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Original Research

Acetabular Fracture Outcomes and Complications: An International Comparison

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ABSTRACT

Introduction. Despite the groundbreaking research by Judet and Letournel in the 1960s, the specific equipment, surgical approach, fixation strategy, and post-operative course for treating acetabular fractures have not been standardized. Therefore, this study aimed to compare technological resources, operative procedures, and post-operative complications between patients treated for acetabular fractures in Romania and the United States (U.S.).

Methods. Between February 2011 and August 2018, a total of 116 Romanian patients and 373 U.S. patients underwent open reduction and internal fixation for acetabular fractures. Data were collected prospectively for Romania and retrospectively for the U.S. The authors used T-tests, Fisher's exact tests, and odds ratios to analyze categorical data while ordinal date were assessed using logistic regression.

Results. U.S. patients had higher comorbidity rates for diabetes, obesity, and hypertension. However, the initial quality of reduction, graded with Matta's criteria, was similar between American and Romanian patients. Post-operatively, U.S. patients had significantly higher Brooker criteria scores for heterotopic ossification. Rates of deep vein thrombosis, infections, sciatic nerve lesions, and loss of reduction between the two countries were not significantly different.

Conclusions. Given the similar initial reduction quality despite technological differences, the authors suggest that fundamental factors, such as surgeon training and experience, may have a greater impact than the availability of technologically advanced operative resources. Future research focusing on the efficacy of these advanced resources for acetabular fracture fixation could help determine their true impact on patient outcomes and improve the cost-effectiveness of this surgery.

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INTRODUCTION

Acetabular fractures, often caused by high-energy mechanisms, were historically treated non-operatively and had a poor prognosis before the 1960s.[1,2] However, in 1963, Judet and Letournel published a seminal study recommending open reduction and internal fixation for certain acetabular fractures, marking a significant shift in treatment approach.[3,4] Despite initial reluctance to adopt these recommendations, Judet and Letournel's work laid the foundation for acetabular fracture classification and treatment systems.[2]

Their classification system remains widely used today, but further research was needed to refine the treatment of acetabular fractures.[5] For instance, post-Judet and Letournel, radiology-based studies showed that traditional anterior-posterior (AP) radiographs were inadequate for visualizing precise fracture outlines.[6] Instead, three standardized X-ray projections (AP, iliac oblique, and obturator oblique) and visualization of four anatomical lines (iliopectineal, ilioischial, both walls) were recommended for fracture classification and pre-operative planning.[2] Subsequent research demonstrated the value of computed tomography (CT) scans in improving the accuracy of diagnosing certain acetabular fracture subtypes.[7] More recently, 3D virtual planning has been explored for its potential to enhance acetabular fracture outcomes. In addition to radiological advancements, the quality of implants and equipment used for fracture reconstruction has been found to impact outcomes.[8]

Given these advancements, the authors aimed to compare outcomes of acetabular surgery between two institutions with substantial differences in resources. This study sought to highlight the impact of resources on operative treatments by comparing technological resources, operative procedures, and post-operative complications in patients treated for acetabular fractures in Romania and the United States (U.S.).

METHODS

Study Design and Data Acquisition. After obtaining Institutional Review Board approval through Flexible Review, we conducted a retrospective review of acetabular fracture patients treated at the orthopedic departments of the University of Kansas Medical Center in Kansas City, U.S., and Spitalul Judetean de Urgenta Mavromati Botosani in Botosani, Romania. The study included patients who underwent surgical open reduction and internal fixation (ORIF) for acetabular fractures between September 2011 and May 2018. Inclusion criteria were patients aged 18 years or older who had documented ORIF surgery for an acetabular fracture. Patients were excluded if their injured hip had been previously treated with total hip arthroplasty (THA) or hemiarthroplasty, if the presenting injury was definitively fixed with THA or hemiarthroplasty, or if the fracture was managed without internal fixation.

The Romanian data was collected in real-time by co-investigator RIM from patients who underwent ORIF for acetabular fractures. For the U.S. data, a retrospective approach was used, utilizing an informatics database called Healthcare Enterprise Repository for Ontological Narration (HERON).[9,10] HERON is a search engine that allows researchers to access de-identified data from a medical center. The research team searched HERON using International Classification of Diseases (ICD) codes for acetabular fractures and Current Procedural Terminology (CPT) codes for ORIF. Additionally, the HERON system was queried for ICD codes for demographic comorbidities, number of days between injury and definitive fixation, concomitant injuries, intraoperative blood transfusions, and post-operative complications or procedures.

For U.S. patients, co-investigator JD performed a chart review to

confirm inclusion criteria and collect missing data such as mechanism of injury and fracture pattern. Mechanisms of injury were classified as road accidents, falls, or crush injuries. Road accidents included motor vehicle accidents, motorcycle accidents, bicycle accidents, and pedestrian accidents. The study data was stored and managed using REDCap®, a secure, web-based software platform designed for research data capture.[11,12] REDCap provides an intuitive interface for validated data capture, audit trails for tracking data manipulation and export procedures, automated export procedures for seamless data downloads to common statistical packages, and procedures for data integration and interoperability with external sources.

Romanian and U.S. Radiographic Evaluation (Table 1). At both institutions, pre-operative CT scans and radiographs (anterior-posterior, Judet iliac oblique, and obturator oblique views) were reviewed. The acetabular fracture patterns were classified according to the Judet and Letournel system, which includes five elementary fracture patterns (posterior wall, posterior column, anterior wall, anterior column, transverse) and five associated fracture patterns (associated both column, transverse + posterior wall, T-type, anterior column/wall + posterior hemitransverse, and posterior column + posterior wall).[4] The injuries were further classified by the presence of posterior hip dislocation (and the number of days after injury for which the closed reduction of the hip occurred), loose intra-articular bodies, articular surface traumatic injury, and femoral head fracture.

The quality of reduction achieved by ORIF was determined by reviewing the initial post-operative radiograph and scoring according to Matta's criteria as follows: anatomical reduction (0-2mm displacement), imperfect (2-3mm displacement), or poor (>3mm displacement).[13] The only significant difference in radiographic evaluation was for heterotopic ossification (HO) evaluation. In Romania, surgeons calculated Brooker's criteria for HO in real-time during each post-operative appointment, while in the U.S., musculoskeletal radiologists (co-investigators BE, LF, and JC) scored HO with Brooker's criteria in a retrospective fashion.[14]

Surgical Technique and Operative Management (Table 2). The majority of U.S. cases were performed by one fellowship-trained attending orthopedic surgeon with the assistance of one or more residents and an occasional medical student. In Romania, all surgeries were performed by two attending orthopedic surgeons, with residents or other learners occasionally present. Only 10 cases in the U.S. were performed by two attending surgeons. Aside from surgeon variability, a range of operating room (OR) management factors were considered and analyzed, including intraoperative imaging, OR equipment, implants, and the use of bone grafting.

Variations in intraoperative imaging, OR equipment, implants, and bone graft usage reflect institutional resources and the innovativeness of the surgeons. Romanian surgeons used only plain-film "C-arm" radiographs for intraoperative imaging, while U.S. surgeons primarily used the "C-arm" but also had access to an intraoperative CT "O-arm" machine for 3-dimensional images. Regarding OR equipment, the U.S. operating table is radiolucent and designed for procedures requiring intraoperative fluoroscopy, while Romanian surgeons used a wooden traction table made by local carpenters.

Table 1. Pre-operative radiographic evaluation for Romania and U.S.

	Romanian Radiographic Evaluation	U.S. Radiographic Evaluation
Similarities	• Pre-operative CT scans and pre-operative radiographs* were reviewed. • Classified the acetabular fracture patterns according to the Judet and Letournel system of five elementary fracture patterns and five associated fracture patterns.† • Assessment for the following at the time of injury: o Posterior hip dislocation o Loose intra-articular bodies o Articular surface injury o Femoral head fracture • Utilized Matta criteria to assess the quality of reduction attained by ORIF by reviewing the initial post-operative radiographs.††	
Differences	• Romanian surgeons assessed for HO in real-time during post-operative appointments. If present, Booker's criteria was used to score the HO at the appointment.	• Musculoskeletal radiologists (co-investigators BE, LF, and JC) reviewed each participant's latest chronological imaging to assess for HO retrospectively. If present, Booker's criteria was used to score HO.

* Pre-operative radiographs included anterior-posterior, Judet iliac oblique, obturator oblique views.
† The Judet and Letournel system of five elementary fracture patterns include posterior wall, posterior column, anterior wall, anterior column, and transverse. The five associated fracture patterns include associated both column, transverse + posterior wall, T-type, anterior column/wall + posterior hemitransverse, and posterior column + posterior wall.[4]
†† Matta's criteria for initial quality of reduction are as follows: anatomical reduction (0-2mm displacement), imperfect (2-3mm displacement), or poor (>3mm displacement).[13]

In terms of implants, U.S. surgeons had access to various options such as pre-contoured plates, mini-fragment plates and screws, locking plates, and anatomical quadrilateral surface plates. The U.S. pre-contoured plates were shaped by implant manufacturers pre-operatively to fit a patient's bony anatomy. In contrast, Romanian surgeons only had stainless steel non-locking plates. For customized implants, the Romanian surgeons required 3D-printed reconstructions of the patient's anatomy to pre-shape, size, and cut the plates, which then needed sterilization before use in the OR. While U.S. surgeons frequently used bone grafts for bony defects, Romanian surgeons did not use bone grafting for any patient.

Regarding surgical approach, this factor was not controlled or thoroughly analyzed in this study due to inter-surgeon variability, fracture pattern, and shared decision-making with patients. Most Romanian patients underwent a Kocher-Langenbach posterior approach, a practice initially adopted regardless of fracture pattern or recommendations from Western European and American literature.[15] To note, the Romanian surgeons gradually transitioned to anterior approaches, such as the Modified Stoppa approach, by the end of the study period.[16] In contrast, U.S. surgeons referred to American and Western European literature guidelines before selecting a surgical approach.

Table 2. Surgical technique, equipment, and management for Romanian and U.S. patients.

	Romania	U.S.
Personnel	Two attending orthopedic surgeons with an occasional resident or medical student.	One, fellowship-trained, attending orthopedic surgeon with the assistance of one or more residents and an occasional medical student. Two attending orthopedic surgeons were present for only 10 patients.
Intraoperative Imaging	Only access to plain films via "C-arm."	Primarily utilized "C-arm" but had access to CT "O-arm" for 3D imaging.
Operating Table	Wooden traction table that was created by carpenters in the community.	Radiolucent table compatible with intraoperative fluoroscopy.
Operating Plating	Only stainless steel non-locking plates unless 3D-printed reconstruction of patient anatomy is obtained.	Pre-contoured plates that are customized for each individual patient.
Bone Grafting	No bone graft supplementation.	Frequent bone graft usage.
Surgical Approach	Primarily employed the Kocher-Langenbach posterior approach.[15] A number of patients also received an anterior approach.	Followed the American and western European literature guidelines when selecting a surgical approach.

Statistical Analysis. We used t-tests to analyze continuous data and calculate the differences of means with a 95% confidence interval. For categorical data, we used Fisher's exact test and calculated odds ratios with a 95% confidence interval. Additionally, categorical variables were analyzed using Pearson's Chi-square in IBM SPSS Statistics (Version 29.0.0). For the analysis of ordinal outcomes such as HO and Matta scores, we used ordinal logistic regression. Proportional odds ratios, along with 95% confidence intervals, were calculated. A p-value less than 0.05 was considered statistically significant. We conducted all statistical analyses using R (Version 4.1.0).

RESULTS

Patient Demographics, Comorbidities, and Injury Characteristics. A total of 365 patients were included in this study, with 249 from the U.S. and 116 from Romania. Patient demographics, comorbidities, and injury characteristics for each country are summarized in Table 3. Age was not a significant determinant for acetabular fractures in either country or between countries. However, females comprised a significantly larger portion of acetabular fractures in the U.S. than in Romania (Odds Ratio (OR) = 4.41, 95% CI = [2.3, 9.15], $p < 0.001$).

The U.S. cohort also showed significantly higher rates of diabetes (OR = 2.71, 95% CI = [1.07, 8.17], $p = 0.027$), obesity (OR = 4.73, 95% CI = [1.94, 13.93], $p < 0.001$), and hypertension (OR = 3.14, 95% CI = [1.70, 6.07], $p < 0.001$). U.S. patients were diagnosed with loose intra-articular bodies (OR = 6.27, 95% CI = [3.51, 11.70], $p < 0.001$) and femoral head fractures (OR = 3.41, 95% CI = [1.38, 10.17], $p = 0.004$) more frequently at the time of injury, while no statistically significant difference was found for articular surface traumatic injuries.

In both countries, road accidents were the most common mechanism of injury (69% overall), and the predominant Judet and Letournel fracture pattern classifications were posterior wall, associated both column, and transverse + posterior wall. U.S. patients experienced a shorter pre-operative delay compared to Romanian patients (M = -4.09, 95% CI = [-6.26, -1.92], $p < 0.001$).

Table 3. Patient demographics and injury type.

Measures	**U.S. (N=249)**	**Romania (N=116)**	**Total (N=365)**
Age at injury			
Mean years (SD)	44.63 (17.12)	45.87 (14.75)	45.03 (16.40)
Patient sex			
Female (%)	65 (26.21%)	12 (10.34%)	77 (21.15%)
Comorbidities			
Diabetes	32 (12.90%)	6 (5.17%)	38 (10.44%)
Obese/overweight	51 (20.56%)	6 (5.17%)	57 (15.66%)
Hypertension	83 (33.47%)	16 (13.79%)	99 (27.20%)
Mechanism of injury			
Crush	8 (3.2%)	43 (37.1%)	51 (14%)
Fall	52 (20.9%)	10 (8.6%)	62 (17%)
Road accident	189 (75.9%)	63 (54.3%)	252 (69%)
Judet & Letournel Class. (Fx. Pattern)			
Elementary patterns			
Posterior wall	43 (17.27%)	36 (31.03%)	79 (21.64%)
Posterior column	1 (0.40%)	0 (0.00%)	1 (0.27%)
Anterior wall	1 (0.40%)	0 (0.00%)	1 (0.27%)
Anterior column	7 (2.81%)	6 (5.17%)	13 (3.56%)
Transverse	19 (7.63%)	16 (13.79%)	35 (9.59%)
Associated patterns			
Associated both column	54 (21.69%)	22 (18.97%)	76 (20.82%)
Transverse + posterior wall	45 (18.07%)	23 (19.83%)	68 (18.63%)
T-type	19 (7.63%)	8 (6.90%)	27 (7.40%)
Ant. wall/col + post. hemitransverse	22 (8.84%)	3 (2.59%)	25 (6.85%)
Posterior column + posterior wall	38 (15.26%)	2 (1.72%)	40 (10.96%)
Injury characteristics			
Femoral head fracture	39 (15.7%)	6 (5.2%)	45 (12.3%)
Articular surface traumatic injury	43 (17.3%)	32 (27.6%)	75 (20.5%)
Loose intra-articular bodies	134 (53.8%)	18 (15.5%)	152 (41.6%)
Pre-operative delay			
Mean number of days (SD)	3.78 (11.48)	7.87 (4.54)	5.09 (9.99)

Initial Quality of Reduction. Initial patient outcomes did not differ significantly between countries (Table 4). In both countries, the initial quality of reduction did not vary with patient age, sex, obesity, hypertension status, diabetes status, or mechanism of injury. However, the initial quality of reduction for Romanian patients was influenced by the fracture pattern ($\chi^2[2, N = 116] = 52.63$, $p < 0.001$), which was not observed in the U.S. cohort ($\chi^2[2, N = 249] = 42.02$, $p = 0.20$).

Table 4. Matta's grading for initial quality of reduction.

Matta's criterion	U.S. (N= 249)	Romania (N=116)	Total (N=365)
• Anatomical (0-2mm) • Imperfect (2-3mm) • Poor (>3mm) • Can't determine/missing imaging	103 (41.4%) 73 (29.3%) 69 (27.7%) 4 (1.6%)	64 (55.2%) 26 (22.4%) 23 (19.8%) 3 (2.6%)	167 (45.8%) 99 (27.1%) 92 (25.2%) 7 (1.9%)

Peri-Operative Complications. No statistically significant differences were found for most peri-operative complications such as the incidence of deep vein thrombosis, post-operative infections, common peroneal nerve lesions, or loss of reduction (Table 5). However, U.S. patients received blood transfusions less frequently (OR = 0.13, 95% CI = [0.08, 0.22], $p < 0.001$). The U.S. cohort also recorded higher scores for HO (OR = 14.86, 95% CI = [8.17, 27.01], $p < 0.001$). For both countries, falls demonstrated a lower extent of HO than road accidents (OR = 0.43, 95% CI = [0.24, 0.78], $p = 0.006$), but HO was not affected by age, sex, obesity, and pre-existing hypertension or diabetes.

Table 5. Post-operative complications.

	U.S. (N=249)	Romania (N=116)	Total (N=365)
Deep vein thrombosis	17 (6.85%)	2 (1.72%)	19 (5.22%)
Post-operative infection	8 (3.22%)	1 (0.86%)	9 (2.48%)
Sciatic nerve injury	3 (1.21%)	1 (0.86%)	4 (1.10%)
Loss of reduction	5 (2.01%)	2 (1.72%)	7 (1.92%)
Brooker's criteria for HO • Grade I • Grade II • Grade III • Grade IV • Can't determine/missing imaging	 171 (68.7%) 44 (17.7%) 24 (9.6%) 1 (0.4%) 9 (3.6%)	 13 (11.2%) 11 (9.5%) 6 (5.2%) 3 (2.6%) NA	 184 (50.4%) 55 (15.1%) 30 (8.2%) 4 (1.1%) NA

DISCUSSION

Considering acetabular fractures are technically complex fractures associated with significant complications, a surgeon must consider patient comorbidities, fracture pattern, and surgical training/experience when counseling patients on functional and radiographic outcomes for surgical treatment.[17,18] In the present study, U.S. patients appeared to have poorer baseline characteristics and had a greater number of complications at the time of injury, which is widely accepted as a factor that contributes to poor peri-operative outcomes.[19] However, U.S. patients also had a significantly shorter average pre-operative delay which has been shown to decrease the mortality risk in elderly patients undergoing orthopedic surgery.[20] When treating acetabulum fractures, the timing for definitive surgical stabilization has been controversial. In the past, stabilization surgery has been staged for acetabular fractures; however, recent studies have described early definitive fixation is a safe and viable treatment option even for hemodynamically unstable and polytrauma patients.[21] Our results align with these findings as U.S. patients experienced significantly shorter average pre-operative delay without a significant increase in morbidity and mortality.

In addition to pre-operative comorbidity and delay concerns, surgeons must also consider the disputed focus on surgical approach/technique and equipment utilized to achieve a quality reduction for acetabular fractures.[22] Unfortunately, the operative approach and surgical fixation strategies were not controlled in the presented study which is significant considering the current literature suggests the surgical approach is a predominant factor determining quality of reduction.[23] In the early part of the study period, Romanian surgeons relied on surgical approaches that were not the standard of care for certain fracture patterns included in this study as indicated by current literature. As the Romanian surgeons developed their familiarity and skillset with respect to surgical approaches to the acetabulum, operations in the latter end of the study period were performed using the surgical approaches as indicated by current literature. The results of our study suggest that surgeon familiarity may be equally as important as surgical approach in settings and contexts in which resources are limited. Additionally, Romanian surgeons lacked access to mini-fragment screws and plates and pre-contoured plates; however, the efficacy and cost effectiveness of this instrumentation has already been questioned in the literature.[23] Lastly, Romanian surgeons did not use bone grafts in any patient, which has previously been reported as a time consuming and technically demanding option that improves the viability of any future reconstruction in acetabular fracture patients when performed correctly.[24] While the presented results were not affected by the lack of bone grafting, the long-term outcomes for acetabular fracture patients, as well as morbidity and mortality from required revision surgeries, should be a focus of future studies in Romania. These considerations may underlie the finding that Romanian Matta scores were affected by fracture pattern, while no such differences were identified in the U.S.

Despite differing technological resources, operative procedures, equipment, and methodologies, patients in the U.S. and Romania did not have significantly different initial reduction scores for acetabular fractures. Additionally, no significant difference was discovered between each country for the post-operative complications associated with increased mortality (DVT, sciatic nerve injury, infection, and loss of reduction).[25] Altogether, U.S. surgeons had access to more advanced technologies and resources, but did not record greater scores for initial quality of reduction or lower rates of post-operative complications, which further questions the efficacy and cost effectiveness of these advancements. This concern was previously addressed by orthopedic surgeons in the U.S. and United Kingdom when discussing arthroplasty technology: "Technology is expensive, increasing operating room time, and the benefits remain unclear."[26] Future research needs to evaluate the efficacy and cost effectiveness of technological advancements prior to implementation.

Limitations. The present study is limited due to its retrospective nature and reliance on clinical coding and documentation. The investigators did not have the ability to evaluate functional outcomes for patients after their treatment, nor was long-term follow-up information available at the time of the investigation. Additionally, while the authors made methodological decisions to optimize consistency and congruency between countries, unintended differences in exact operation/procedure, imaging technique, data collection, and assessment may have affected our results. Future studies should seek to evaluate long-term follow-up data, including functional outcomes, patient satisfaction, biomechanical stability, survivorship, the need for revision and/or conversion to THA. Furthermore, future studies should specifically evaluate peri-operative considerations, including opioid use, as well as financial and cost of care differences. Given this study's assessment of the numerous differences in methodology, technique, equipment, and instrumentation between the two countries, future studies should seek to identify the effectiveness, safety, and relative benefit of those differences to improve outcomes internationally.

CONCLUSIONS

Despite the advanced technological capabilities and resources employed by U.S. surgeons for acetabular fractures, the initial quality of fracture reduction was not statistically significant between U.S. and Romanian patients. This suggests that certain fundamental factors, such as surgeon training and experience, may outweigh the potential impact of advanced technology and methodology. Therefore, future research should focus on determining the efficacy and cost-effectiveness of technological advances for acetabular fracture fixation before implementation. Additionally, the conclusions from this study should guide more judicious purchasing of resources at resource-rich institutions and be expanded upon to help undersourced hospitals obtain necessary resources.

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