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Original Scientific Paper

OUTCOMES OF SURGICAL TREATMENT FOR DISPLACED BOTH-COLUMN ACETABULAR FRACTURES

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SUMMARY – Complex both-column acetabulum fractures are severe injuries, often with associated injuries and complications with uncertain clinical and functional outcome. Modern traumatological protocols point to early surgical treatment, with anatomical reduction and stable internal fixation of fragments as a prerequisite for achieving a good treatment outcome. This retrospective-prospective multicenter cohort study was conducted during the 2014-2020 period and included 24 cases that met the input parameters, using the Letournel and Judet classification, and application of a combined surgical approach, a modified Stoppa and Kocher-Langenbeck approach. The results of treatment with complications, associated injuries and functional outcome are described. Fractures were caused by high kinetic energy trauma, and the cause was traffic accident in 17/24 (70.84%), fall from a height in 5/24 (20.83%) and crash injuries in 2/24 (8.33%) cases. The sample included 18 (75.00%) male and 6 (25.00%) female, with 10/24 (41.67%) right sided and 14/24 (58.33%) left sided fractures. Their mean age was 45.06 (range, 24-62) years. The mean follow-up time was 2.8 (range, 1-5) years. Postoperative complications were detected in 14/24 (58.33%) cases, including wound infection in 4/24 (16.67%), deep vein thrombosis in 2/24 (8.33%), heterotopic ossification in 2/24 (8.33%), hip osteoarthrosis in 3/24 (12.50%), avascular necrosis of femoral head in 2/24 (8.33%), total hip arthroplasty procedures in 3/24 (12.50%), abdominal complications in 2/24 (8.33%), urologic complications in 2/24 (8.33%), iatrogenic nerve lesion in 3/24 (12.50%), and fatal pulmonary embolism in 2/24 (8.33%) cases; there was no loss of reduction or non-union acetabular fracture. Associated injuries that we recorded as major trauma were presented in 13/24 (54.17%) study patients. The final functional results according to the Harris Hip Score (HHS) were excellent in 7/22 (31.82%), good in 10/22 (45.45%), moderate in 4/22 (18.18%) patients, and poor in 1/22 (4.55%) patient. The mean HHS was 84 (range 34-98). Complications and results have led us to a conclusion that primary injuries significantly affect the clinical and functional results. A good diagnostic procedure, assessment of the general condition and application of the trauma scoring system, surgical treatment that includes early hip reduction, open reduction internal fixation and physical rehabilitation are necessary.

Key words: *Both-column acetabulum fractures; Complications; Internal fracture fixation*

Introduction

The management of displaced fractures of the acetabulum, especially both-column fractures, is challenging for the orthopedic surgeon, potentially leading to devastating complications, with often uncertain course of treatment and final outcome. Acetabular fractures are relatively uncommon, with an incidence rate ranging from 3 to 8.1 cases/100,000 person/year, have a high impact on the patient quality life, and are mostly seen in younger patients and persons aged over 50 years[1]. Both-column acetabular fractures are the most serious, relatively common in-

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jury and the second most common type of acetabular fractures resulting from high-energy trauma (87.4%), with 61.5% of patients injured in road traffic accidents[1]. Approximately 21% of all acetabular fractures involving both columns of the acetabulum, which require good reduction and stable internal fixation to prevent post-traumatic arthrosis, occur in up to 20% of patients and have excellent clinical outcomes[1,2]. Both-column acetabular fractures characterized by complete discontinuity of the acetabular articular surface from the rest of the axial skeleton, are assumed to result from lateral compressive forces transmitted through the femoral head, producing medialization of the articular hip joint fragments and rotation of both acetabular columns[3]. The ground-breaking work of Robert Judet and Emile Letournel[2] in the mid-1960s led to a change in decisions regarding therapeutic regimen for acetabular fractures and consequently, there has been an increase in the proportion of surgically treated fractures[2,4]. According to Letournel classification[2,5], acetabular fractures were divided into five elementary and five associated fracture patterns, and it has become widely accepted and is still used today as the gold standard all over the world. The treatment principles founded by them are still valid today and include open acetabular reduction and stable internal fixation, and early activation. In addition, timing of the operative management, choice of surgical approach and quality of reduction are among the most surgeon related controllable factors influencing the functional outcome[5-7]. The surgical approaches for both-column acetabular fractures are still controversial because complex anatomy of the pelvis with its array of critical structures such as major nerves, vessels and adjacent viscera greatly impedes access to and visualization of the acetabulum, which makes them the most challenging fractures to treat. Acetabular surgical approaches are divided according to the anterior and posterior columns and extensile approaches. On the anterior side, the traditional ilioinguinal approach is preferred by the Leeds group, and the newer Stoppa and pararectus approaches is preferred by the Bernese group. On the posterior side, the workhorse (Kocher-Langenbeck) approach has been promoted from the Leeds group, and the same approach was used in surgical hip dislocation illustrated by the Bernese group[8]. These surgical techniques give good results but despite appropriate surgical work by an experienced surgical team are followed by numerous complications such as nerve injury, infection, deep venous thrombosis (DVT), heterotopic ossifications (HO), avascular necrosis of femoral head (AVN), post-traumatic arthrosis of hip joint (OA), and poor functional outcomes. Complications such as AVN and OA often require total hip arthroplasty (THA)[8,9]. The authors of this paper try to answer the question whether and how the complications of acetabular fractures could be avoided, presenting an overview of their results and complications, including how proper understanding of fracture displacement, the choice of combining two approaches in one stage surgery, plate and screw fixation strategies, affect the outcome as compared with the results reported by other authors in the literature.

Patients and Methods

The study was a multicenter, cohort, prospective and partially retrospective study including patients surgically treated at our institutions from 2014 to 2020 for both-column acetabular fractures. The mean time of follow-up was 2.8 (range, 1-5) years. Most of the patients (66.66%, (16/24) were admitted to the intensive care unit (ICU) due to severe life-threatening injuries. Patients with hip dislocation underwent closed reduction under general anesthesia in the emergency room, within 24 hours of the injury, and then skeletal traction was applied until the surgery with a Steinman nail passing through the supracondylar part of the femur. Patients were operated on within 3 weeks after the injury in relation to the assessment of the general condition and associated injuries, and the risk for surgical intervention, based on the principles of damage control in orthopedics (DCO). Diagnostic procedure was performed from three standard x-ray projections (anteroposterior –AP, iliac and obturator) and following four lines (iliopectineal, ilioischial, both walls), always using computed tomography (CT) and assessing the degree of displacement and fracture pattern. All patients had defined indications for surgery with more than 2 mm displaced acetabular fractures, articular impaction, unstable and non-concentric reduction hip joint, Matta roof arc angle less than 45^0 and associated pelvic fractures. A detailed CT assessment of the fracture is clearly the gold standard in pelvis trauma today. It is possible and necessary to understand the 3D morphology of acetabular fractures and classify them according to Letournel and Judet classification[5] into five elementary and five associated types (Fig. 1). The inclusion criteria were the following: age 18-70 years; fracture of both acetabulum columns according to the Letournel-Judet classification[5]; a lapse of fewer than 3 weeks from the injury; and the use of the modified Stoppa

approach (MSA) and Kocher-Langenbeck approach (KLA). The exclusion criteria were age <18 and >70 years; another type of acetabular fracture; an open fracture of the acetabulum; and lapse of more than 3 weeks from the injury. The choice of approach is very important for success of surgical procedures because no single surgical exposure allows for convenient access to both columns without consequences. Usually, after the MSA[10], we used complementary KLA[11] when there is a fracture of the posterior wall and when the posterior column component is hugely displaced and/or cannot satisfactorily reduce it through an anterior approach and gives us a better opportunity for anatomical reduction and stable fixation. Patients were placed on the radiolucent surgical table in supine position for Stoppa approach and pro-supination position for K-L approach. C-arm fluoroscopy was used intraoperatively to the fracture checked with AP, obturator oblique, and iliac oblique views, and to assess the accuracy of reduction and implant position. The KLA is the gold standard for posterior access, namely, for posterior wall, posterior wall + posterior column, selected transverse, T-shaped and transverse + posterior column acetabular fractures[11]. Historically, KLA consists of two parts. Bernhard von Langenbeck (1810-1887) described his "longitudinal incision for hip infections" between the posterior superior iliac spine and the tip of the greater trochanter in 1874. Emile Theodor Kocher(1841-1917) curved extended this approach caudally in 1911. Judet et al. combined these two approach, thus becoming the Kocher-Langenbeck approach in1954.[11]. The MSA as an intrapelvic approach has become popular for fixation of anterior wall and column fractures, as well as those associated with post hemitransverse and even both column fractures; it provides direct access to the pubic bones, the posterior surface of the ramus, the quadrilateral surface, the pubic eminence and the infrapectineal surface. This approach also provides access to the sciatic buttress, sciatic notch, and anterior sacroiliac joint[12,13]. We applied open reduction internal fixation (ORIF) with plate and screw in all patients. The rehabilitation protocol started on the first day after surgery and included active and passive range of motion and isometric quadriceps strengthening, prevention of pressure ulcers and intravenous antibiotic prophylaxis (preferred 1.5 g cefuroxime, usually during 3-4 days). As antithrombotic prophylaxis, subcutaneous low-molecular weight heparin dosed according to body weight was administered daily until the patient became independent for movement activity with an orthopedic walker device, in about 6-8 weeks. Non-weight bearing activities were allowed at 4-6 weeks after the operation, partial weight bearing was allowed at about 6 weeks according to the follow-up radiographs, and full weight bearing was usually allowed in about 3 months. We did not use prophylaxis or therapy protocol for heterotypic ossification, while for the assessment of HO we used plain radiography based on Brooker's classification[13] with four levels. We conducted patient functional state assessment by using the Harris Hip Score (HHS)[14] from 0 to 100, according to the evaluated range of motion, pain levels and functional abilities usually at 1 year after injury. The HHS ≥80 is considered excellent/good and HHS <80 moderate/poor. Clinical outcome is acceptable (excellent or good) and not acceptable (moderate or poor) (Table 3). We analyzed patient radiographs to assess the quality of fixation and post-traumatic degenerative changes, according to Matta's criteria[15]. Fracture reduction with fragment shift of 0-1 mm was considered anatomic, 2-3 mm imperfect and >3 mm poor. The patients were categorized into three groups based on Matta radiological grading as anatomic, congruent and incongruent; anatomical were those where all fracture gaps and steps had been removed intraoperatively and postoperative films showed restoration of all five anatomicallines (ilioinguinal, iliopectineal, dome, posterior wall and anterior wall) with the femoral head centered and parallel beneath the acetabular roof. The patients were followed up clinically and radiologically at six weeks, three months, six months and one year, then usually once per year.

Statistical analysis

The SPSS statistical software (version 20.0) was used on all statistical analyses. Continuous variables were analyzed using a T-test. Categorical variables with expected values greater than 5 were evaluated using the χ^2-test, while categorical variables with expected values less than 5 were evaluated using Fisher exact test. The level of statistical significance was set at $p<0.05$ in all statistical tests.

Results

The study included 24 patients, 18/24 (75.00%) male and 6/24 (25.00%) female patients. There were 10/24 (41.67%) right sided and 14/24 (58.33%) left sided fractures. The mean age of study patients was 45.06 (range, 24-62) years. Study patients were divided into three groups according to age, for simplicity.

Young age group included 11/24 (45.83%) patients aged 20-40, 5/24 (20.83%) female and 6/24 (25.00%) male patients; middle age group included 11 (45.83%) patients aged 41-60, 2/24 (8.33%) female and 9/24 (37.50%) male patients; and old age group included 2 (8.33%) patients aged >60, 1/24 (4.17%) female and 1/24 (4.17%) male patient (Table 1). Fractures occurred due to high kinetic energy trauma; traffic trauma (motor vehicle accident) was the cause in 17/24 (70.84%), fall from a height in 5/24 (20.83%) and crash injuries in 2/24 (8.33%) cases. Skeletal traction as initial treatment was administered in 20/24 (83.33%) patients. We performed ORIF using reconstruction plates and screws (3.5 or 4.5 mm) or a combination of plate and screws. For fractures with medial displacement of the quadrilateral plate, a medial buttress plate was placed infrapectineally on the pelvic brim. The mean follow-up was 2.8 (range, 1-5) years. The mean time interval from the injury to ORIF was 10.5 (range, 5-19) days. The mean duration of operation was 3.5 hours, range from 2.5 to 4.5 hours. Postoperative complications of acetabular fractures were detected in 14/24 (58.33%) cases, with two or more complications 6/24 (25.00%) patients. Wound infection was recorded in 4/24 (16.67%) cases, including superficial wound infection in 3/24 (12.50%) cases and deep wound infection in 1/24 (4.17%) case. Seroma at operative site was found in 2/24 (8.33%) cases, with dehiscence wound in 1/24 (4.17%) case. Wound infections were most commonly treated with dual antibiotic therapy according to microbiological results for several weeks (6-10 weeks) and repeated dressings; in two cases, we performed surgical treatment of the wound, including vacuum-assisted closure procedures in case of delayed wound healing. In case with deep wound infection and occasional fistula secretion, after bone healing, we removed the implant material and fistula as a therapeutic procedure to treat the infection; there was no osteomyelitis. All wound infections were recovered. Intra-articular screw that required revision and screw removal was recorded in 1/24 (4.17%) case. Deep vein thrombosis occurred in 2/24 (8.33%) cases, diagnosed by clinical and ultrasonographic methods and treated with low molecular weight heparin. Heterotopic ossification, according to Broker classification[13] type II occurred in 2/24 (8.33%) cases. Post-traumatic OA was recorded in 3/24 (12.50%) patients from the group with imperfect fracture reduction from the congruent group. Femoral head AVN occurred in 2/24 (8.33%) patients. Both AVN cases had complex fracture of the acetabulum, with traumatic dislocation of the hip; in one of these patients, HO also developed as a complication. Replacement of the damaged hip joint with cementless THA based on post-traumatic OA in 1/24 (4.17%) and AVN was performed in 2/24 (8.33%) patients, respectively; replacement was performed in 3/24 (12.50%) patients at a mean of 2.28 (range, 1.5-3) years after injury. There was postoperative dislocation of the THA in one case on two occasions, during the first three months. Abdominal complications were recorded in 2/24 (8.33%) patients, paralytic ileus and mesenteric vein thrombosis in 1/24 (4.17%) patient each. Urologic complications occurred in 2/24 (8.33%) patients as iatrogenic damage to the urethra during catheter placement, followed by urinary tract infection and transitory incontinence. Iatrogenic neurological lesions were recorded in 3/24 (12.50%) patients. Iatrogenic sciatic nerve palsy with a lesion to peroneal division of the nerve occurred in 1/24 (4.17%) patient with posterior hip dislocation and KLA. Obturator nerve injury in 1/24 (4.17%) and lateral femoral cutaneous nerve palsy occurred in 1/24 (4.17%) patient each in case with the MSA. All cases were characterized by severe fracture reduction and higher body weight. Patients were treated conservatively and final result was full recovery after seven months for sciatic nerve and obturator nerve, and partial recovery after eight months for lateral femoral cutaneous nerve

Table 1. Patient age and gender distribution (N=24)

Age group (years)	Gender		% (Σ)
	Male	Female	
20-40	25.00% (6/24)	20.83% (5/24)	45.83% (11/24)
41-60	37.50% (9/24)	8.33% (2/24)	45.83% (11/24)
>60	4.17% (1/24)	4.17% (1/24)	8.33% (2/24)
	66.67% (16/24)	33.33% (8/24)	100% (24/24)

(LFCN). The most severe complication during the treatment was fatal (lethal) outcome, which occurred in 2/24 (8.33%) cases. On autopsy, the cause of death was fatal PE in 2/24 (8.33%) cases, i.e., one patient with pulmonary embolism (PE) and DVT on postoperative day 12 and day 18 after injury and another patient with PE and mesenteric vein thrombosis on day 14 of surgical intervention and day 21 after injury. During early postoperative period, we recorded 1/24 (4.17%) case of non-fatal PE. The patients with fatal outcome were not included in statistical analysis of functional outcome. We had no case of the loss of reduction and non-union (0/24, 0%). We had 3 (12.50%) surgical revisions during the first month and one (4.17%) revision in the late postoperative course, with a total of 4 (16.67%) revisions during the follow up period. Table 2 shows the percentage and numerical ratio of complications the patients relative to the entire sample. Associated injuries that we recorded as major trauma included pelvic ring fractures in 6/24 (25.00%), femur fractures in 2/24 (8.33%), lower leg fractures in 3/24 (12.50%) cases, vertebral fractures in

Table 2. Postoperative complications 58.33% (14/24)

Type of complication	n	%	Type of complication	n	%
Superficial wound infection	3	(12.50%)	Intra articular screw	1	(4.17%)
Deep wound infection	1	(4.17%)	Loss of reduction & non-union	0	(0%)
Wound dehiscence	1	(4.17%)	Revision surgery	4	(16.67%)
Seroma at operative site	2	(8.33%)	Total hip arthroplasty	3	(12.50%)
Delayed wound healing	1	(4.17%)	Urological complications	2	(8.33%)
Deep vein thrombosis	2	(8.33%)	Abdominal complications	2	(8.33%)
Mesenteric vein thrombosis	1	(4.17%)	Fatal pulmonary embolism	2	(8.33%)
Avascular necrosis of femoral head	2	(8.33%)	Non-fatal pulmonary embolism	1	(4.17%)
Osteoarthrosis	3	(12.50%)	Iatrogenic nerve injury	3	(8.33%)
Heterotopic ossification	2	(8.33%)	Dislocation of THA	1	(4.17%)

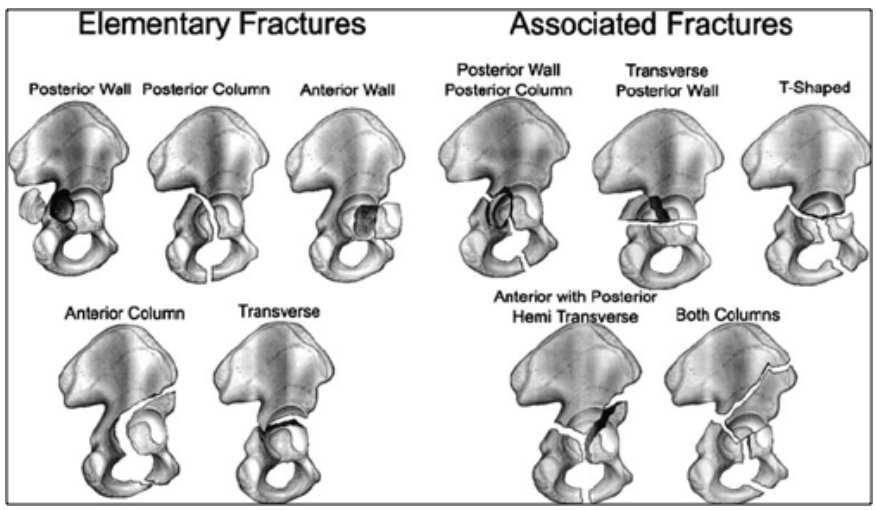

Fig. 1. Letournel and Judet classification[5].

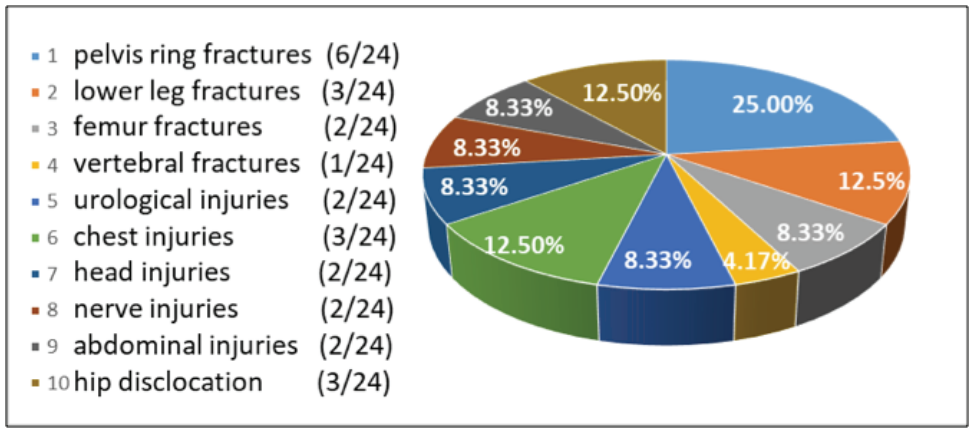

Fig. 2. Associated injuries: n=13/24 (54.17%).

1/24 (4.17%) case, urological injuries in 2/24 (8.33%), chest injuries in 3/24 (12.50%), abdominal injuries in 2/24 (8.33%), head injuries in 2/24 (8.33%), nerve injuries in 2/24 (8.33%) and traumatic hip dislocation in 3/24 (12.50%) cases. In total, 13/24 (54.17%) patients had associated injuries, and 7/24 (29.16%) patients had two or more associated injuries. Figure 2 shows the percentage and numerical ratio of associated injuries in relation to the total number of study patients. Residual displacement was measured on postoperative radiographs and evaluated according to Matta's criteria[15]; we determined anatomical group of 20/24 (83.33%) patients and congruent group of 4/24 (16.67%) patients with imperfect fracture reduction. All these patients were further subcategorized into acceptable group. Out of 4 patients from the congruent group, two developed degenerative changes (hip joint OA). Clinical assessments were made using the HHS criteria[14] according to which we evaluated the range of motion, pain level and functional abilities using the 0-100 scoring system. The results were excellent in 7/22 (31.82%), good in 10/22 (45.45%), moderate in 4/22 (18.18%) patients and poor in 1/22 (4.55%) patient (Table 3). The mean HHS[14] was 84 (range, 34-98). Patients with excellent to good outcomes were in the acceptable group (17/22, 77.28%) and those with fair to poor outcomes in the unacceptable group (5/22, 22.72%). Regarding the patient degree of satisfaction, 15/22 (68.19%) patients were very satisfied, 5/22 (22.72%) were satisfied, and 2/22 (9.09%) were dissatisfied but would still undergo the surgery again.

Table 3. Evaluation according to the Harris Hip Score (n=22)

Score	n	(%)
Excellent (90-100 points)	7	(31.82)
Good (80-89 points)	10	(45.45)
Moderate (70-79 points)	4	(18.18)
Poor (<70 points)	1	(4.55)
Mean: 84 points	22	(100)

Discussion

Due to the complexity of the pelvic anatomical structure, acetabular fractures represent a challenging procedure for orthopedic surgeons. Both-column fractures are more complex and most complicated of all acetabular fractures, characterized by a 'floating acetabulum' because the entire weight bearing articular surface is detached from the sacroiliac joint and the fracture lines involve multiple planes and damage the cartilage surface of the bone[6]. Complete understanding of fracture morphology is essential for treatment decisions and achieving the important goal of surgical treatment, which is restoration of a smooth, gliding surface of the hip, which requires anatomical reduction of the fracture and stable internal fixation to prevent post-traumatic arthritis and obtain excellent clinical outcomes[16]. Because of the complex acetabular anatomy and fracture morphology, various classification schemes have been suggested, but the majority of authors use Judet and Letournel classification[2] for its comprehensiveness and simplicity. According to their classification from 1964 with slight refinement in

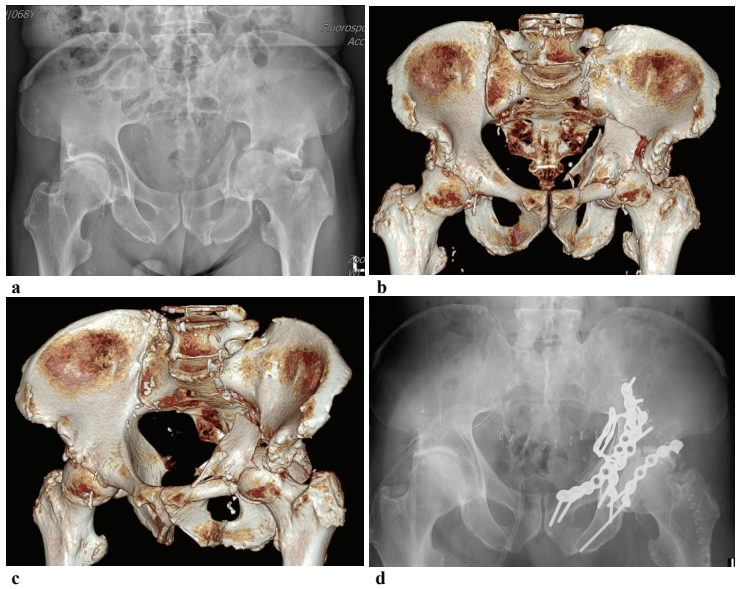

Fig. 3. (a) Preoperative pelvis x-ray; (b, c) preoperative computed tomography scan; (d) postoperative pelvis x-ray.

1974, acetabular fractures are divided into elementary and associated fracture patterns (Fig. 1). This classification is considered to be the gold standard; it is important for setting an indication for surgical therapy and is preferred by the majority of orthopedic trauma surgeons[2,5,7]. Using this classification, Chen *et al.*[17] focused on the types of acetabulum fractures; they report on 52 cases, of which 10 were T shaped fractures, 16 were associated with anterior column + posterior hemi-transverse (ACPHT) fractures, and 26 were both-column fractures, with reduction and fixation the bicolumnar fractures through a single supra-ilioinguinal approach. Regardless of the degree of displacement and severity of the injury, both-column fractures normally present two main converging fracture lines, determining a T or Y shaped fracture morphology. Secondary fracture lines are common and can be observed as an association, including a fracture line that separates the posterior wall of the acetabulum from the posterior column, and another one that separates a small medial fragment of the acetabular roof from the anterior column. The typical pattern of both-column fracture presents a comminuted anterior column fracture extending up to the iliac crest (high anterior column fracture) with a simple posterior column fracture[18]. Generally, the more dislocated column dictates both the choice of approach and patient positioning. As a kind of serious fracture, both-column fractures are always caused by high-energy trauma. Fractures with additional relevant soft tissue damage and/or intrapelvic injuries such as vascular damage or open fractures are graded as complex fractures. Thus, polytrauma including other organ injury, extremity and spine fractures, including the injury severity score (ISS) value, may be a factor that would affect therapeutic strategies. Cardiopulmonary resuscitation is the overriding initial procedure. Timely use of pelvic pocket is advocated to decrease bleeding in the fracture area. Then, injuries involving important organs such as brain, chest and gastrointestinal system should be managed. Skeletal traction or Ex-fix of the extremity should be done in order to stabilize the general condition, facilitate care and diagnostic procedures, and ultimately reduce difficulty of the intraoperative reduction. Some authors recommend definitive internal fixation of long bone fractures, especially of lower extremities, conducted after obtaining stable general condition and vital signs. These should be treated before the pelvis, which would facilitate the intraoperative maneuver for reduction of the acetabular fracture[6,18,19]. In our study, we mostly had definitive osteofixation of long bone fractures after ORIF of the acetabulum (60%). The German Pelvic Registry[20], an international multicenter registry of patients with pelvic and acetabular fracture, determines the patient-related factors as predictors for surgical treatment, and one of most important is ISS.

The mean ISS of 4213 patients was 14.8±10.2. Patients who underwent surgery for their acetabular fracture had a mean ISS of 14.3±9.3, while patients with conservative therapy had a mean ISS of 15.6±11.4[20]. When planning surgical approach, it is essential to perfectly understand orientation of the major fracture lines, degree of displacement and closest neurovascular structure. The goal of surgery is to achieve a functional and painless hip that would continue to function for the rest of the patient's life[7,16,18]. In the case of both-column fractures, the use of extensile approaches, such as the extended iliofemoral approach suggested by Pierannunzii *et al.*[3], has been associated with more complications. Nevertheless, Giannoudis *et al.*[6] concluded that only 17% of patients would require an extensile or combined approach. In our experience, the use of combined surgical approaches (KLA+MSA) in both column acetabular fractures in relation to the total number of fractures of this type is 31%. Therefore, Letournel *et al.*[2] suggest to start with the ilioinguinal approach in the majority of both-column fractures because its advantages are wide access to the acetabulum, the muscle-sparing nature, the extensibility and historical familiarity of the pelvic surgeon with a highly established surgical technique. This approach allows for exposure of the entire anterior column the sacroiliac joint, the lateral ala of the ipsilateral sacrum and the inner part of the posterior column. Some experts believed that ilioinguinal and Kocher-Langenbeck approaches were indispensable because neither the ilioinguinal approach nor KLA alone was capable of exposing and managing all of the fragments[8,11,21,22]. Gusic *et al.*[23] in a study of 156 patients with 157 acetabular fractures involving both columns and T types treated surgically with four surgical approaches, i.e., single Kocher-Langenbeck, single ilioinguinal, combined Kocher-Langenbeck and ilioinguinal and extended iliofemoral approaches, concluded that the majority of such acetabular fractures could be treated successfully through single surgical approaches. Alternative options for the ilioinguinal approach are the MSA and the pararectus approach. The Stoppa approach was first described in 1973 as a subperitoneal median approach for the treatment of groin hernias. Later, Hirvensalo *et al.*[26] applied this approach for pelvic fractures and achieved good results. Subsequently, this approach was used for acetabular fractures, especially after improvements introduced by Cole and Bolhofner in 1994. The Stoppa approach and its modified approaches has become alternative for traditional ilioinguinal approach and has the advantage to facilitate treatment of severely medially displaced fracture patterns involving the quadrilateral plate and claimed to be a viable alternative for the ilioinguinal approach for treatment of anterior acetabulum fractures. In the case of complex fractures of both-column fractures, the MSA must be combined with lateral window of the ilioinguinal approach (so-called Olerud approach) to expose all fracture lines extending superiorly to the iliac crest, or with KLA in case of dislocated posterior wall fractures with unstable hip and posterior column fractures.[2,7,10,11,24,25,27]. In our research, we used surgical treatment, combined of KL+MSA. On comprehensive literature search performed in the Pubmed and Embase databases, we found a small number of studies describing treatment with this combined surgical approach. The main cause of acetabular injury in our study was a road traffic accident, recorded in 17/24 (70.84%) patients, followed by fall from a height in 5/24 (20.83%) and crash injuries in 2/24 (8.33%) patients. These injuries were more common in young patients. Jindal *et al.*[28] and Dakin *et al.*[29] report on similar statistical results. Giannoudis *et al.*[6] report on the patient mean age of 38.6±4.6 years and 69.4% of male patients. In our study, the mean patient age was 45.06 years and there were 18/24 (75.00%) male and 6/24 (25.00%) female patients. Letournel and Judet[2,5] divided acetabular fracture surgery into three categories based on the time of injury as follows: within 3 weeks, 3 weeks to 4 months, and longer than 4 months, and concluded that the surgery performed 3 weeks after fracture was significantly more difficult because of the amount of soft-tissue scarring around the fracture site. Madhu *et al.*[30] report on an increased risk of worse outcome if surgery is delayed by more than 5 days for complex fractures and more than 10 days for simple fractures. Most authors[3,6,9,19,30] recommend that pelvic and acetabular internal fixation be performed within 3 weeks, i.e., they prefer to have acetabular fracture surgery performed in the first week (4-7 days) after injury. In our study, all patients were operated on between day 5 and day 19 after injury, mean 10.5 days. According to a meta-analysis of 14 publications including 1496 patients performed by Giannoudis *et al.*[6], the mean time of surgery was 8.9±2.9 days. Early ORIF is crucial for achieving anatomical reduction of fracture. Two weeks after the injury, it is considerably harder to achieve anatomical or acceptable reduction, which is crucial for

good treatment; after 3 weeks, internal fixation is not recommended. Cahueque *et al*.[30] recommend internal fixation of acetabulum up to 7 days from the injury. According to Matta *et al*.[15], the number of anatomical reductions decreased as the time to surgery increased, emphasizing the importance of early surgical treatment; according to these authors, the criteria for reduction of the fracture are regarded as satisfactory if the dislocation is smaller than 2 mm, emphasizing that anatomical reduction depends on the type of fracture and the interval between injury and surgical treatment, while the experience of the surgical team and working conditions are also important. The percentage of anatomical reduction in our series was 83.33% (20/24), representing success of our surgical team. Mears *et al*.[31] showed in surgically treated 424 fractures that simple fractures were reduced anatomically in 86.36% of cases, whereas associated fractures could be reduced anatomically in only 59% of cases. The radiological outcome correlates significantly with functional outcome and quality of reduction of fracture was the single most important predictor of clinical function, radiological grade and development of arthritis. The literature states that most complications following acetabular fractures are osteoarthritis, avascular necrosis of femoral head with shortening of the affected extremity, painful limitation of the range of motion, heterotopic ossification, DVT, infection, nerve injury which may require further reconstructive procedures and consequent disability of the injured extremity. Post-traumatic AVN and OA usually are associated with non-anatomical reduction and hip joint dislocation, which confirms the importance and severity of fracture and anatomical specificity of the acetabulum and hip joint[5,9,14,28]. Meena *et al*.[32] report that failure in achieving anatomical reduction, associated injuries, initial hip dislocation >20 mm, late ORIF and age can negatively affect achievement of good outcomes and are prognostic factors for the development of OA. AVN of the femoral head causes later fragmentation and collapse of the head. Joint damage similar to post-traumatic OA leads to serious hip problems manifesting as severe pain and limitation of the range of motion, and often requires further surgery, i.e., THA[33-35]. According to Rollmann *et al*.[34], about 20% of patients with acetabular fractures require THA; the risk factors are patient age, femoral head lesion/subluxation, and involvement of the posterior wall. Similar results were published by Dunet *et al*.[35], reporting on 34.7% of THA after acetabular fractures. ORIF of acetabular fractures in elderly patients results in excellent outcomes at short-term follow-up when anatomical reduction can be achieved. In case of negative predictive factors, ORIF cannot be regarded as a definitive solution, rather as the construction of a stable socket for secondary THA[36]. The rate of ORIF conversion to THA in the study by Capone *et al*.[37] was 17% at a mean of 27.7 months, which is by far higher than the rate of 8.5% reported by Giannoudius *et al*.[6] in the treatment of acetabular fractures. Madhu *et al*.[38] conclude that abnormal anatomical structure after acetabular fracture usually is responsible for subsequent THA failure. Literature data show a higher percentage of ORIF conversion THA in elderly patients, mean age 60 years, as well as primary of THA implantation for acetabular fractures[36,37]. Our rate of ORIF conversion to secondary THA was 12.50%. Heterotopic ossification or myositis ossificans is a recognized complication of posterior surgical approach in revision hip arthroplasty, hip fracture dislocation and brain injury, in relationship to acetabular fractures. Its etiology is poorly understood and thought to be multifactorial, the incidence has been reported to be as high as 26%-41%, it can lead to painful restriction of joint motion and belongs to the group of early complications that can appear after a few weeks. Broker types I and II are not considered to cause functional deformity in most patients[13,32]. Effective therapy strategies have been found with the use of non-steroidal anti-inflammatory drugs (indomethacin) and focused radiotherapy (low dose). The incidence of 8.33% (2/24 patients) Broker type II was significantly lower than stated by other authors, and this degree of HO does not lead to functional disorders of the hip joint, as shown in our research[9,13,30]. In our series, we had 2/24 (8.33%) patients with DVT and 4/24 (16.67%) patients with wound infection. Complications such as DVT and PE have been described and they accompany this type of surgery despite prophylaxis. Early ORIF and mobilization with thromboprophylaxis are important factors for reducing the rate of these complications[3,6,19]. Wang *et al*.[39] report on 29.09% of DVT after pelvic and acetabular fracture in a series of 110 patients, 48 pelvic fractures and 62 acetabular fractures, aged ≥60, with associated injuries, complex fractures and postponed internal fixation of acetabulum after 14 days, which increase the risk of DVT. There are literature reports on 4.3% of thromboembolic complications and 4.4%

of local infections[9,19,28]. In the literature and clinical practice, it is stated that nerve injuries may be a consequence of the initial trauma or injury at the time of ORIF as a late complication[28,40,41]. Simske *et al.*[40] report on the peroneal division of the sciatic nerve to be affected in 65% of cases, usually spontaneously, 50% of patients recovered partially, 22% had complete recovery, whereas in 24% there was no neurological recovery. Urgent reduction of dislocated hip is of utmost importance in order to reduce the femoral head pressure or dislocated bone fragment pressure on the nerve, which later has a better chance for recovery. Also, early ORIF of acetabulum has an important role in neurological recovery. We detected 8.33% (2/24) of traumatic sciatic nerve injuries associated with hip dislocation, clinically diagnosed immediately after admission, and 12.50% (3/24) of iatrogenic nerve injury during surgical procedures. In total, we had 20.83% (5/24) of nerve injuries, of which three (12.50%) patients had sciatic nerve palsy, and 1/24 (4.17%) patient had obturator nerve palsy and 1/24 (4.17%) LFCN palsy. In the last 12 months after injury, complete nerve recovery was achieved in 3/24 (12.50%), partial recovery LFCN in 1/24 (4.17%) patient and no neurological recovery in 1/24 (4.17%) patient, in this case, due to traumatic damage to the sciatic nerve, tendon transfer was performed after 12 months in order to reduce morbidity. Iatrogenic injuries of the sciatic nerve are most often associated with KLA, whereas injuries of the obturator and lateral femoral cutaneous nerves are associated with MSA; in conclusion, nerve injuries can be avoided by careful surgery, identification and protection of the nerves[26,28,39,40]. According to the literature, 16.4% of nerve injuries are recorded, as well as 8% of iatrogenic nerve palsy, most frequently of the sciatic nerve. In some series of acetabular fractures with posterior hip dislocation, the rate of sciatic nerve injuries increased to 40.3%[9,11,18,40]. In the meta-analysis of 2426 fractures performed by Giannoudis *et al.*[6], the rate of iatrogenic sciatic nerve palsy was 4.7%. Haidukewych *et al.*[41] report on 7.9% of post-traumatic and 5.6% of iatrogenic sciatic injuries in a series of 252 patients. Our final functional outcome of HHS 84 is similar to the results reported by most authors on acetabular fractures after surgical treatment[14,42]. Most of the associated injuries had no significant effect on functional outcome in this study. Moed *et al.*[42] conclude that associated injuries have a significant negative effect on functional outcome. Letournel *et al.*[5] report on 350 fractures of the acetabulum with very good results (75%), good results (8%) and poor results (17%). Of the 74% of the patients with an anatomically reduced hip joint, 90% had a good result. Of the 26% imperfectly reduced, only 55% had a good result if some incongruity remained, only 11% if a degree of protrusion remained, and only 9% if there were major technical failures. In our study, the acceptable group included 17/22 (77.28%) and unacceptable group 5/22 (22.72%) patients according to the patient degree of satisfaction.

Conclusions

The aims of acetabulum fracture management have been defined as pain elimination, early activation, and prevention of post-traumatic OA. Although they cannot be avoided, by continuous learning and improving the acetabular surgical field, we can achieve more excellent treatment results and less complications. We cannot influence the severity of initial trauma, patient general condition and age, and bone quality, but these are just some of the factors which have an effect on final functional outcome and complications. A good diagnostic procedure, proper understanding of fracture morphology, assessment of the general condition and application of the trauma scoring system is necessary. Proper timing of operative management, choice of surgical approach, and quality of reduction are among the surgeon-related controllable factors influencing functional outcome. Our recommendation for complex acetabular both column fractures, when it is necessary to expose all fragments, when it is not possible to achieve satisfactory reduction and rigid fixation, especially of the opposite side, column and wall, with one approach, use a combined surgical approach, of MSA+KLA; sometimes an incision should be made to fix a fracture of the iliac wing; we also recommend MSA as an initial approach; the use of plates and screws provides stable fixation, necessary for early rehabilitation.

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Sažetak

ISHODI KIRURŠKOG LIJEČENJA DISLOCIRANIH PRIJELOMA OBA STUPCA ACETABULUMA

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Složeni prijelomi oba stupa acetabuluma teške su ozljede, često praćene pridruženim ozljedama i komplikacijama s neizvjesnim kliničkim i funkcionalnim ishodom. Suvremeni traumatološki protokoli ukazuju na rano kirurško liječenje s anatomskom repozicijom i stabilnom unutarnjom fiksacijom fragmenata kao preduvjet za postizanje dobrog ishoda liječenja. Ova retrospektivno-prospektivna multicentrična kohortna studija provedena je u razdoblju od 2014. do 2020. godine i uključila je 24 slučaja koji su zadovoljili ulazne parametre prema klasifikaciji Letournela i Judeta. Primijenjen je kombinirani kirurški pristup, tj. modificirani pristup Stoppe i Kocher-Langenbecka. Prikazuju se rezultati liječenja, komplikacije, pridružene ozljede i funkcionalni ishod. Prijelomi su nastali djelovanjem traume visoke kinetičke energije, a uzrok je bila prometna nesreća u 70,84% (17/24), pad s visine u 20,83% (5/24) i ozljede u sudaru u 8,33% (2/24) slučaja. Uzorak je obuhvatio 18 (75,00%) muškaraca i 6 (25,00%) žena s 41,67% (10/24) desnostranih i 58,33% (14/24) lijevostranih prijeloma. Srednja dob ispitanika bila je 45,06 (raspon 24-62) godina. Srednje vrijeme praćenja bilo je 2,8 (raspon 1-5) godina. Poslijeoperacijske komplikacije zabilježene su kod 58,33% (14/24) ispitanika, uključujući infekciju rane u 16,67% (4/24), duboku vensku trombozu u 8,33% (2/24), heterotopičnu osifikaciju u 8,33% (2/24), osteoartrozu kuka u 12,50% (3/24), avaskularnu nekrozu glave femura u 8,33% (2/24), totalnu artroplastiku kuka u 12,50% (3/24), abdominalne komplikacije u 8,33% (2/24), urološke komplikacije u 8,33% (2/24)), jatrogenu leziju živaca u 8,33% (3/24), smrtonosnu plućnu emboliju u 8,33% (2/24), dok nismo imali gubitak redukcije i nesrastanje prijeloma. Pridružene ozljede zabilježene su kod 54,17% (13/24) ispitanika. Konačni funkcionalni rezultati prema *Harris Hip Score* (HHS) bili su odlični u 31,82% (7/22), dobri u 45,45% (10/22), umjereni u 18,18% (4/22) te loši u 4,55% (1/22) ispitanika. Srednja vrijednost HHS bila je 84 (raspon 34-98) bodova. Komplikacije i rezultati upućuju na zaključak da težina primarne ozljede značajno utječe na klinički i funkcionalni rezultat. Potreban je dobar dijagnostički postupak, procjena općeg stanja i primjena bodovnog sustava traume, kirurško liječenje koje podrazumijeva pravodobnu repoziciju kuka, otvorenu redukciju sa stabilnom unutarnjom fiksacijom prijeloma te fizikalnu rehabilitaciju.

Ključne riječi: *Prijelomi dva stupa acetabuluma; Komplikacije; Unutarnja fiksacija prijeloma*