

Matta's criteria may be useful for evaluating and predicting the reduction quality of simultaneous acetabular and ipsilateral pelvic ring fractures

Yi-Hsun Yu (✉ alanyu1007@gmail.com)

Linkou Chang Gung Memorial Hospital

Chang-Heng Liu

Linkou Chang Gung Memorial Hospital

Yung-Heng Hsu

Linkou Chang Gung Memorial Hospital

Ying-Chao Chou

Linkou Chang Gung Memorial Hospital

I-Jung Chen

Linkou Chang Gung Memorial Hospital

Chi-Chuan Wu

Linkou Chang Gung Memorial Hospital

Research Article

Keywords: pelvic fracture, acetabular fracture, simultaneous fracture, Matta criteria, reduction quality

Posted Date: March 15th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-290117/v1>

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Abstract

Background Although the incidences, fracture types, and radiological outcomes for simultaneous ipsilateral pelvic ring and acetabular fractures were reported, there have been no reports on factors that may affect reduction quality of an acetabular fracture. Here, we evaluate the radiological outcomes of patients treated for simultaneous ipsilateral pelvic and acetabular fractures and analyze the factors that affect the reduction quality of acetabular fractures.

Methods We conducted a retrospective review of patients treated for simultaneous ipsilateral pelvic ring and acetabular fractures between 2016 to 2020. Potential factors were analyzed to predict inadequate reduction of the acetabular fractures.

Results Data from 27 hips of 26 patients were collected. AO B2.2 and anterior columnar fractures were the most common fracture types of the pelvic ring and acetabular fractures, respectively. Univariate analysis revealed that Matta's criteria for pelvic ring fracture may be useful for predicting fair to poor reduction quality of acetabular fractures on X-rays. Furthermore, associated fractures identified by Letournel's classification system on CT scan may be factors for predicting greater step-offs.

Conclusions The associated fractures identified via Letournel's classification may be factors that contribute to inadequate reduction for such fractures. Matta's criteria for pelvic ring fractures may also be useful for predicting the similar risk of inadequate reduction of the acetabulum on X-ray scans. These findings may be applied intraoperatively by fluoroscopy before the beginning of osteosynthesis for acetabular fractures.

Background

The optimal treatment of pelvic ring and acetabular fractures is still challenging for orthopedic surgeons, especially for multi-planar unstable pelvic and complex acetabular fractures [1-4]. Unstable pelvic ring and acetabular fractures are usually caused by high energy traumas, such as high-speed motor vehicle accidents, falls from height, and crush injuries. The treatment strategies include restoring the biomechanics of the pelvic ring and congruency of the hip joint aim to achieve satisfactory surgical outcomes and also allow the patient to more quickly return to activities of daily living.

The goals of osteosynthesis for pelvic ring fracture are to restore bone continuity and symmetry as well as to regain biomechanical stability. Anatomical reduction of the pelvic fracture is crucial since an unstable or asymmetric pelvic ring may lead to chronic pain and long-term morbidity [5-7]. Similarly, the goals of osteosynthesis for acetabular fracture are anatomical reduction and rigid fixation and thus the restoration of joint congruency. Residual non-anatomical reduction may bring inevitably poor surgical outcomes, following acetabular fractures that lead to early onset of post-traumatic osteoarthritis [7-10].

Since satisfactory reduction is similar for pelvic ring and acetabulum fractures in patients with both types of fractures, the reduction sequence is of utmost importance. Several previous studies regarding

combined pelvic ring and acetabular fractures focused on the incidence, treatment protocol, treatment sequence, and radiological outcomes [4,7,11-13]. In general, the consensus has been for posterior pelvic ring reduction and fixation before osteosynthesis for acetabular fractures. However, there are no parameters to evaluate the reduction quality after pelvic ring fractures and before osteosynthesis for acetabular fractures. These factors could be useful for predicting poor reduction quality. Therefore, the current study aimed to (1) evaluate the radiological outcomes of patients with simultaneous ipsilateral pelvic ring and acetabular fractures in a single trauma center and (2) explore the potential factors of non-anatomical reduction for the acetabulum.

Methods

We performed an IRB-approved retrospective review of the medical records and images of patients with simultaneous ipsilateral pelvic ring and acetabular fractures (2016–2020) treated at a level-one trauma center. Age, sex, injury mechanism, injury severity score (ISS), and surgical details were recorded. The inclusion criteria of the current study were as follows: (1) patients with simultaneous pelvic ring and acetabular fractures of the ipsilateral body, (2) age >18 years, (3) patients who underwent osteosynthesis for the pelvic ring and acetabular fractures, and (4) completeness of clinical and image follow-ups. Patients were excluded for the following: (1) injuries of the pelvic ring and acetabulum located at opposite sites, (2) conservative treatment for either pelvic ring or acetabulum fracture, or (3) incomplete radiological follow-ups.

All patients were treated by one senior surgeon. After the patients were well-resuscitated and medically optimized, osteosynthesis was performed as soon as possible. All patients underwent complete radiological examinations, including X-rays (anterior-posterior [AP], inlet, outlet, iliac oblique, and obturator oblique views) and computed tomography (CT) scans. Operative indications for pelvic ring fractures were significant displacement (>2 cm) of the fracture in a stable pelvic fracture, rotational instability, and global (rotational + vertical) instability. Similarly, surgical indications for acetabular fracture were displacement of components (wall, column, or both) by >2 mm, incongruent hip joint, intra-articular osteochondral fragments, and persistent subluxated or dislocated hip joint.

Variable surgical approaches were applied, according to the fracture patterns. Generally, the reduction sequence was initially started from the posterior pelvic ring for fractures such as spinopelvic dissociation, crescent fracture, sacral fractures, and sacroiliac joint diastasis. Once the pelvic fracture or dislocation was reduced and fixed, either temporarily or permanently, the osteosynthesis was changed to reduce and fix the acetabular fractures. A single surgical approach or two or more surgical approaches (simultaneous or sequential) were performed, depending on the presentation of the fractures. All of the patients underwent postoperative image examinations, including X-rays (AP, inlet, outlet, and 2 Judet views) and CT scans, to evaluate the reduction quality of the fractures. We used the picture archiving and communication system to adjust the magnification in the area of interest, and all radiographs were measured the same way.

Several classifications and evaluation parameters of image outcomes were adopted in this study. We used the AO classification for the pelvic ring fracture [14] and Letournel's classification for the acetabular fractures [5]. The evaluation parameters of the radiological outcomes of the pelvic ring injury were determined using (1) Matta's criteria [14, 15], (2) the inlet and outlet ratio proposed by Sagi et al. [16], and (3) Henderson's criteria [17], and (4) Lefaivre's method to evaluate pelvic vertical and rotational displacement and symmetry of the pelvis [18]. The quality of the acetabular fracture reduction was evaluated on AP and 2 Judet views on X-ray scans using Matta's criteria [19]. In addition, the quality of acetabular fractures reduction was also evaluated by postoperative CT scans, including axial, coronal, and sagittal planes, to determine the maximum residual step-off after osteosynthesis. All of the images were interpreted by 3 surgeons. For Matta's criteria, if the surgeons had similar interpretations, the score was reported as the mean of the data. If the images were diversely interpreted, but 2 of the surgeons had similar interpretations, they were considered the same, and the score was reported. However, if all of the interpreters' opinions were different, another senior surgeon (Y.-H, Y.) interpreted the images to determine the final score.

Continuous variables are reported as mean and standard variation. Categorical variables are reported as the number of patients per variable. The distribution of the continuous variables was examined using the Kolmogorov-Smirnov test and Shapiro-Wilk test. Univariate and multivariate analyses were conducted to determine the potential factors as seen on X-ray and CT images that may contribute to poor reduction quality of the acetabulum. The univariate analysis was performed using Fisher's exact test, multiple logistic regression test, general linear models, and Kruskal-Wallis and Mann-Whitney U tests. The multivariate analysis was performed using a general linear model and multiple logistic regression test. Inter-observer reliability was also calculated and reported as Cronbach's alpha.

Results

From the study period, 26 pelvises and 27 hips of 26 eligible patients were enrolled in this study. There were 17 males and 9 females with a mean age of 47.8 ± 14.8 years. The mean ISS was 16.7 ± 8.6 (median: 17, interquartile range: 12). The most common fracture type was AO B2.2 for the pelvis, and anterior column for the acetabulum. Nineteen pelvic fractures were sorted as rotational instability and 7 as global instability. Fourteen acetabular fractures were classified as elementary fractures and 13 as associated fractures. There were no isolated posterior wall, anterior wall, and posterior column fractures in this cohort. The demographic data of the patients are shown in Table 1.

Table 1 Demographic data of patients with simultaneous ipsilateral pelvic and acetabular fractures.

Patient number	26
Sex	
Male	17
Female	9
Age (year-old)	47.89 ± 14.82
Trauma Mechanism	
Motorbike accident	11
Fall from height (>6 meter)	11
Car accident	3
Pedestrian injury	1
Fracture classification	
Pelvis (AO classification)	
A1.1	1
B2.1	2
B2.2	10
B2.3	3
B3.2	1
B3.3	2
C1.3	4
C3.1	2
C3.3	2
Acetabulum (Letournal classification)	
Anterior column	10
Transverse	4
Transverse + posterior wall	1
T-shape	1
Anterior column plus hemi-transverse	4
Associated both columns	5
T-shape plus posterior wall *	2
Sacral fracture	
Rotational instability	7
Rotational + Vertical instability	6
Sacral-iliac joint diastasis	14
Injury severity score	16.7 ± 8.6 (median: 17, interquartile range: 12)
Follow up (mons)	14.7 ± 8.90 (range: 3 - 43)
Post-traumatic osteoarthritis (THA)	2 hips (in one patient)

*This type of fracture was not included in Letournal's classification.

Ten patients underwent a single approach for simultaneous reduction and fixation of the pelvis and acetabulum, and 16 underwent simultaneous or sequential approaches for the fractures. A variety of approaches were adjusted and applied to the patients according to the fracture types and combined injuries/fractures of the chest wall, abdominal cavity, and lower extremity. The perioperative data are shown in Table 2.

Table 2. Perioperative data patients with simultaneous ipsilateral pelvic and acetabular fractures.

Operation duration (mins)	236.67 ± 86.86
Estimated blood loss (mL)	783.33 ± 400.17
Number of operations	
Single approach	10
Two or more approaches	16
Approach Sequence	
Anterior first	19
Posterior first	8
Approaches	
Ilioinguinal	8
Anterior intrapelvis	13
Kocher-Lagenbeck	5
Gibson + trochanteric osteotomy	2
Iliosacral or trans-iliac trans-sacral screws	5
Open reduction for sacroiliac joint	
Pararectus	3
Spinopelvic osteosynthesis	4
	3

To determine the postoperative reduction quality of the pelvis and acetabulum, several diagnostic criteria were adopted (Table 3). The results showed that. X-ray examinations revealed an average discrepancy rotational instability of 9 mm for the pelvic ring. Residual step-off after osteosynthesis was also detected via CT: the widest step-off distance (2.63 ± 2.57 mm) was observed on the coronal view compared to that on the axial and sagittal views. The inter-observer reliability was examined, and the reliability was excellent despite the use of Matta's criteria for predicting the reduction quality of the pelvis (Table 3).

Table 3. Reduction quality evaluations of the pelvis and acetabulum and inter-observer reliability.

Pelvis			Acetabulum		
Parameters	Outcome	Cronbach's Alpha	Parameters	Outcome	Cronbach's Alpha
Matta's criteria	25	0.658	Matta's criteria (X ray)		0.988
Excellent	1		Anteroposterior view	17	
Good	0		Excellent	8	
Fair	0		Fair	2	0.972
Poor			Poor	17	
			Iliac oblique view	9	
			Excellent	1	
			Fair	17	0.985
			Poor	5	
			Obturator oblique view	5	
			Excellent		
			Fair		
			Poor		
Sagi			CT scan (residual step-off, mm)		
Inlet ratio	0.96 ± 0.06	0.921	Axial	1.62 ± 1.56	0.988
Outlet ratio	1.02 ± 0.17	0.973	Coronal	2.63 ± 2.57	0.993
			Sagittal	1.27 ± 1.50	0.998
Henderson's criteria*	-3.28 ± 10.24	-			
Lefaivre's method*	-9.10 ± 11.15	-			

*The value was calculated by (lesion hemipelvis) minus (intact hemipelvis)

Among the chosen factors the univariate analysis showed that the associated fractures (Letournel's classification) and reduction quality of the pelvis, as evaluated by Matta's criteria, were independent factors that may contribute to inadequate reduction quality of the acetabulum on the AP view of iliac obturator X-ray scans (Table 4). Furthermore, associated fractures of the acetabulum were the only predicting factor on axial and sagittal views of the CT scan. However, no single factor on X-ray or CT scans affecting the reduction quality of the acetabulum was revealed in the multivariate analysis.

Table 4. Univariate analysis of factors involving reduction quality of the acetabulum on X rays (anteroposterior, iliac oblique, and obturator oblique views) and CT scan (axial, coronal and sagittal views)

Selected factors	X ray			CT scan		
	P value			P value		
	AP	Iliac oblique	Obturator oblique	Axial	Coronal	Sagittal
Classification of pelvic fracture (AO)	1	0.159	0.37	0.788	0.658	0.297
SI joint diastasis	0.327	0.067	0.114	0.322	0.519	0.217
Sacral fracture	0.931	0.456	0.763	0.639	0.702	0.187
Classification of acetabular fracture (Letournel)	0.001*	0.007	0.168	0.002*	0.059	0.020*
Sequence of surgical approaches	0.599	0.748	0.511	0.447	0.680	0.680
Reduction quality of pelvis (Matta)	0.011*	0.030*	0.335	0.087	0.708	0.173
Reduction quality of pelvis (inlet ratio)	0.412	0.941	0.414	0.107	0.650	0.407
Reduction quality or pelvis (outlet ratio)	0.862	0.823	0.470	0.985	0.354	0.209
Vertical reduction quality or pelvis	0.620	0.291	0.479	0.377	0.481	0.174
Rotational reduction quality of pelvis	0.966	0.177	0.130	0.109	0.159	0.291

*Statistical significance

Discussion

The current study examined the surgical radiological results of simultaneous ipsilateral pelvic ring and acetabular fractures, to evaluate the factors that may contribute to inadequately reduced acetabular fractures. The results revealed that the most common fracture type was B2.2 for pelvic ring fractures and of the anterior column for acetabular fractures. Additionally, the univariate analysis demonstrated that the associated fractures of the acetabular fracture and reduction quality of the pelvis, by Matta's criteria, were the two independent factors that affected the reduction quality of subsequent acetabular fractures. However, no significant factors were identified via the multivariate analysis.

Anatomical reduction is the main goal in osteosynthesis for acetabular fractures, to minimize the risk for post-traumatic osteoarthritis. Tannast et al. reviewed a series of 816 patients with acetabular fractures and followed them for 2–20 years [8]. They showed that non-anatomical fracture reduction was the most significant negative predictor leading to total hip arthroplasty. Additionally, most studies reporting outcomes after acetabular fractures have indicated the importance of anatomical fracture reduction [8,10,19-21]. There are several factors that might affect the reduction of the acetabular fractures, and the complexity of the fracture pattern is one of them. Thirteen acetabular fractures (48.1%) were classified as associated fractures in Letournel's classification. Among the 13 associated acetabular fracture patterns, ten were graded as fair to poor reduction quality on AP iliac, oblique, or obturator oblique views in X-ray scans. Additionally, there were greater step-offs on CT scans for the associated fracture patterns.

Therefore, our results revealed that the classification might lead to inadequate reductions of acetabular fractures.

However, the acetabulum is part of the pelvis; therefore, in cases of pelvic ring fracture without sufficient reduction, the reduction of the acetabulum may not be adequate. Suzuki et al. confirmed that the initial accurate reduction of the posterior pelvic lesion appeared to be necessary to obtain optimal reduction of the acetabulum [4]. Since accurate reduction of the posterior pelvic ring is key to anatomical fracture reduction of the acetabulum, the sequences of fracture reduction and fixation may be critical. Although this study consisted of 19 patients with anterior approaches (ilioinguinal, anterior intrapelvic, and pararectus), the principles of the reduction sequence did not differ. These approaches mostly aimed to reduce and fix anterior lesions; however, posterior pelvic ring injuries such as crescent fracture, sacral fractures, and sacroiliac joint diastasis could also be managed using these approaches. On the other hand, posterior approaches were still important and necessary when a displaced posterior pelvic ring existed and should be performed prior to anterior approaches. There were three cases of spinopelvic osteosynthesis and three cases of open reduction and fixation to address posterior sacroiliac joint injuries. These six patients also underwent subsequent anterior approaches for acetabular fractures.

The reduction of the posterior pelvic ring is crucial in obtaining satisfactory radiological results; however, there has been no discussion on how to evaluate the pelvis's reduction quality before beginning osteosynthesis of the acetabulum. Our study shows that Matta's criteria may be useful in evaluating the reduction of the acetabulum. Since fluoroscopy is the most common tool for intraoperative evaluations of fracture reduction, Matta's criteria can be used before the beginning of osteosynthesis for acetabular fractures to determine whether the reduction should be more accurate before proceeding with the osteosynthesis. This method may be applied intraoperatively to ensure the following reduction quality of the acetabulum.

There have been similar reports of combined pelvic ring and acetabular fractures [4,7,11,12,22]. According to previous findings, the most common fracture type of the pelvis in similar cohorts was the lateral compression type [4, 7, 22]. However, Osgood et al. found the AP compression type was the most common in their cohort [11]. In our study, we show that the most common fracture type was the lateral compression type. Because the most common type of fracture of the pelvis in our study was B2.2 (lateral compression type), the injury force was probably applied directly and laterally towards the greater trochanter of the femur, which would be similar to the injury force resulting in anterior column fractures of the acetabulum [23], the most common type of acetabular fractures in our study. Therefore, we observed similar fracture types from injuries to the pelvis and acetabulum, consistent with previous studies.

Although we made efforts to avoid bias, this study had some limitations. First, this study included a relatively small number of patients, which might result in statistical bias. However, similar to previous studies, the incidence of simultaneous pelvic and acetabular fractures was low, and the numbers of enrolled patients were naturally limited in our group. Second, although one of the major findings of this study was the proposal to apply Matta's criteria for the pelvic ring intraoperatively, it was evaluated from

postoperative images in this study. The actual intraoperative usefulness of Matta's criteria to predict the reduction quality of acetabular fractures in this cohort should be determined in a future study. However, the strength of our study includes the fact that the patients were all treated by a single surgeon in a single institute with a similar treatment protocol. All patients were followed up with complete postoperative X-rays and CT scans, and 3 independent examiners conducted the interpretations of the images with excellent inter-observer reliability. Therefore, the obtained data were reliable and convincing.

Conclusion

The results of the current study demonstrated that Letournel's classification for associated fractures of the acetabulum, and Matta's criteria for pelvic ring injuries, might be useful in predicting the reduction quality of acetabular fractures in patients with simultaneous ipsilateral pelvic ring and acetabular fractures. The findings could be applied preoperatively (Letournel's classification) and intraoperatively (Matta's criteria) before the start of osteosynthesis of the acetabulum.

Abbreviations

AP: anteroposterior; CT: Computed tomography

Declarations

Ethics approval and consent to participate:

This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol was approved by the Institutional Review Board (IRB No.: 202000543B0) of Chang Gung Memorial Hospital. The written informed consent was obtained from study participants.

Consent to Publish

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

Funding

Not applicable

Authors' Contributions

Conceptualization: Y.-H. Y, C.-H. L., and Y.-H. H; Investigation: Y.-C. C. and I.-J. C; Writing: Y.-H.Y.; Writing - Review and Supervision: C.-C. W. All authors read and approved the final manuscript.

Acknowledgement

Not applicable

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