

Learning curve in management of both column acetabular fractures in a specialized pelvic trauma center

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Received: July 3, 2023
Accepted: July 28, 2023

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How to cite this article: Aprato A, Limone B, D'amelio A, et al. Learning curve in management of both column acetabular fractures in a specialized pelvic trauma center. Lo Scalpello Journal 2023;37:82-89. <https://doi.org/10.36149/0390-5276-288>

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SUMMARY

Objective. The purpose of this study is to explore the learning curve for both column acetabular fractures in a specialized pelvic trauma center.

Methods. 97 patients with a both column fracture of the acetabulum (from 2008 to 2017) were retrospectively analyzed. They were treated by five different specialized pelvic surgeons at pelvic units. Operator1 was the most experienced, with 500 cases of pelvic surgery performed. Surgery delay, surgery time and complications were considered. The modified Merle d'Aubigne score was used for clinical evaluation. Radiological results were classified using Matta's criteria. For each parameters the mean was calculated. Data of patients were firstly analyzed all together to compare them to literature. Then, further statistical analysis was conducted stratifying results for each surgeon.

Results. Mean time between trauma and surgery was 10,1 days. Mean surgery time was 169.3 minutes. A total of 36 patients developed post-operative complications. The mean of Merle d'Aubigne score was 16.2. Matta post-operative radiological assessment showed satisfying reductions in 91.7%. Comparing Operator1's clinical and radiological results to the others, no statistical differences have been observed.

Conclusions. The achievement of such good results within a pelvic unit supports the need for these fractures to be treated in a specialized center, which also represent the best place for pelvic surgeons to improve their skills, quickly running across the learning curve and reaching clinical and radiological outcomes.

Key words: acetabular fractures, column fractures, pelvic surgery, learning curve, surgery experience

Introduction

The management of pelvic fractures is very challenging due to the tridimensional anatomy of the pelvis, complex fracture patterns, and highly demanding surgical procedures. Open reduction and internal fixation (ORIF) is widely accepted as the standard treatment for these fractures: the goal of the surgery is anatomical reduction of the articular surface ¹. To achieve an acceptable reduction and fixation, the surgeon's skills are essential ^{2,3}.

However, the learning curve for treating complex pelvic fractures is long and the surgeon must perform multiple interventions to obtain good radiological and clinical results. According to the literature, a correlation between the accuracy of reduction and clinical outcome has been demonstrated, and thus these fractures need to be treated in a highly specialized trauma center by expert surgeons ^{4,5}.

The aim of the present study is to explore the learning curve in the treatment of such fractures in a specialized pelvic unit. To reach the goal, both-column fractures have been considered: due to their high incidence in pelvic traumatology (25% of all acetabular fractures), they represent a perfect and typical example of a high-complex pelvic fracture pattern, which may be evaluated to determine the key role of a specialized Pelvic Unit in dealing with this type of injury ⁶.

Materials and methods

Patients

This is a retrospective study including 97 patients with a both column fracture of the acetabulum (classified according to Letournel and AO classification) who underwent pelvic surgery from February 2008 to February 2017.

They were treated by five different specialized pelvic surgeons at the pelvic units of San Luigi Gonzaga Hospital (Orbassano) and CTO (Turin).

Each surgeon is identified as “Operator-number”. The number of procedures performed by each surgeon is reported in Table I. Operator1 is the most experienced, with 500 cases of pelvic surgery performed. The other surgeons underwent a trainee period, assisted by the more experienced ones for at least about 30 surgeries, before reaching complete autonomy. Overall, operators from 2 to 5 performed fewer than 500 surgeries.

Patients were admitted either directly from emergency department of the two cited hospitals (both first level trauma centers) or transferred from minor centers after an initial first aid service (hemodynamic stabilization, trans-skeletal traction and dislocation reduction if needed) thanks to an effective trauma network.

Surgery delay, surgery time, and post-operative complications were considered for each case. Clinical and radiographical out-

comes were evaluated in our surgeries at the last visit at follow-up (mean follow-up time was 70.42 months).

Pre-operative radiological evaluation

First diagnosis of the pelvic fractures was made at the emergency department using conventional anteroposterior X-ray. To obtain a better understanding of the fracture pattern, Judet’s oblique projections (iliac-oblique and obturator-oblique) and CT scan with 3D reconstruction were performed.

Surgical procedure and post-operative indications

As suggested by AO, the patient was positioned supine. Next, axial and lateral traction of lower affected limb was applied. An ilioinguinal approach was performed for each case.

Superficial and deep dissection were performed until anterior pelvic column was reached. During the procedure, a bone hook in the lesser sciatic notch and asymmetric reduction clamps were used to reduce the fracture.

Sometimes, to avoid clamps sliding on bone oblique surfaces, a specific type of asymmetric clamp with auto-locking system, named “collinear clamp”, was used.

Reduction and fixation of the anterior column with plates or free screws was then performed.

After anterior column fixation, posterior column and lamina quadrilatera synthesis was performed. A large choice of instruments is available to reduce these fractures, such as bone hook, Queen Tong, King Tong or Matta’s Oblique reduction clamps and Collinear Reduction clamp.

Once surgery was performed, deep tissues and skin were sutured, and dressing was applied.

Post-operative indications consisted of forbidden weight-bearing on the operated limb for 60 days; for the next 30 days, partial weight-bearing was allowed; from the 3rd month after surgery patients could walk without crutches.

During the first 40 days after surgery, active and passive flexion over 40° must be avoided. A complete range of motion was then allowed.

Post-operative radiological evaluation

X-rays (AP and oblique views) were performed immediately after surgery.

The accuracy of reduction was classified in three degrees according to Matta’s criteria:

- anatomical: residual displacement of articular surface from 0 to 1 mm;
- satisfying: residual displacement from 1 to 3 mm;
- unsatisfying: residual displacement greater than 3 mm.

Post-operative clinical evaluation

For clinical evaluation the modified Merle d’Aubigne score was used.

Table I. Number of surgical procedures performed by each surgeon.

Surgeon	No of ORIFs performed
Operator1	51
Operator2	14
Operator3	13
Operator4	13
Operator5	6

Table II. Modified Merle D'Aubigne score.

Score	Pain	Gait	ROM
1	No	Normal	95-100%
2	Slight or intermittent	Slight limp, no cane or crutch	80-94%
3	After ambulation but resolves	Long distances, with cane or crutch	60-79%
4	Moderately severe, ambulation allowed	Limited distances, even with cane or crutch	40-59%
5	Severe, ambulation allowed	Very limited	
6	Severe, prevents ambulation	Bed-bound, impossibility to walk	0-39%

Table III. Modified Merle D'Aubigne clinical grade.

Result (pain+gait+ROM)	Clinical grade
18	Excellent
15-17	Good
12-14	Fair
< 12	Poor

It evaluates three parameters, which are pain, range of motion (ROM), and gait. For each a score from 1 to 6 is given. The three scores are then added, and the resulting number indicates the group to which the patient belongs (excellent, good, fair, poor).

Tables II and III shows the criteria and clinical groups according to Modified Merle d'Aubigne scale.

Statistical analysis

For each parameter analyzed (surgery delay, surgery time and surgery complications), the mean was calculated. Data on patients were firstly analyzed together in order to compare with literature results. Further statistical analysis was conducted by stratifying clinical and radiological results for each surgeon, using the statistical program Stata to perform linear regression and polytomous logistic regression models. Polynomic logistic regression with post-operative complications was also performed. Results were considered statistically significant if the p-value was < 0.05.

Results

Mean age at the trauma event was 52.3 years (SD: from 19 to 84 years). There were 73 (75.2%) males and 14 (24.8%) females. Mean follow-up was 70.55 months (5.88 years).

Surgery delay

Mean time between trauma and intervention was 10.1 days (range 1-23); 59 patients (60.1%) underwent the intervention within the 11th day after trauma.

Surgery time

Surgery performed with the ilioinguinal approach which took a mean time of 184.25 minutes.

Surgery complications

A total of 36 (37.1%) patients developed post-operative complications:

- infections: 1 case (2.8% of complications, 1% over the totality of patients);
- necrosis of the head of the femur: 1 case (2.8% of complications, 1% of patients);
- heterotopic ossifications: 1 case (2.8% of complications, 1% of patients);
- sciatic nerve injuries (both motor and sensitive impairments): 9 cases (25% of complications, 9.2% of patients);
- femoral cutaneous nerve injuries: 11 cases (61.1% of complications, 11.3% of patients);
- secondary arthritis: 13 cases required hip replacement surgery after a mean time of 24 months from the first intervention.

Clinical outcome

According to the modified Merle d'Aubigne score, we obtained a mean score of 16.2. Results were as follows:

- Excellent: 24 patients (24.74%);
- Good: 59 patients (60.82%);
- Fair: 8 patients (8.25%);
- Poor: 6 patients (6.19%).

We obtained a Merle score ≥ 15 (Excellent/Good) in 85.57% of patients.

Clinical outcomes were then evaluated with linear regression, using Operator 1 as the reference. Applying it to both univariate analysis (Tab. IV) and adjusted analysis (correcting the results for age of patients, surgery duration and delay of surgery from trauma) (Tab. V), no significant differences with other surgeons were found. The only variable close to statistical significance was the delay of surgery after trauma ($p = 0.137$, 95% CI -0.087637 - 0.0119938), which was not correlated with operator experience.

Even comparing Operator1 to all other surgeons, polytomous regression showed a non-significant difference

Table IV. Linear regression applied to univariate analysis

	Beta	Std. Err.	z	p	95% CI
Operator_2	0.0874811	0.3499863	0.25	0.803	-0.5984794; 0.7734417
Operator_3	0.3347339	0.3398798	0.98	0.325	-0.3314183; 1.000886
Operator_4	0.3951735	0.3499863	1.13	0.259	-0.2907871; 1.081134
Operator_5	-0.2843137	0.4861771	-0.58	0.559	-1.237203; 0.6685759

Table V. Linear regression applied to results corrected for age of patients, surgery duration and delay of surgery from trauma.

	Beta	Std. Err.	z	p	95% CI
Operator_2	.1881842	.3562646	0.53	0.597	-.5100816; .88645
Operator_3	.3680603	.3454395	1.07	0.287	-.3089886; 1.045109
Operator_4	.3968169	.358495	1.11	0.268	-.3058203; 1.099454
Operator_5	-.1018348	.5413268	-0.19	0.851	-1.162816; .9591463
Delay	-.0378216	.0254165	-1.49	0.137	-.087637; .0119938
Age	-.0097313	.0077383	-1.26	0.209	-.0248982; .0054356
Surgery time	-.001408	.0024375	-0.58	0.563	-.0061853; .0033693
Complications	-.1107117	.2447683	-0.45	0.651	-.5904487; .3690253

($p = 0.235$, 95% CI -0.7400211 - 0.1817277) with clinical outcome (Tab. VI). The variables closest to statistical significance were delay of surgery after trauma ($p = 0.117$, 95% CI -0.0883762 - 0.0098907) and age of patients at trauma ($p = 0.163$, 95% CI -0.0252253 - 0.0042475). However, these parameters are not correlated with operator experience.

Radiological outcome

According to Matta post-operative radiological assessment of fracture reduction and fixation, we obtained the following results:

- anatomical reduction: 50 cases (51.5%);
 - satisfying reduction: 39 cases (40.2%);
 - unsatisfying reduction: 8 cases (8.3%).
- Among the 8 patients with an unsatisfying result, 7 (87.5%) underwent total hip replacement surgery during follow-up.

On the other hand, only 5 of 39 (12.8%) patients with a satisfying reduction and 3 of 50 (6%) patients with an anatomical reduction experienced secondary arthrosis and arthroplasty.

Radiological outcomes were evaluated with the Matta score, applying linear regression using Operator 1 as reference. No significant differences were found, for either univariate analysis (Tab. VII) or adjusted analysis (correcting the results for age of patients, surgery duration and delay of surgery from trauma) (Tab. VIII).

Even comparing Operator1 to all other surgeons, polytomous regression found no significant difference in radiological outcomes ($p = 0.836$, 95%CI -0.297073; 0.2403439) (Tab. IX).

Correlation between clinical and radiological outcomes and date of surgery stratified for each operator.

A mild positive correlation for Operator 1 was observed: Matta

Table VI. Polytomous regression applied to clinical outcomes.

	Beta	Std. Err.	z	p	95% CI
Operator_1	-.2791467	.2351443	-1.19	0.235	-.7400211; .1817277
Delay	-.0392428	.0250686	-1.57	0.117	-.0883762; .0098907
Age	-.0104889	.0075187	-1.40	0.163	-.0252253; .0042475
Surgery time	-.0017396	.0022765	-0.76	0.445	-.0062015; .0027223
Complications	-.1650571	.2327241	-0.71	0.478	-.621188; .2910738

Table VII. Linear regression applied to univariate analysis

	Beta	Std. Err.	z	p	95% CI
Operator_2	.1432881	.2020015	0.71	0.478	-.2526277.5392038
Operator_3	-.1204482	.1961684	-0.61	0.539	-.5049312.2640348
Operator_4	-.0105581	.2020015	-0.05	0.958	-.4064738.3853577
Operator_5	.2843137	.2806068	1.01	0.311	-.2656655.8342929

Table VIII. Linear regression applied to results corrected for age of patients, surgery duration and delay of surgery from trauma.

	Beta	Std. Err.	z	p	95% CI
Operator_2	.1069885	.2065923	0.52	0.605	-.2979249.511902
Operator_3	-.113879	.200315	-0.57	0.570	-.5064891.2787311
Operator_4	.0095112	.2078857	0.05	0.964	-.3979372.416959
Operator_5	.3168027	.313907	1.01	0.313	-.2984437.9320491
Delay	.0227063	.0147386	1.54	0.123	-.0061809.0515935
Age	.0032367	.0044873	0.72	0.471	-.0055584.0120317
Surgery time	.0000864	.0014134	0.06	0.951	-.0026839.0028566
Complications	-.0868885	.1419373	-0.61	0.540	-.3650805.1913036

Table IX. Polytomous regression applied to radiological outcomes.

	Beta	Std. Err.	z	p	95% CI
Operator_1	-.0283646	.1370987	-0.21	0.836	-.297073.2403439
Delay	.0240398	.014616	1.64	0.100	-.004607.0526866
Age	.0036006	.0043837	0.82	0.411	-.0049913.0121925
Surgery time	.0003442	.0013273	0.26	0.795	-.0022572.0029457
Complications	-.0453547	.1356876	-0.33	0.738	-.3112974.2205881

score improved over the years (p value = 0.04). Merle score showed the same result (p = 0.15) (Tab. X).

As operator 1 had the highest number of surgeries performed, it was easier to reach statistical significance and reduce the alpha error. Thus, improvement of clinical and radiological outcomes over the years for other operators cannot be excluded.

Polynomic logistic regression with post-operative complications

For post-operative complications, no statistical differences between operators compared to Operator 1 were observed (Operator 5 was excluded because he obtained no complications) (Tab. XI).

However, according to the data, the longer the surgery time, the higher the risk for complications: for each minute of surgery added, the risk increased by 1.8% (OR = 1.018; p = 0.017).

Table X. Correlation between clinical and radiological score and the data of surgery stratified for each surgeon.

	Matta score (rho; p)	Merle score (rho; p)
Operator_1	-.029; 0.04	0.21; 0.15
Operator_2	0.14; 0.66	0.05; 0.88
Operator_3	0.15; 0.60	-0.49; 0.07
Operator_4	0.55; 0.05	-0.19; 0.54
Operator_5	-0.38; 0.45	-0.60; 0.21

Similarly, the longer the delay between trauma and surgery, the higher the risk for complications: for each day of delay added risk for complications increased by 18% (OR = 1.175; p = 0.026).

Table XI. Polynomic logistic regression applied to postoperative complications.

	OR	Std. Err.	z	p	95% CI
Operator_2	.5979592	.573693	-0.54	0.592	.0912039 3.920395
Operator_3	.5601865	.5385424	-0.60	0.547	.0851176 3.68677
Operator_4	3.720796	3.376871	1.45	0.148	.6282224 22.03729
Delay	1.175355	.0850546	2.23	0.026	1.019934 1.354461
Age	1.008876	.0204497	0.44	0.663	.9695812 1.049763
Surgery time	1.017651	.007473	2.38	0.017	1.003109 1.032403

Discussion

Management of pelvic fractures represents a major challenge for orthopedic surgeon ⁷. The complexity of pelvic anatomy and fracture pattern makes these injuries very difficult to be treated. Indeed, they often require highly demanding surgical procedures and open techniques are commonly preferred ⁸. However, in order to restore correct joint anatomy and to achieve adequate clinical and radiographical results, the surgeon must have appropriate technical skills ⁹. Operators may achieve adequate surgical experience in specialized pelvic trauma centers which are widely known to play a fundamental role in treatment and clinical outcomes ¹⁰.

The aim of our study was to evaluate the learning curve of surgeons in treating both column acetabular fractures in two specialized pelvic trauma centers. Results were compared to the literature and among surgeons with different experience operating in the same hospitals.

All cases underwent early surgery. The mean time between admission and surgical procedure was 10.1 days. According to Damage Control Orthopedics (DCO), patients with major trauma must firstly undergo temporary stabilization of fractures and hemodynamical stabilization. Definitive treatment is delayed for 7-10 days for pelvic fractures, as in the current study ¹¹. The purpose of DCO is to minimize the risk of complications, such as fat embolism, clotting, and severe hemorrhage, triggering the lethal triad ¹².

Once patients went into the surgical theatre, the preferred surgical approach was the ilioinguinal one. Even if many approaches for open reduction and internal fixation of a both-column fracture have been described (single ilioinguinal approach, combined approaches – ilioinguinal and Kocher Langenbeck posterolateral, iliofemoral approach), the one described is often the preferred solution ^{13,14}. It allows a direct view of the anterior column and the possibility to indirectly reduce and repair the posterior column. Furthermore, it is less traumatic for soft tissue than the iliofemoral approach and often requires a shorter operating time than a combined approach ^{15,16}. The surgeon's skills are essential to obtain a good indirect reduction of the posterior column and good placement of screws.

However, lateral femoral cutaneous nerve injury is a typical

complication that may occur during the ilioinguinal approach, because it courses between the sartorius and tensor fasciae lata muscle ¹⁷. Eleven cases of hypoesthesia or burning sensation due to LFCN injury (11.3% of patients) were observed in the current study.

Another serious consequence of acetabular fracture and treatment, particularly when the posterior wall is involved, is sciatic nerve injury. In our study, 9 events (9.2%) were described. Our results are in line with data reported in the literature ¹⁸. The major complications after these fractures remain posttraumatic osteoarthritis (OA), avascular necrosis of the femoral head (AN), and heterotopic ossification (HO). We observed 13 cases of OA, 1 case (2.8%) of AN, and 1 case (2.8%) of HO. As these complications typically lead to functional limitations and consequent decrease in the quality of life, total hip arthroplasty (THA) may be often required ¹⁹.

Particularly encouraging are the clinical results. The modified Merle D'Aubigne score was used to evaluate patients. It is an instrument with a high level of significance and reliability among evaluators and provides information about functional results ²⁰. Our data revealed a score > 15 in 85.57% of patients (mean 16.2), which means that good outcomes have been clinically reached in terms of pain control, gait, and ROM.

Using Matta post-operative radiological assessment, the percentage of anatomic and satisfying reductions was 91.7%. These criteria can be applied intra and postoperatively to ensure the anatomical reduction of acetabular fractures, the quality of which influences the postoperative results ²¹. The fact that the post-operative displacement of the acetabular articular surface observed in our study is less than 3 mm in a high percentage of patients this suggests good correlation with functional and clinical outcomes.

Comparing Operator1's clinical and radiological results to the others, no significant differences were seen. Even performing a polynomic logistic regression with post-operative complications no significant differences were shown. The achievement of such good goals within a pelvic unit emphasizes the importance of the surgeons' specialization in this complex field. According to our experience, operative treatment of acetabular fractures requires a steep learning curve, and an adequate training period is necessary to improve surgical skills ²². The

absence of differences among surgeons belonging to the same trauma unit suggests that teamwork reduces the extent of the learning curve and rapidly brings all surgeons to almost the same level ²³.

The findings of the study demonstrate the role of a specialized pelvic center in the treatment of acetabular fractures. As shown in the literature, they benefit from an organized trauma unit which represents a predictor of morbidity and mortality outcomes, due to the expertise reached thanks to high volumes of severely injured patients ²⁴. This is why specific injuries must be treated at an appropriate center and an efficient trauma network is beneficial to improving care ²⁵.

Conclusions

Our results support the need for acetabular fractures to be treated in a Pelvic Unit, which also represent the best place for pelvic surgeons to improve their skills, quickly completing the learning curve and reaching clinical and radiological outcomes that are not different from those obtained with more experienced surgeons.

Acknowledgements

We acknowledge the support and cooperation of our respondents.

Conflict of interest statement

The authors declare no conflict of interest.

Funding

The authors declare that no funds, grants or other support were received.

Author contributions

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical consideration

This is a retrospective study and Ethical Approval is not usually required since the data cannot be traced back to specific patients.

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