ORIGINAL ARTICLE

Radiographic and functional outcome of complex acetabular fractures: implications of open reduction in spinopelvic balance, gait and quality of life

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ABSTRACT

Aim To investigate the effects of surgical reduction of complex acetabular fractures on spine balance, postural stability and quality of life.

Methods Twenty-six patients with acetabular fractures surgically treated by open reduction and internal fixation were divided into two groups according to the amount of reduction. Group A consisted of 18 patients with satisfactory reduction (≤2 mm), and group B of eight patients with incomplete reduction (>2 mm). Functional outcome was measured with Harris Hip Score (HHS), Oswestry Disability Index (ODI), and Short Form (12) Health Survey (SF-12). Radiological parameters were assessed with standing whole spine, pelvis and hip X-rays, including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and sagittal vertical axis (SVA). Follow-up intervals were 1, 3, 6 and 12 months and annually thereafter. Gait analysis and baropodometry were performed after 24 months of operation.

Results Mean HHS, ODI, and SF-12 was improved during the first postoperative year in both groups. After two years average scores kept improving for group A, but worsened for group B. Mean PI, PT, and SS increased in both groups during the first postoperative year, with further increase after two years only in group B. After two years, 16 (89%) patients in group A and four (50%) in group B had a balanced spine (SVA <50 mm). Gait analysis and baropodometry showed greater imbalance and overload for group B compared to group A.

Conclusion In the long term, incomplete reduction of associated acetabular fractures may lead to poor outcome because of secondary spinopelvic imbalance, with posture and gait impairment.

Key words: acetabulum, fracture, gait analysis, open reduction, postural balance

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INTRODUCTION

Acetabular fractures are increasing, especially in the elderly population (1-3). However, even in the young, these fractures may have unfavourable outcomes from the quality of life and social health point of view (2,4). Open reduction with internal fixation (ORIF) is the gold standard of treatment for acetabular fractures in young adults, while prosthesis in the acute phase is usually not considered in this age group (1,5,6). However, even after surgical repair, such fractures may lead to malalignment of the acetabulum with biomechanical compromise of the hip joint (7,8). While the impact of misaligned acetabular fractures on the coxofemoral joint is well known (9, 10-13), their influence on spine and spine balance is underestimated and not clearly explained in the literature (14).

The aim of our study was to evaluate retrospectively the impact of surgical reduction of complex acetabular fractures on sagittal balance, gait analysis, foot loading, and overall quality of life, with regard to the coxofemoral joint and the spine, in young adult patients.

PATIENTS AND METHODS

Patients and study design

From January 2016 to December 2018, 67 patients with associated acetabular fractures according to Letournel classification (12) aged between 16 and 50 (mean 31.5 years, 22 males and four females) were treated with ORIF at five Italian institutions. Twenty-six patients were selected for the study after applying exclusion criteria: significant associated head, chest, or abdomen injury, fractures of the lower limbs or spine, injury of the pelvic ring, disease or axial deviation or previous operation of the lower limbs, spinal deformities, significant degenerative spine disease, disc herniation, spondylolysis or spondylolisthesis, avascular necrosis of the femoral head throughout the follow-up (Table 1).

The patients were divided into two groups according to the degree of fracture reduction after ORIF, as assessed by postoperative three-projection Judet X-rays: group A consisted of 18 patients with anatomical reduction, i.e. residual fracture diastasis ≤2 mm (Figure 2A-C), and group B with eight patients who had unsatisfactory reduction with residual diastasis >2 mm. Patients were treated according to the ethical standard of the Helsinki Declaration and were invited to read, understand and sign the informed consent form.

Table 1. Patients' demographics and characteristics

Characteristic*	Group A (fracture reduction ≤2mm)	Group B (fracture reduction >2mm)
Number of patients	18	8
Mean age (range) (years)	32.3 (16-50)	30.7 (16-50)
Male/female (ratio)	15/3 (5:1)	7/1 (7:1)
	No (%) of patients	
Employment		
Agriculture	8 (44.5)	3 (37.5)
Industry	8 (44.5)	3 (37.5)
Tertiary sector	2 (11)	2 (25.0)
Type of accident		
Car accident	14 (77.8)	4 (50)
Motorbike accident	4 (22.20)	4 (50)
Energy of trauma:		
High	18 (100)	8 (100)
Low	-	-
Type of fracture (Letournel classification)		
"T" fracture	1 (5.5)	1 (12. 5)
Posterior column+posterior wall	5 (28)	3 (37.5)
Transverse+posterior wall	8 (44.5)	2 (25)
Anterior wall+hemitransverse posterior fracture	2 (11)	1 (12)
Both columns	2 (11)	1 (12)
Secondary THR	8 (44.5)	8 (100)

*No statistically significant difference was found between the groups for all items (p>0.05), except for THR; THR, total hip replacement;

The Azienda Sanitaria Locale Lecce/Italy Ethical Committee approved this research.

Methods

Outcome measurements included functional and radiographic parameters, comparing the two groups.

Functional outcome was measured with the Harris Hip Score (HHS) (16), Oswestry Disability Index (ODI) (17), and The Short Form (12) Health Survey (SF-12). Spinopelvic parameters (pelvic incidence – PI, pelvic tilt – PT, sacral slope - SS, sagittal vertical axis - SVA, and lumbar lordosis – LL) were assessed with standing whole spine; pelvis and hips X-ray and X-ray of an affected hip carried out after surgery and during the follow-up.

Spinal balance is the result of a lordotic arrangement of the lumbar spine above a correctly oriented pelvis, in such way that the centre of gravity of the trunk is supported by the femoral heads, to maintain balance with minimal muscular effort. Modifications of sagittal spinal curvatures and changes in pelvic orientation are interconnected, with PI index being the key anatomic parameter of sagittal balance regulation, and PT, SS and LL changing depending on PI and spine alignment (14). The functional and radiographic tests were performed at 1, 3, 6 and 12 months, and annually thereafter. Static and dynamic baropodometry with gait analysis were performed at 24-month follow-up to assess loading on the injured limb. Dynamic pedography was performed on a multifunctional platform on treadmills with Zebris system with video recording (FDM-THM, GmbH. Munich, Germany). Patients were allowed unlimited number of barefoot walks. At least five accurate measurements for injured sides were carried out in ten areas (heel, midfoot, metatarsals 1-5, hallux, second toe, toes 3-5) for pressure, loading, contact time during the roll-over process and force-time integral. Data were analysed and averaged, and gait axis was depicted. The average follow-up was 3.2 years (range 2-4 years).

Statistical analysis

Descriptive statistics were used to summarize the characteristics of the study group and subgroups. T-test was used to obtain continuous outcomes. The χ^2 or Fisher exact tests were used to compare categorical variables. Statistical significance was defined with $p<0.05$. The correlation between functional outcome and X-ray was determined by the Cohen's k index. The correlation between changing spinopelvic parameters was evaluated with Pearson's index.

RESULTS

There were no significant differences in demographic and patient's characteristics between the groups. Surgery in both groups was performed between 5 and 7 days after the trauma. The mean time for anaesthesia and surgical procedures was similar with an average of 160 min (range 120-180). During the surgery, no impact of the femoral head, no visible subchondral hematoma, and no loss of articular cartilage of more than 25% were found. The mean time to verticalization was about nine days after the surgery, there were no perioperative complications, and patients were able to flex their hips more than 90° and to sit down 21 days after surgery.

Functional results

The average HHS before the trauma was about 98/100 for both groups. At the time of the trauma, both groups showed a severe mean functional loss without significant differences. At follow-up, HHS improved until 1 year, with no significant differences between the groups, to about 82/100. However, a statistically significant difference occurred 24 months after the trauma, with mean HHS score of 88.6 points in group A, and a worsening 74.6 in group B ($p<0.05$). During the follow-up, five patients with severe arthrosis and three with hypotrophy of the gluteus, abdominal and paravertebral muscles were found in the group B; all patients of the group B showed a significantly limited hip extension. Eight (44.5%) patients in the group A and eight (100%) in the group B required secondary total hip replacement (THR) ($p<0.05$) (Figure 1).

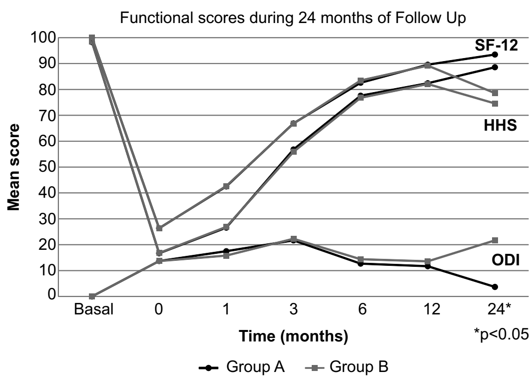

Figure 1. The trend of functional scores (HHS, SF-12, and ODI): until 1-year follow-up scores were similar between the groups; after 2 years there was a significant difference in favour of the group A; HHS, Harris Hip Score; SF, Short Form Health Survey; ODI, Oswestry Disability Index;

The average ODI before the trauma was 0% in both groups. At the time of the trauma, patients of both groups had a moderate low back pain without significant difference. At follow-up until 1 year, ODI was similar in both groups A and B, with minimal to moderate disability. Statistically significant difference appeared at 2-year follow-up with ODI of 3.7% in the group A, and 21.7% in the group B ($p<0.05$). After 2 years, all patients in the group B and only two patients in the group A were suffering from facet joint syndrome of L3-L4 and L4-L5 (Figure 1).

The mean SF-12 score before injury was 100 points in both groups, with a severe loss at the time of trauma. One month after trauma the mean SF-

12 score was similar both in the groups A and B with 42.5 and 42.7 points, respectively, and kept improving until 1-year follow-up to about 89, without significant difference. Two years after trauma the SF-12 score continued to improve in the group A to a mean score of 93.5, while it regressed to 78.6 in the group B, with statistically significant difference (p<0.05) (Figure 1).

Radiological results

Fracture reduction was assessed with postoperative radiographs, with a mean residual diastasis of 0.9 mm (range 0-1.9 mm) in the group A, and 2.7 mm (range 2-6.2 mm) in the group B.

All of the three pelvic parameters (PI, SS, and PT) showed an increase. Mean pre-operative PI was 50.3° and 51.2° in the group A and B, respectively (p>0.05); after surgery, average PI was 52° and 56° in the groups A and B, respectively (p>0.05), rising after 1 year to 61.3° and 65° in the groups, respectively (p>0.05); after 24 months, average PI was stable at 61.9° in the group A, while it further increased to 74.8° in the group B (p<0.05). Mean postoperative SS was 33.4° in the group A and 35.3° in the group B, rising after 1 year to 37.9 and 40.6° in the groups, respectively (p>0.05); after 24 months, SS further increased in the group B only (43.4°) (p<0.05). Mean postoperative PT was 17.4° in the group A, and 20.2° in the group B (p>0.05); after 12 months, mean PT was 23.6° and 25.8° in the groups, respectively (p>0.05); after 24 months, mean PT was stable at 23.7° in the group A, while it further increased to 30.5° in the group B (p<0.05) (Table 2).

After 2 years, SVA ≤50 mm indicating a balanced spine, was found in 16 (89%) patients in the group A (Figure 2D) and only in four (50%) of the group B (Figure 3A) (p<0.05). Moreover, the Pearson's index showed moderate direct correlation (ρ_{XY}=0.56) between the increase of PI, PT and SVA after 2 years in the whole series. When considering group B only, the direct correlation was strong (ρ_{XY}=0.71). Also, there was moderate direct correlation when considering the evolution of PI, PT and SVA over preoperative to 2-year follow-up period (ρ_{XY}=0.62) (Table 2).

Overall, radiographic analysis showed that normal lordosis was maintained in 10 patients in the group A and in one in the group B, five patients with hyperlordosis in the group A and two in the group B, and three patients with flat back syndrome in the group A and five in the group B. In the statistical analysis of the correlation between functional and clinical results with Coen's k, HHS, ODI and SF-12 scores correlated with radiographic results both in the group A (mean k=0.786) and B (k= 0.784) (p<0.05).

Table 2. Summary of spinopelvic parameters during the follow-up

Parameter	Pre-operative	Post-operative	12 months	24 months
Pelvic incidence (±SD)				
Group A	50.3° (±10.4)	52° (±10.6)	61.3° (±12.4)	61.9° (±12.7)
Group B	51.2° (±10.3)	56° (±10.2)	65.8° (±12.7)	74.8° (±12.8)
p				<0.05
Pelvic tilt				
Group A	-	17.4° (±10.2)	23.6° (±14.2)	23.7° (±12.2)
Group B	-	20.2° (±10.2)	25.8° (±12.6)	30.5° (±13.8)
p				<0.05
Sacral slope (±SD)				
Group A	-	33.4° (±10.2)	37.9° (±12.2)	37.9° (±12.1)
Group B	-	35.3° (±10.0)	40.6° (±12.2)	43.4° (±12.1)
p				<0.05
Lumbar lordosis (±SD)				
Group A	-	-	-	63.4° (±9.36)
Group B	-	-	-	51.6° (±10.4)
p				<0.05
SVA (≤50 mm) (No; %)				
Group A	-	-	-	16 (89)
Group B	-	-	-	4 (50)
p				<0.05

SVA, sagittal vertical axis;

Baropodometry

At two-year follow-up, baropodometry revealed greater static foot overload in the affected side in the group B compared to A (Figure 2, Figure 3) in the heel region (176±71 vs 146±53N; p<0.05), and under the fifth metatarsal (99±55 vs 67±44N; p<0.05) (Figure 2E, Figure 3B). Also, there was higher force-time integral on foot in the group B compared to A (91±8 vs 64±17N·s; p<0.05). Dynamic pedography revealed a severe impairment of walking pattern in the group B: in the heel and first metatarsal regions, there was greater loading (621±102 vs 498±77N, and 181±81 vs 134±76N, respectively (p<0.05) and higher force-time integral (177±82 vs 131±69N·s, and 98±67 vs 78±58N·s, respectively (p<0.05) in the group B compared to group A.

Overall, in all patients there was a deviation of the longitudinal axis towards the affected side with functional overload on the affected foot, but these dysfunctions were significantly more prominent in the group B. Moreover, gait analysis showed that such dysmetria was compensated during ambulation in the group A (Figure 2F),

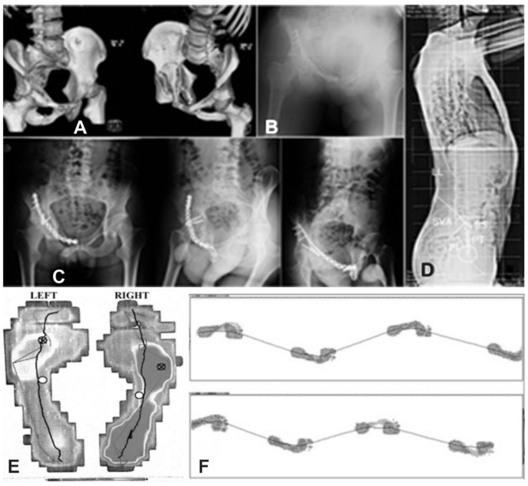

Figure 2. Illustrative case of the group A*. 39-year-old male sustaining car crash. A) 3D TC: right anterior wall and hemi-transverse anterior fractures; B) Postoperative radiograph showing anatomical reduction of the fractures and fixation with shaped plate and screws through ileo-inguinal approach. c 6-month follow-up radiograph; C) 1-year follow-up three Judet's projections radiographs show perfect healing; D) Lateral standing full spine X-rays after 24 (12) months of operation, depicting good sagittal balance (PI 48°, PT 4°, SS 43°, LL 55°, SVA -7 mm); E) Static and F) dynamic baropodometry 24 months after the operation shows right overload compensated during walking (Meccariello L, 2017)

Group A consisted of 18 patients with anatomical reduction, i.e. residual fracture diastasis ≤2 mm; ORIF, open reduction and internal fixation; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis;

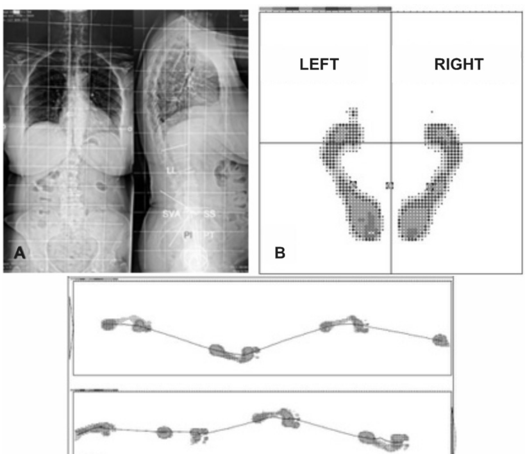

Figure 3. Illustrative case of the group B*. Four years before, a 45-year-old woman underwent ORIF of left both columns fractures. A) X-ray after plates removal, before hip replacement. Advanced spine degeneration and compensatory lumbar hypolordosis (PI 40°, PT 9°, SS 31°, LL 46°, SVA 8 mm) with a decompensation to the right: left arthritic hip, with protrusion of the acetabular head, and right convex lumbar rotoscoliosis; B) static and C) dynamic baropodometry shows a patent overload on the left foot (Meccariello L, 2017)

Group B included eight patients who had unsatisfactory reduction with residual diastasis >2 mm; ORIF, open reduction and internal fixation; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis.

while in the group B, the greater deviation of the longitudinal axis and the considerable functional overload were not compensated (Figure 3B-C).

DISCUSSION

Associated acetabular fractures are the most common fractures in young adults, and also the most difficult to treat operatively, with a high risk of poor outcomes (9,15,18). The effects of misaligned acetabular fractures on coxofemoral joint are well known, with the amount of surgical reduction being crucial (7,8,9, 11-13, 19). However, the impact of such fractures on spine balance is less clear, and probably underestimated. In fact, acetabular fractures and their repair, may alter spinopelvic relationships and lead to spine imbalance, as well as foot load and gait disturbance depending on the quality of reduction (9).

In this retrospective observational study, we investigated long-term effects of the amount of reduction of acetabular fractures on spine and hip function and overall outcome. Patients were retrospectively grouped and compared, with the group A receiving anatomical reduction, and the group B resulting in poor reduction. Both HHS and SF-12 scores improved during follow-up in both groups of patients until one year. At two-year follow-up, however, both scores worsened in group B, while they kept improving in the group A, with significant differences. Consistently, we found in the group B five patients with severe hip degeneration and three with gluteus hypotrophy, and all having very limited hip extension. A consistent body of literature showed that the quality of postoperative reduction correlated with HHS, postoperative arthritis, and need for THR, underscoring the importance of anatomical reduction in achieving successful outcomes (3,5, 7-9, 11-13, 20,21).

Among acetabular fracture outcomes, low back pain is very common and persistent over years (22). In our series, ODI was significantly worse in the long term in patients with unsatisfactory fracture reduction, possibly because of greater changes in spinopelvic parameters. Our results showed a slight increase of mean PI in both groups during the first postoperative year. However, after two years, while mean PI remained substantially stable in the group A, there was a further considerable increase in the group B. We speculated that some bone remodelling occurred during months after ORIF, with axial load causing a change in acetabular alignment with PI increase. The PI is a fundamental pelvic parameter, pivoting three-dimensional regulation of spine sagittal balance (14). When considering spinopelvic parameters modification, PT, SS and lumbar lordosis are a function of PI, which is given as an anatomical constant. However, in the present study, PI has shown significant changes over time in the group B, thus inducing unusual modification of spinopelvic parameters. Expectedly, PI increase was paralleled by an increase of PT and SS, and the equation PI=SS+PT was fulfilled in all patients during the entire follow-up. However, in the group B there was a relative greater increase of PT (+51% on average) compared to SS (+23%). Functionally, PT increase corresponds to pelvic retroversion, which in turn involves a decrease of SS with the decrease or loss of lumbar lordosis, resulting in sagittal imbalance, as defined by anterior displacement of C7 plumb line with increase of SVA (23). On the other hand, as shown in healthy subjects, with higher PI femoral heads are projected forward relative to the sacrum (6,24). In our study, this may explain the need of flattening the back to reposition the C7 plumb line close to the femoral heads, attempting a compensatory balance. Consistently, after two years, we found 50% of cases with an imbalanced spine (SVA >50 mm) in the group B compared to only 11% in the group A. The correlation found between the increase of PI, and PT and SVA increase, which becomes strong when considering group B only, supports our hypothesis that during the healing process of the fracture there might be a remodelling causing PI increase. While these changes seem to be minor and well tolerated after anatomical reduction, with poor reduction they may be greater and lead to significant modification of pelvic parameters, and ultimately result in spinopelvic imbalance. In these patients, the greater increase of PT compared to SS may represent an adaptation of hip joint in response to long term changes in acetabular orientation (14). While changes in acetabular orientation after ORIF have been studied (7), this is, to our knowledge, the first study in which changes in PI have been shown. However, further investigation correlating PI and acetabular orientation is needed to draw definite conclusions.

To the best of our knowledge, there are not previous reports on the results of baropodometry in patients with acetabulum fracture. A previous paper showed impairment of gait, muscle strength, and functional outcome in patients operated for displaced acetabular fracture regardless of the approach, suggesting that gait changes after injury and treatment are related to other factors (25). In our study, incomplete fracture reduction correlated with worse outcome in gait and foot load analysis, indicating the amount of reduction as a crucial factor affecting gait function. Incomplete recovery of hip muscles and loss of circumferential resistance to load of repaired acetabulum probably result in overload, and may represent a concurring factor of poor functional outcome (8,26). The restoration of hip joint centre (HJC) is another important biomechanical issue concerning gait function after ORIF. A significant correlation was found between the restoration of HJC and the quality of reduction, and misplacement of HJC may result in alteration of hip loading pattern (7,8). Therefore, HJC shift due to incomplete fracture reduction may be a possible mechanism for poor gait outcome.

Main limitations of our study are the retrospective design and limited number of the patients. However, all patients in this consecutive, multicentric series matching inclusion criteria were included, and all underwent the same diagnostic protocol and surgical treatment, thus limiting possible selection and treatment biases. Another limitation of the study is the lack of data about acetabular alignment and its correlation with PI, which could help to explain the underlying mechanism of spinopelvic modifications after ORIF. Hopefully, our findings might trigger future, prospective investigation.

In conclusion, associated acetabular fractures are challenging, and ORIF remains a mainstay of treatment, especially in young adults. According to the literature, the results of our study underscore the importance of anatomical reduction to achieve favourable outcomes. Long term analysis showed a significant increase of pelvic incidence after incomplete fracture reduction, which correlates with spinopelvic imbalance and ultimate hip and back disability.

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TRANSPARENCY DECLARATION.

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