Reliability of Diagnosis of Acetabular Fracture from Radiographic Films Using Systematic Guidelines: A Sawbones Study

Yanin Plumarom MD*, Poom Purksamatanun MD*, Ong-art Phruetthiphat MD*, Aran Sawatdeepong MD*, Woodthipong Chanpradap MD*

* Department of Orthopedics, Phramongkutklao Hospital and College of Medicine, Bangkok, Thailand

Background: *The treatment of injuries involving the acetabulum is challenging. A surgeon has to decide whether surgical intervention is indicated, and choose the ideal surgical approach. According to Letournel-Judet, each acetabular fracture pattern is approached by a unique, individual approach. The correct classification of the injury pattern is based on the observation of radiography using anteroposterior and two oblique views. However, the ideal radiographic examination, which helps identify the correct classification could still be problematic. The systematic evaluation is initially based on the integrity of the iliopectineal and/or ilioischial line, called "basic lines".*

Objective: *To investigate whether the implementation of a radiographic algorithmic method could increase the reliability and validity of the Letournel classification system among orthopedic surgeons.*

Material and Method: *All of the fractured-saw bones were sent to take radiographs. The radiographies of all ten types of Letournel-Judet classification were randomly selected in order to be evaluated by 20 orthopedic residents and fellows. Each of them made a diagnosis of five types of radiographs, which had been already randomized. Therefore, there were 100 randomized radiographs that were evaluated. There are two methods used as guidelines in the present study. First, every observer studied with no instructions or guidelines. Second, the observers had to examine the same set of radiographs by taking into account a guideline algorithm protocol. Last, the agreement of the observers, related to the bone models was estimated. The unweighted kappa coefficient was utilized to estimate the observers' agreement arising from the examination of the given X-rays.*

Results: *The main finding in the present study lied on improvement of the agreement, in the second group over the first. The total agreement rate was increased from 61.0% in the first group to 81.0% in the second group after using the systematic guidelines, (p-value <0.001).*

Conclusion: *Findings from the present study confirmed the reliability of Letournel classification system and the systematic guideline algorithm protocol further improved the ability to classify the acetabular fractures types.*

Keyword: *Acetabulum, Letournel-Judet classification, Iliopectineal line, Ilioischial line, Proposed guidelines, Reliability*

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The treatment of fractured acetabulum is very challenging. Orthopedists have to make a decision to treat by surgery when it has indication. They need to choose the most appropriate procedure. Each type of fractured acetabulum can be determined surgical approaches from radiographic finding of Letournel-Judet classification. Martin et al found that making a diagnosis and identifying fracture characteristics accurately resulted in choosing the proper treatment for a successful result[4]. Making a diagnosis relied on three radiographic findings composed of AP and two oblique views. Even though there are various classification systems recommended, Letournel-Judet classification is still the most popular classification, which is widely used. This classification is divided to elementary or associated types, which depends on the characteristics of the radiographic findings. Letournel emphasized on drawing fracture characteristics seen from radiographic findings either on radiography or on a model pelvis. Although there are good radiographic findings, correct Letournel-Judet classification remains problematic. Patel et al found that the process of diagnosis of fractured acetabulum was unclear, which made differences on perspectives[8]. There was no method to make the diagnosis easily. Prevezas et al

Correspondence to:

Plumarom Y, Department of Orthopedics, Phramongkutklao Hospital and College of Medicine, 315 Ratjavithi Road, Ratchathewi, Bangkok 10400, Thailand.
Phone: +66-2-3547600 ext.93504, Fax: +66-2-6444940
E-mail: yaninyo24@gmail.com

showed that reliability using the method of the proposed guidelines increase total agreement rate from 59.9% to 72.1%[1], which used an operative finding as a gold standard. The purpose of this study aimed to use pelvis models that were fractured by the investigator of the study with clear characteristic of the fractures as a gold standard. Then, the authors used systematic guidelines to evaluate how to increase reliability and validity of Letournel-Judet classification system among orthopedists.

Material and Method

The present study protocol was approved by the Ethical Committee of the Royal Thai Army Medical Department. The subjects enrolled in the present study were third and fourth year residents and fellows trained at the Department of Orthopedics, Phramongkutklao Hospital. They were consecutively asked to participate in the present study.

Pelvis models were fractured, using a saw, following the 10 types of Letournel-Judet classification system. They were used as a gold standard to make a diagnosis. The cut pelvis models were used to make radiographies in the three positions (AP, obtulator oblique, and iliac oblique) for each type of acetabular fracture (Fig. 1). Each of the radiographies was attached by number, between one and ten. Five of the ten types were randomly selected, each of which had three positions of radiographies, and was evaluated by 20 orthopedic residents and fellows. Each of them made a diagnosis on the five types of acetabular fractures from that radiographies, which had already been randomized. Therefore, there were 100 randomized-radiographs for 20 examiners to evaluate.

Table 1. Letournel acetabulum fracture classification

Elementary	Associated
Posterior wall fracture	Posterior column fracture plus posterior wall fracture
Anterior wall fracture	Transverse plus posterior wall fracture
Anterior column fracture	T-type fracture
Posterior column fracture	Anterior column plus posterior hemitransverse fracture
Transverse fracture	Both column fracture

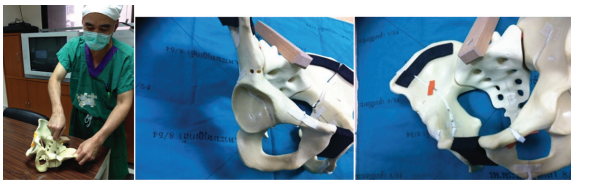

Fig. 1 The cut pelvis models.

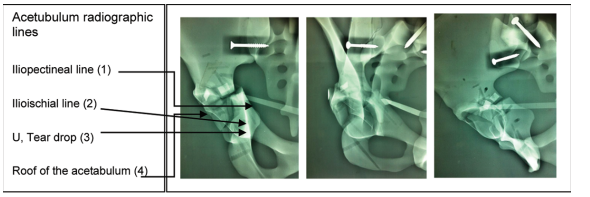

Fig. 2 Radiographic film of pelvic model and six important radiological lines.

All 20 volunteers evaluated three radiographies of pelvis, which were AP, obtulator oblique, and iliac oblique, by drawing lots. Each group of films was divided into five categories of Letournel-Judet classification, to make a diagnosis of fracture characteristics in accordance with Letournel-Judet classification system using traditional method.

Six weeks later, the investigator provided the examiners with the table of the 10 different types of the acetabular fractures according to the Letournel classification (Table 1). They also received a diagram showing the six important radiological lines (Fig. 2). Then, the examiners used the systematic guidelines to determine the kinds of acetabular fractures of Letournel-Judet classification system again. This data was analyzed to evaluate reliability of diagnosis types of acetabular fracture.

Method of assessment

To be able to use systematic guidelines to make a diagnosis fracture of acetabulum in accordance with Letournel-Judet classification system, the subjects could review all ten types, which are divided to three groups (A, B, C). By using this way, they used basic lines that were iliopectineal and ilioischial (Table 2). After reviewing iliopectineal and ilioischial lines, radiographic finding were categorized into one type,

Table 2. Basic lines: iliopectineal and ilioischial lines

Group (A): both basic lines integrity	(1) Posterior wall fracture
Group (B): one of the two basic lines interruption	(2) Anterior wall, (3) Anterior column, (4) Posterior column, (5) Posterior column plus posterior wall fracture
Group (C): both basic lines interruption	(6) Transverse, (7) Transverse plus posterior wall, (8) T-type, (9) Anterior column plus posterior hemitransverse, (10) Both column fracture

either A, B, or C. The following steps were used in making a diagnosis (Fig. 3).

First, incomplete fracture lines were not considered as disruption. They were evaluated by considering the integrity of iliopectineal and ilioischial lines to classify fracture in each one of the three groups (A, B, C).

Second, the fracture was classified in group A when the two basic lines were intact. It was categorized as the posterior wall fracture. In this case we could see the fracture of posterior rim.

Third, the fracture was classified in group B if one of the two basic lines was not intact. The differentiation of the two fractures was the evaluation of the discontinuation of the anterior rim line (fracture of the anterior wall) and the level of the discontinuation of the iliopectineal line (fracture of the anterior column). If the iliopectineal line was not intact, it was a fracture of the anterior wall or anterior column. If the ilioischial line was not intact, it was a fracture of the posterior column or posterior column combined posterior wall.

The fracture was classified in group C, if both lines were not intact (Fig. 4). Then, the evaluation of the disruption of the obturator foramen should be determined. When the obturator foramen was intact, the diagnosis was transverse fracture only when the two basic lines were disrupted (iliopectineal and ilioischial lines). It was transverse combined posterior wall fracture when the posterior rim line was disrupted. When the obturator foramen was not intact, there was probably either a T-type, an anterior column plus posterior hemitransverse, or both column fracture.

The differentiation of these three types depended on the characteristics of radiographic finding as follow, the direction and level of the fracture of lines of anterior and posterior column, spur sign (medialisation), or when part of the acetabulum remains intact and stable, which meant partial attachment of the acetabulum with the Sacroiliac joint.

If part of the acetabulum was stable, the direction of the fracture lines of anterior and posterior column was the same, and there was no spur sign, then it was T-type fracture. If part of the acetabulum was stable, the direction of the fracture lines of anterior and posterior were different, there was no spur sign, then it was anterior column plus posterior hemitransverse fracture. If there was complete instability of the acetabulum, spur sign was present, then it was both column fracture. In this case, the direction and level of the fracture lines of anterior and posterior column were not in consideration.

Fig. 3 Steps to make a diagnosis according to proposed guidelines.

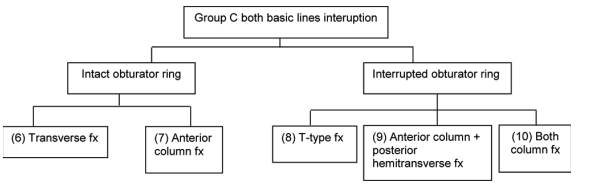

Fig. 4 Both basic lines interruption and obturat or ring fracture.

The integrity of the thyroid foramen was a valuable parameter only in group C where both column lines are discontinued. On the contrary, if the fracture line came across the whole body of the ischial rami longitudinally, and then the thyroid foramen was considered disrupted.

Statistical analysis

Comparing the two steps of observation was achieved using two parameters, the proportion of agreement and the kappa coefficient as proposed by Fleiss. The observed proportion of agreement was the percentage of instances in which the observers agreed with gold standard method. The kappa coefficient involved adjustment of the observed proportion of agreement by correction for the proportion of agreement that arised due to chance. Observers agreement with the gold standard method was examined using Cohen's quadratic weighted kappa (K) coefficient. According

Table 3. The proportion of agreement of all volunteers in the tradition and systematic steps

	% agreement	Kappa	95% CI	*p*-value
Traditional	61.0	0.565	0.545 to 0.619	<0.001
Systematic guidelines	81.0	0.788	0.742 to 0.843	<0.001

Table 4. The proportion of agreement of all volunteers in the tradition and systematic steps method between first and second time

	% agreement	Kappa	95% CI	*p*-value
Traditional	82.0	0.798	0.784 to 0.854	<0.001
Systematic guidelines	93.0	0.922	0.899 to 0.933	<0.001

Table 5. The agreement proportion between traditional and systematic method

	% agreement	Kappa	95% CI	*p*-value
	64.0	0.598	0.574 to 0.641	<0.001

to Landis and Koch, agreement was graded as slight (K = 0 to 0.2), fair (K = 0.21 to 0.40), moderate (K = 0.41 to 0.60), substantial (K = 0.61 to 0.80), and almost perfect (K = 0.81 to 1). The comparison of the observed proportion of agreement with the gold standard method between the two phases was examined using the Chi-square test or the Fisher's exact test. The level of significance was *p*-value less than 0.05. The statistical analysis was performed using STATA/MP 12.

Table 6. The difference between residents and fellows in evaluating radiographic findings

	Residents n (%)	Fellows n (%)	*p*-value
Traditional			0.893
Wrong	27 (38.6)	12 (40.0)	
Correct	43 (61.4)	18 (60.0)	
Systematic guidelines			0.697
Wrong	14 (20.0)	5 (16.7)	
Correct	56 (80.0)	25 (83.3)	

Chi-square test

Results

Each radiography of the pelvic models was attached with a number from one to ten. They were divided into three groups, each of which comprised of five random films groups. The 20 subjects, who were residents and fellows, evaluated radiographies. Therefore, 100 films groups were evaluated.

First, the proportion of agreement of all volunteers in the first and second observation steps was assessed taking our diagnosis as the gold standard. When the volunteers used a classification system with 10 different fracture types, the proportion agreement in the first step using traditional method was 61.0%, while the kappa measure of agreement was 0.565 (moderate agreement), 95% CI (0.545 to 0.619), *p*-value <0.001. In the second session using systematic guidelines, there was a clear improvement of the agreement proportion. It was 81.0%, while the kappa measure of agreement was 0.766 (substantial agreement), 95% CI (0.742 to 0.843), *p*-value <0.001 (Table 3).

The agreement proportion in the traditional method between first and second time was 82.0%, while the kappa measure of agreement was 0.798 (substantial agreement), 95% CI (0.784 to 0.854), *p*-value <0.001. The agreement proportion in the systematic method between first and second time was 93.0%, while the kappa measure of agreement was 0.922 (almost perfect agreement), 95% CI (0.899 to 0.933), *p*-value <0.001 (Table 4).

The agreement proportion between traditional method and systematic method was 64.0%, while the kappa measure of agreement was 0.598 (moderate agreement), 95% CI (0.574 to 0.641), *p*-value <0.001 (Table 5).

There was no difference between residents and fellows in evaluating radiographic findings to determine the Letournel-Judet classification system using traditional method. Residents made 61.4%, while fellows made 60.0% correct diagnosis, *p*-value = 0.893. At the same time, there was no difference between residents and fellows in evaluating radiographic findings to determine the Letournel-Judet classification system using the systematic method. Residents made diagnosis correctly 80.0%, while fellows were correct 83.3%, *p*-value = 0.697 (Table 6).

When the investigator compared only the elementary types, there was no difference between

Table 7. The difference between residents and fellows in evaluating elementary and associated types

Elementary	Residents n (%)	Fellows n (%)	*p*-value
Traditional			0.326
Wrong	13 (37.1)	4 (23.5)	
Correct	22 (62.9)	13 (76.5)	
Systematic guidelines			0.467†
Wrong	8 (22.9)	2 (11.8)	
Correct	27 (77.1)	15 (88.2)	
Associated			
Traditional			0.183
Wrong	14 (40.0)	8 (61.5)	
Correct	21 (60.0)	5 (38.5)	
Systematic guidelines			0.687†
Wrong	6 (17.1)	3 (23.1)	
Correct	29 (82.9)	10 (76.9)	

Chi-square test, † Fisher's exact test

residents and fellows in evaluating radiographic findings to determine the Letournel-Judet classification system using traditional method. Residents made the correct diagnosis 62.9%, while fellows were correct 76.5%, *p*-value = 0.326. When using the systematic method, residents made correct diagnosis 77.1%, while fellows were correct 88.2%, *p*-value = 0.467. Meanwhile, the investigator compared only the associated types and found that there was no difference between residents and fellows in evaluating radiographic findings to determine the Letournel-Judet classification system using the traditional method. Residents made diagnosis correctly 60.0%, while fellows were correct 38.5%, *p*-value = 0.183. When using systematic method, residents made correct diagnosis 82.9%, while fellows were correct 76.9%, *p*-value = 0.687 (Table 7).

Discussion

Accurate diagnosis and classification of the acetabular fracture patterns are the most important thing that we must know before surgery, which help surgeons determine how to approach, make definite diagnosis, as well as predict prognosis. There are many reasons of incorrect diagnosis of acetabular fracture such as complex anatomy, inexperienced surgeons, small number of cases, and insufficient referral centers. Letournel-Judet classification is still the most common classification to make a diagnosis of acetabular fractures using radiographic finding.

Beaule et al found that the diagnosis of types of acetabular fracture mainly depended on interpretation of AP and oblique radiographic finding, and found that using computed tomography (CT) scans or 3D-CT scans did not increase accuracy of diagnosis of classification[2]. Letournel and Judet stressed that making diagnosis and classifying of acetabular fracture were important to determine treatment and prognosis[3]. However, this classification was difficult for young surgeons. Saks found that there were many reasons for evaluating inaccurately acetabular fracture. It may be because of complex anatomy, few patients, or lack of tertiary care especially in Europe[5]. Ohashi et al did a research and found that there were frequent mistakes making diagnosis of acetabular fractures from CT or 3D-CT rather than radiographic finding[6]. The main problems resulted from not explaining radiographic finding and correlating with anatomy.

The goal in the present study was to define and confirm the reliability of systematic guidelines, and use it to implement the Letournel-Judet classification to interpret radiographic finding. Hüfner et al revealed that orthopedists who had little experience made correct diagnosis of acetabular fractures only 11%[7]. Patel et al found that there were only five out of eight criteria that became reliable[8], even though they assessed the fracture lines of iliopectineal, ilioishial, and obturator ring. This was unreliable with inexperienced surgeons.

The present study revealed that there was no difference between residents and fellows in evaluating radiographic findings to determine the Letournel-Judet classification system either by using the traditional method or the systematic method. It might simply explain that there was no difference in determining radiographic finding or in experience between residents and fellows, which was the limitation of the present study. The authors would like to expand on this data and find some experienced surgeons who are expertise in acetabulum treatment to study further in the future. Patel et al demonstrated there were no clear steps in making diagnosis of acetabular fractures[8]. However, this resulted in different views, and there was no easy method to make a diagnosis. Brandser and Marsh did a research to make a systematic diagnosis of acetabular fracture by dividing into three groups, and offered inexperienced surgeons an easier method[9]. However, there were mistakes between the groups as they mainly used the fracture of obtulator ring.

A recent study showed that there was no different between residents and fellows in evaluating elementary and associated types. From the authors perspective, it may be the result that both groups had similar experience. Durkee et al found that

using obturator ring to make a diagnosis could only differentiate five of the ten types of fracture[10]. Martin et al found that to make a diagnosis and classify characteristic of a fracture accurately resulted in guideline and success of treatment[4]. Prevezas et al found that the reliability of proposed guidelines helped increase total agreement rate from 59.9% to 72.1%[1].

The present study confirmed this research in that systematic guidelines enhanced the agreement proportion when compared with traditional method. In addition, the present study used pelvic models as a gold standard, which determined each type of Letournel-Judet classification precisely.

The current study revealed that the proportion agreement had been improved from the first step using traditional method 61.0% (kappa measure of agreement = 0.565, moderate agreement) to using systematic guidelines 81.0% (kappa measure of agreement = 0.766, substantial agreement).

The guidelines help us simplify the Letournel-Judet classification system and make the reliable diagnosis for the orthopedic surgeons especially those who are less experienced. These radiographic guidelines are simple to use. It is based on the standard radiographic finding, which consists of an antero-posterior radiograph and two oblique views. Practically, it provides the important steps of the initial assessment of the injury, resulting in the appropriate surgical and treatment approach.

Conclusion

Results from the present study confirm the reliability of Letournel-Judet classification system. Furthermore, the systematic guidelines protocol help improve the ability of diagnosis to classify the acetabular fractures types in both elementary and associated types.

What is already known on this topic?

In Prevezas et al study, they used guideline algorithm protocol, which was called proposed guidelines[1]. This study used preoperative radiographic and intraoperative finding as a gold standard. They found that the total agreement rate was increased from 59.9% to 72.1% B (p-value = 0.0267). They also confirmed that reliability of Letournel-Judet classification system. Their proposed guideline algorithm protocol further improves the ability to classify the most complex acetabular fractures types. Therefore, the results of their study were similar to this study.

What this study adds?

The present study confirmed that using systematic guidelines helps improve reliability of the Letournel-Judet classification system. The present study used saw bone of pelvis models as a gold standard, which were exactly created for the ten types of Letournel-Judet classification system.

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Potential conflicts of interest

None.

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ความน่าเชื่อถือในการวินิจฉัยกระดูกเบ้าสะโพกหักจากภาพฉายรังสี โดยการใช้การอ่านแบบเป็นระบบ (proposed guidelines)

ญาณินภ์ ปลื้มอารมย์, ภูมิ พฤกษาเมธานันท์, องอาจ พฤทธิภาส, อารัญ สวัสดิพงษ์, วุฒิพงษ์ ชั้นประดับ

ภูมิหลัง: *การรักษากระดูกเบ้าสะโพกหักเป็นความท้าทายอย่างหนึ่ง ศัลยแพทย์จำเป็นต้องตัดสินใจผ่าตัด ถ้ามีข้อบ่งชี้และต้องเลือกการผ่าตัดที่เหมาะสมที่สุดตามที่ ลิโทเนลและจูเด กล่าวไว้ (Letournel-Judet) แต่ละรูปแบบของการหักของกระดูกเบ้าสะโพกมีการเข้าการผ่าตัดที่จำเพาะ การจำแนกรูปแบบการหักที่ถูกต้อง ขึ้นอยู่กับการอ่านภาพฉายรังสี ในท่าหน้า-หลัง และอีกสองท่าเอียงเฉพาะ (anteroposterior and two oblique views) การอ่านภาพฉายรังสีให้ถูกต้องตามรูปแบบการหักที่ถูกต้องยังคงเป็นปัญหาอยู่ การอ่านแบบเป็นระบบเริ่มต้นโดยขึ้นอยู่กับการหักของเส้น iliopectineal และ/หรือ ilioischial line ที่เรียกว่า เส้นพื้นฐาน*

วัตถุประสงค์: *ต้องการดูการนำไปใช้ของการอ่านแบบเป็นระบบในศัลยแพทย์ออร์โธปิดิกส์ว่า จะเพิ่มความน่าเชื่อถือของการอ่านภาพฉายรังสีตามรูปแบบการหักของ Letournel classification หรือไม่*

วัสดุและวิธีการ: *นำกระดูกเทียมที่ตัดเป็นรูปแบบการหักตามของ Letournel classification ไปฉายภาพรังสีทั้งหมด 10 รูปแบบ นำมาสุ่มเลือกให้อ่านโดยแพทย์ประจำบ้าน และแพทย์ประจำบ้านต่อยอดทั้งหมด 20 คน มี 2 วิธี ที่ใช้ในการอ่านภาพฉายรังสีในการศึกษานี้ ลำดับแรกทุกคนอ่านโดยไม่มีรูปแบบเป็นระบบ ลำดับที่สองทุกคนอ่านโดยใช้การอ่านแบบเป็นระบบ (proposed guidelines) นำผลที่ได้มาคำนวณหาค่า agreement ของผู้อ่านนำค่า unweighted kappa coefficient มาประเมินหา agreement ของแต่ละผู้อ่านจากภาพฉายรังสี*

ผลการศึกษา: *ผลการศึกษาหลักพบว่ามีการเพิ่มขึ้นของค่า agreement ในกลุ่มที่สองเหนือกว่ากลุ่มแรก the total agreement rate เพิ่มจาก 61.0% เป็น 81.0% หลังจากการใช้การอ่านแบบเป็นระบบ (p-value <0.001)*

สรุป: *การศึกษานี้ช่วยยืนยันว่าการอ่านแบบเป็นระบบ (the proposed guidelines) เพิ่มความน่าเชื่อถือในการแยกชนิดของการหักกระดูกเบ้าสะโพกตาม Letournel classification*