accordance with the basic principles causes 65–91 % of excellent and good functional results (according to the modified Merle d'Aubigné and Postel scale) depending on the type of fracture [22].

Against the background of the general tendency to minimize the trauma of surgical interventions, alternative techniques such as osteosynthesis with cerclage, cable systems and cannulated screws deserve attention. Cable systems have proven themselves well for the treatment of fractures due to osteoporosis in the elderly, where the stability of the screws is compromised by low bone density, and the quality of reposition is not very important given the low functional needs. The technique of cerclage fixation involves its use as a means of repositioning and final fixation at the same time [29].

Minimally invasive percutaneous osteosynthesis with long cannulated screws involves conducting them along both columns of the acetabulum under radiological control. Elderly age, overweight, early onset of axial loads in the case of fractures without displacement are considered traditional indications for minimally invasive treatment [30, 31].

However, osteosynthesis, even in the case of ideal performance, does not guarantee the absence of late

complications after fractures of the acetabulum, which lead to unsatisfactory functional results and repeated surgical interventions. In general, the disadvantages of osteosynthesis include: traumatic intervention, iatrogenic damage to neurovascular structures, heterotopic ossification, the risk of infectious complications, aseptic necrosis of fragments and the formation of false joints in the acetabulum [32, 33]. The incidence of ANFH was found to be 5.6 % [32] occurring more often after posterior dislocations of the femoral head. Some experts emphasize that critical circulatory disorders in the femoral head occur at the time of injury and do not depend on further treatment [34]. Fusion disorders, according to E. Letournel and R. Judet [16], were detected in only 0.7 % of cases. Summing up the general opinion, D. Morita stated that the formation of a false joint of the acetabulum complicates multifracture fractures in the absence of reposition and unstable fixation [35]. Heterotopic ossification in the area of the hip joint is a long-known complication of fractures of the acetabulum, the frequency of which is from 3 to 69 % [36, 37]. Factors that significantly increase the risk of this complication include access trauma, gender, concomitant damage to the skull and peripheral nerves, delayed repositioning and internal fixation, trauma energy, multifragmentation of the fracture and concomitant defects in osteogenesis [37]. Post-traumatic osteoarthritis of the hip joint is the most common complication of fractures of the hip cavity, the frequency of which according to various data is from 4 to 48 %. E. Letournel and R. Judet [16] reported 17 % of cases complicated by post-traumatic coxarthrosis, in 10 % of which an ideal reposition was achieved during the operation [6]. Similar statistics are given by other authors, which, in addition, emphasize the importance of factors such as ANFH, damage to the articular cartilage of the femoral head, old age, long complicated primary surgery [22]. A retrospective study showed that under conditions of ideal reposition coxarthrosis developed in 18 % of cases, in the case of residual displacement of fragments of the acetabulum 1–3 mm, the incidence of arthrosis increased to 58 %, in diastase over 3 mm up to 100 %. The diagnosis of «post-traumatic coxarthrosis» was established in 32 months after injury [34].

A directly proportional deterioration of the results of osteosynthesis in the case of fractures of the acetabulum depending on the age of patients was shown [2]. Comorbidity, diffuse osteoporosis, characteristic of the older age group, causes unsatisfactory structural properties of bone tissue, which is realized

in massive impression, multifragmentary fractures of the acetabulum as a result of minimal trauma [3]. In young people, fractures resulting from high-energy trauma, despite the good condition of bone tissue and lack of comorbidity, can be complicated by fragmentation of the acetabulum of high degree, often with damage to the femoral head, which worsens the prognosis. These groups of patients are the most likely candidates for primary arthroplasty after hip injury [38]. However, there is no consensus on the role of this surgical method in the treatment system. In our opinion, the controversy is related to different approaches in orthopedic centers, which face mainly the consequences of trauma and low-energy injuries secondary to structural changes in bone tissue, and those departments of emergency trauma and polytrauma, whose patients are young people after high-energy injuries, infrequently with multiple injuries, in a state of shock. Accordingly, in the first case, the training of surgeons, the experience of performing complex reconstructive surgery determines the propensity for endoprosthesis, and in emergency trauma centers teams with extensive experience in osteosynthesis, emphasize the inexpediency of endoprosthesis [39].

Primary endoprosthesis in case of fractures requires elimination of gross deformations, restoration of concentricity of the acetabulum and its stable fixation for reliable fixation of the acetabular component of the endoprosthesis with plastic replacement of existing defects and restoration of the anatomical center of joint rotation [40]. If necessary, in order to stabilize the acetabulum, in addition to plate fixation, the method of cerclage fixation has been widely used [41]. In the process of endoprosthesis selection, cementless acetabular components with the possibility of polyaxial fixation with screws are preferred. Porous acetabular components with tantalum coating have a significantly better potential for reliable fixation in the presence of a deficit of contact area with intact bone [42].

Various options for stabilization of the acetabulum are not always sufficient for stable installation of the acetabular component of the endoprosthesis due to the formation of a bone defect of the acetabulum. Promising ways to solve this problem are the use of methods of revision arthroplasty, in the presence of defects of the acetabulum [43, 44]. In general, a successfully performed primary arthroplasty becomes the only surgical intervention that effectively stabilizes the fracture of the acetabulum, allows early function of the operated limb and rehabilita-

tion of the patient, prevents the possible development of secondary degenerative changes in the joint.

## Conclusions

Treatment of hip fractures remains a topical issue in orthopedics and traumatology given the controversial approaches and the high level of unsatisfactory results.

The hip joint is a complex two-component articulated system supported by two columns of the acetabulum. Articular cartilage of articulating surfaces, capsular ligament, blood supply system, localization of damage taking into account the distribution of loads in the joint are important anatomical and functional factors that affect the outcome of treatment and should be evaluated at the stage of diagnosis. The generally accepted Muller-AO classification is based on the anatomical concept of construction of the acetabulum of two columns and focuses on the degree of damage to the articular surface.

The leading methods of diagnosis of fractures of the acetabulum are visual. In addition to standard radiography, CT is the «gold standard» in the diagnosis of intra-articular fractures, including the acetabulum. An important aspect in the diagnosis of fractures of the acetabulum is the timely detection of concomitant injuries that can worsen the general condition of the patient and compromise the results of treatment.

The generally accepted surgical method of treatment of fractures of the acetabulum is open reposition and osteosynthesis, the results of which are directly proportional to the quality of reposition of the articulating surfaces and the stability of their fixation. Hip injuries are known for their severe complications, which can nullify the results of even perfect anatomical osteosynthesis. The development of such secondary changes as post-traumatic coxarthrosis, ANFH, today remains largely unpredictable. These complications become a significant obstacle to the restoration of joint function and lead to repeated surgery and, finally, total arthroplasty. Staged surgical interventions are always associated with trauma, long periods of incapacity for work and significant socio-economic consequences. In certain situations, only primary arthroplasty can solve this problem. The information described in the current literature on the results of primary arthroplasty states its effectiveness, but is generalized, empirical, based on the clinical experience of individual clinics and does not contain a biomechanical justification of the ability of the method taking into account different types of fractures. Endoprosthetic replacement in fractures of the acetabulum is a non-trivial task, which often leads to the implementation of measures aimed at

stabilizing its fragments and replacing bone defects. Systematization of these techniques for differentiated application in the case of certain types of fractures is of considerable research interest.

**Conflict of interest.** The authors declare no conflict of interest.

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## CURRENT TRENDS IN THE TREATMENT OF ACETABULAR FRACTURES (LITERATURE REVIEW)

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