Posterior acetabular arc angle of unstable posterior hip fracture–dislocation

Thos Harnroongroj · Kongkhet Riansuwan ·
Narumol Sudjai · Thossart Harnroongroj

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Abstract

Purpose Posterior hip fracture–dislocation needs stability evaluation. A previous study in the normal acetabulum has shown that the coronal posterior acetabular arc angle (PAAA) could be used to assess an unstable posterior hip fracture. Our study was designed to assess PAAA of unstable posterior hip fracture–dislocation and whether posterior acetabular wall fracture involves the superior acetabular dome.

Methods Using coronal computed tomography (CT) of the acetabulum and 3D reconstruction of the lateral pelvis, we measured coronal, vertical PAAA and posterior acetabular wall depth of 21 unstable posterior hip fracture–dislocations and of 50 % normal contralateral acetabula. Posterior acetabular wall fracture was assessed to determine whether the fracture involved the superior acetabular dome and then defined as a high or low wall fracture using vertical PAAA in reference to the centroacetabulo–greater sciatic notch line.

Results The coronal PAAA of unstable posterior hip fracture–dislocations and of 50 % of the posterior acetabular wall of normal the contralateral acetabulum were 54.48° (9.09°) and 57.43° (5.88°) and corresponded to 15.06 (4.39) and 15.61 (2.01) mm of the posterior acetabular wall without significant difference ($p > 0.05$). The vertical PAAA of unstable posterior hip fracture–dislocation was 101.67° (20.44°). There were 16 high posterior acetabular wall fractures with 35.00 (16.18) vertical PAAA involving the acetabular dome and 5 low wall fractures. High posterior wall fractures resulted in four avascular necroses of the femoral head, three sciatic nerve injuries and one osteoarthritic hip.

Conclusion Coronal and vertical PAAA of unstable posterior hip fracture–dislocations were 54.48° and 101.67°. Vertical

PAAA assesses high or low posterior acetabular wall fracture by referring to the centroacetabulo–greater sciatic notch line. High posterior wall fracture seems to be the most frequent and is involved with many complications.

Keywords Unstable posterior hip fracture–dislocation · Coronal · Vertical · Posterior acetabular arc angle · Centroacetabulo–greater sciatic notch line · High · Low · Posterior wall fracture · Complications

Introduction

Posterior hip fracture–dislocation causes intra-articular fracture of the acetabulum and an unstable hip. The fracture may involve only the posterior acetabular wall or the fracture can extend upwards into the superior acetabular dome when it requires meticulous management [1]. Emergency reduction requires a stable hip and a concentric and smooth articular surface. Preoperative assessment of posterior hip fracture–dislocation is to determine whether it is either stable or unstable and whether the fracture involves the superior acetabular dome. Previous studies have shown that a posterior wall defect of over 50 % or an acetabular fracture index less than 34 % cause an unstable posterior hip [2–5]. Both measurements include only the posterior acetabular wall, but the normal contralateral acetabulum is required for the calculation. Moreover, neither measurement allows evaluation of whether the posterior acetabular wall involves the superior acetabular dome. A previous study as shown that the coronal posterior acetabular arc angle (PAAA) of the femoral head is another method by which to determine a unstable posterior hip dislocation [6]. Measurement included arc coverage of the posterior half of the medial wall and posterior acetabular wall. The study found that a less than 50° coronal PAAA indicates an unstable hip. However, the study was performed using normal

T. Hamroongroj · K. Riansuwan · N. Sudjai · T. Hamroongroj (✉)
Department of Orthopaedic Surgery, Faculty of Medicine Siriraj
Hospital, Mahidol University, Salaya, Thailand
e-mail: tmthr@mahidol.ac.th

acetabula, and there was no study of vertical PAAA. Therefore, we have used coronal and vertical PAAA to study unstable posterior hip fracture–dislocations, including whether posterior acetabular wall fracture involved the superior acetabular dome.

Materials and methods

The study was performed after receiving ethics approval from the Siriraj Institutional Review Board. Between 2001 and 2011, we reviewed medical records, pelvic radiographs and one millimetre coronal computed tomography (CT) scans of acetabula and 3D CT reconstruction of the lateral pelvis of patients who sustained acute, clinical unstable posterior hip fracture–

dislocations. Inclusion criteria were acute clinical unstable posterior hip fracture–dislocations with normal contralateral acetabula. Clinical identification of the unstable hip was confirmed by an intraoperative fluoroscopic stress test [7], which was routinely performed after successful hip reduction using 90° flexion, 0° abduction and 0° rotation. Exclusion criteria were posterior fracture dislocation combined with fracture of the acetabular posterior column, femoral head fracture and old fracture dislocation. There were 21 clinically unstable fracture dislocations (Table 1), comprising 16 men and five women, with an age range from 16 to 82 years; 16 were on the right side and five on the left. All were caused by traffic accidents, including 11 motorcycles, seven pick-up trucks and three cars. Associated injuries including six ligamentous knee injuries,

Table 1 Demographic data, coronal posterior acetabular wall depth and coronal posterior acetabular arc angle (PAAA) of the femoral head of a normal contralateral acetabulum and unstable posterior hip fracture–dislocation

Patient no.	Sex	Age (years)	Sites	Normal contralateral acetabulum			Unstable posterior hip fracture–dislocation	
				Intact wall depths (mm)	50 % wall (mm)	Coronal PAAA of 50 % wall	Posterior acetabular wall depth (mm)	Coronal PAAA of femoral head (°)
1	M	30	L	32.13	16.07	48	16.96	47
2	F	63	R	33.43	16.72	51	17.38	47
3	M	35	L	29.39	14.67	50	11.24	48
4	M	25	R	30.38	15.19	60	18.12	63
5	F	44	R	25.77	12.89	61	10.44	47
6	M	28	R	26.13	13.06	54	11.46	46
7	F	17	R	27.17	13.59	46	18.59	52
8	M	16	R	29.54	14.77	50	10.34	45
9	M	37	R	33.48	16.74	56	17.39	59
10	M	55	R	37.59	18.80	52	20.61	53
11	M	63	R	36.35	17.66	61	13.17	57
12	F	38	R	33.36	16.68	65	14.96	51
13	M	28	R	29.38	14.69	63	15.19	60
14	M	28	R	30.48	15.24	62	15.48	62
15	M	42	R	30.25	15.12	59	16.40	49
16	M	54	L	38.12	19.11	63	9.28	55
17	M	24	R	30.76	15.38	57	22.42	75
18	M	38	R	38.07	19.04	60	24.60	76
19	F	82	L	30.92	15.46	63	8.70	42
20	M	26	L	30.99	15.49	65	12.52	54
21	M	26	R	22.86	11.43	60	11.09	56
Mean				31.26	15.61	57.43	15.06	54.48
Standard deviation				4.07	2.01	5.88	4.39	9.09
95 % confidence interval				29.41–33.12	14.69–16.52	54.75–60.10	13.07–17.06	50.34–58.61
Intraclass correlation coefficient		Intraobserver 1		0.973	0.947	0.926	0.908	0.879
		Intraobserver 2		0.950	0.914	0.901	0.884	0.857
		Interobserver		0.911	0.882	0.874	0.847	0.826

P-value=0.544 of paired *t* test between coronal posterior acetabular wall depth of the unstable posterior hip fracture–dislocation and of 50 % posterior wall of normal contralateral acetabulum

P value=0.160 of paired *t* test between coronal PAAA of the unstable posterior hip fracture–dislocation and of 50 % posterior wall of normal contralateral acetabulum

two patellar fractures, two tibial plateau fractures, one popliteal artery injury, one fracture of the transverse processes of L₁ to L₄, four multiple rib fractures with three pneumothoraxes, one scapular fracture, one radius with fifth metacarpal fracture, one mandibular fracture and one scalp wound. Preoperative one millimetre coronal CT scans of the acetabulum and 3D CT reconstructions of the lateral pelvis with posterior acetabular wall fracture and normal contralateral acetabulum were used for comparative studies. Coronal CTs of the normal contralateral acetabulum at the level of the widest diameter and thinnest medial acetabular wall were selected for measurements using the Picture Archiving and Communication (PAC) digital system. Depth of posterior acetabular wall was measured by drawing a straight PQ line as a reference. The PQ line was tangentially drawn at inner cortex of the thinnest medial wall (X) and directly along base of posterior acetabular wall in order to measure depth of the posterior wall at level of articular surface of middle acetabulum. Then, intact posterior acetabular wall depth (AB) was measured from the top of the wall (A) perpendicularly to the PQ line (B). Fifty percent of the posterior wall (BD) was calculated and marked as D. The centre of the acetabulum (O) was identified with a circle template, using anterior, posterior and medial walls as references [6]. Then, the OX line was drawn from the acetabular centre to the thinnest part of the wall (X). The OD line was drawn from the centre of the acetabulum to the inner cortex of 50 % of the acetabular posterior wall (D). DOX angle was measured as the coronal PAAA of 50 % of the posterior wall of the normal contralateral acetabulum (Fig. 1). One-millimetre coronal CT of the posterior wall of the fractured acetabulum was selected at level of the largest wall defect. The centre of the acetabulum was identified using the same technique and assessed the anterior, remaining posterior and medial acetabular walls as references (Fig. 2). The remaining posterior acetabular wall was measured. Coronal PAAA of posterior acetabular wall fractures was measured in the same manner (Fig. 2). From 3D CT reconstruction of the normal contralateral acetabulum, lateral views of the pelvis were selected using the thinnest lateral aspect of the sacrum as a reference. The acetabular centre (O) was identified by the most appropriate circle template and marked. An OF line was drawn from O to the apex curve of the greater sciatic notch (F) and called the centroacetabulo–greater sciatic notch line (Fig. 3). The OF line divided the ilium from the ischium and was used as a reference that divided the superior acetabular dome from the posterior acetabulum. The OG line was drawn from O to the lower end of the posterior acetabular wall (G). The GOF angle was measured as total vertical PAAA of the femoral head (Fig. 3). In the same manner, lateral pelvic 3D CT reconstruction of the posterior acetabular wall fracture of unstable posterior hip fracture–dislocation was selected. The centre of the acetabulum was identified using the remaining acetabular wall as a reference, and the centroacetabulo–greater sciatic notch line was

drawn. Vertical posterior acetabular arc coverage of the posterior wall fracture was measured as vertical PAAA. Lines from the acetabular centre were drawn to the lower and upper posterior acetabular wall fracture. Then, the vertical PAAA of the posterior acetabular wall fracture was measured (Figs. 4 and 5). Next, the level of the posterior acetabular wall fracture in the vertical plane was determined either below or above the centroacetabulo–greater sciatic notch line. If the upper fracture of the posterior wall was below the line, the fracture was classified as a low posterior acetabular wall fracture and its arc angle below the line was measured as vertical PAAA (Fig. 4). Upper wall fracture was above the line (Fig. 5), which meant the superior dome of the acetabulum was involved, and the fracture was classified as a high posterior acetabular wall fracture. Vertical PAAA above the line was measured. The measurements of the study were measured by two orthopaedic surgeons at six monthly intervals for inter- and intraobserver reliability. Measurements with >0.80 intraclass correlation coefficient were used as data for statistical analyses. Data were recorded and analysed using the paired *t* test. *P* value <0.05 was considered significant.

Results

Table 1 shows the average intact coronal posterior wall of a normal contralateral acetabulum was 31.26 ± 4.07 (22.86–38.12) [95 % confidence interval (CI) 29.41–33.12] and of 50 % of the wall was 15.61 ± 2.01 (11.43–19.11) (95 % CI 14.69–16.52) mm. Coronal PAAA of 50 % of the posterior acetabular wall was $57.43^\circ \pm 5.88^\circ$ (46–65°) (95 % CI 54.75–

Fig. 1 Intact (AB) and 50 % posterior acetabular wall (BD), including coronal posterior acetabular arc angle (PAAA) of femoral head of 50 % of the wall of normal contralateral acetabulum (XOD angle)

Fig. 2 Coronal posterior wall fracture (*BE*) and coronal posterior acetabular arc angle (PAAA) of unstable posterior hip fracture–dislocation (*XOE* angle)

60.10°). In unstable posterior hip fracture–dislocation, coronal PAAA of the posterior wall was $54.48^\circ \pm 9.09^\circ$ (42–76°) (95 % CI 50.34–58.61°) and corresponded to 15.06 ± 4.39 (8.70–24.60) (95 % CI 13.07–17.06) mm of the posterior acetabular wall fracture. Inter- and intraobserver reliability was >0.826 . Statistical analysis showed that coronal PAAA of the unstable

Fig. 4 Low posterior acetabular wall fracture. Lower end of the posterior wall fracture (*I*), upper end of the wall fracture (*H*) below the centroacetabulo–greater sciatic notch line (*OF*), vertical posterior acetabular arc angle (PAAA) of a low posterior acetabular wall fracture (*IOH* angle). Vertical PAAA of a low posterior acetabular wall fracture below the *OF* (*HOF* angle) shows no involvement of the superior acetabular dome

Fig. 3 Lateral pelvic 3D computed tomography (CT) reconstruction of normal contralateral acetabulum showing centre of acetabulum (*O*), centroacetabulo–greater sciatic notch line (*OF*), lower posterior acetabular wall (*G*) and intact vertical posterior acetabular arc angle (PAAA) of the femoral head (*GOF* angle)

Fig. 5 High posterior acetabular wall fracture, Lower end of the posterior wall fracture (*K*), upper end of the wall fracture (*J*) above centroacetabulo–greater sciatic notch line (*OF*). Vertical posterior acetabular arc angle (PAAA) of high posterior acetabular wall fracture (*KOJ* angle). Vertical PAAA of the high posterior acetabular wall fracture above *OF* (*JOJ* angle) showing involvement of the superior acetabular dome

fracture and of 50 % coronal posterior wall of normal contralateral acetabulum exhibited no significant difference ($p = 0.160$). In the same manner, the remaining coronal posterior acetabular wall of the unstable fracture and 50 % of the posterior wall of the normal contralateral acetabulum displayed no statistical significant difference ($p = 0.544$).

Table 2 shows the intact vertical PAAA of the femoral head of the normal contralateral acetabulum was $126.14^\circ \pm 10.36^\circ$ (106 – 146°) (95 % CI 121.43 – 130.86°). The vertical PAAA of

the posterior acetabular wall fracture of the unstable fracture was $101.67^\circ \pm 20.44^\circ$ (63 – 134) (95 % CI 92.36 – 110.97°). There were 16 high and five low posterior acetabular wall fractures. The vertical PAAA of the high fracture above the centroacetabulo–greater sciatic notch line was $35.00^\circ \pm 16.18^\circ$ (5 – 63°) (95 % CI 26.38 – 43.62°). In the low fracture, vertical PAAA of the fracture below the centroacetabulo–greater sciatic notch line was $7.00^\circ \pm 5.92^\circ$ (0 – 14°) (95 % CI 0 – 14.35°). Inter- and intraobserver reliability were >0.821 .

Table 2 Vertical posterior acetabular arc angle (PAAA) for the femoral head of normal contralateral acetabula and unstable posterior hip fracture–dislocation, including high and low posterior acetabular wall fractures in term of vertical PAAA and complications

Patient no.	Normal contralateral acetabulum	Unstable posterior fracture dislocation hip	Vertical PAAA above/below centroacetabulo–greater sciatic notch line ($^\circ$)		Complications
			High	Low	
1	106	74	24	–	
2	139	116	43	–	Avascular necrosis of femoral head
3	123	112	56	–	Avascular necrosis of femoral head, postoperative sciatic nerve injury
4	126	83	22	–	Postoperative sciatic nerve injury
5	130	90	33	–	Avascular necrosis of femoral head
6	131	103	28	–	
7	131	63	–	0	
8	137	126	19	–	Avascular necrosis of femoral head, postoperative sciatic nerve injury
9	117	125	46	–	
10	128	123	5	–	
11	143	134	47	–	Hip osteoarthritis
12	122	98	12	–	
13	129	94	–	14	
14	146	74	–	6	
15	134	114	29	–	
16	117	99	41	–	
17	120	119	50	–	
18	118	112	63	–	
19	117	113	–	3	
20	125	94	42	–	
21	110	69	–	12	
Mean (standard deviation)	126.14 (10.36)	101.67 (20.44)	35.00 (16.18)	7.00 (5.92)	
95 % confidence interval	121.43, 130.86	92.36, 110.97	26.38, 43.62	0, 14.35	
Intraclass correlation coefficient	Intraobserver 1	0.910	0.872	0.863*	
	Intraobserver 2	0.895	0.856	0.868*	
	Interobserver	0.857	0.823	0.821*	

*ICC of vertical PAAA above and below centroacetabulo–greater sciatic notch line

Table 3, shows subgroup analysis of coronal, vertical PAAA and the remainder of the coronal posterior wall of the low posterior acetabular wall fracture as $54.40^{\circ} \pm 7.93^{\circ}$ (42° – 62°) (95 % CI 44.56–64.24°), $82.60^{\circ} \pm 20.60^{\circ}$ (63° – 113°) (95 % CI 57.02–108.18°) and 13.81 ± 3.91 (8.70–18.59) mm (95 % CI 8.96–18.66), respectively. In the same manner, high posterior acetabular wall fractures were $54.50^{\circ} \pm 9.66^{\circ}$ (45° – 76°) (95 % CI 49.35–59.65°), $107.63^{\circ} \pm 16.88^{\circ}$ (74° – 134°) (95 % CI 98.63–116.62°) and 15.46 ± 4.57 (9.28–24.60) mm (95 % CI 13.02–17.89), respectively. Statistical analysis showed that coronal PAAA and the remaining coronal posterior acetabular wall of high and low wall fracture were not significantly different ($p=0.984$ and 0.478), respectively. Vertical PAAA of high acetabular wall fractures was obviously more than that of low wall fractures, with statistically significant differences ($p=0.013$). There were cases of four avascular necrosis of the femoral head, one hip osteoarthritis and three postoperative sciatic nerve injuries in high posterior acetabular wall fracture over the three years of follow-up (Table 2). Low posterior wall fracture had none of these complications.

Discussion

Unstable posterior hip fracture–dislocation remains difficult to evaluate [1–5]. Preoperative evaluation of the unstable hip fracture–dislocation is important for treatment planning and management. Anteroposterior and obturator oblique pelvic radiographs are useful for diagnosis but cannot quantify details such as involvement of the acetabulum in the coronal and vertical planes or extension of the posterior wall into the superior acetabular dome. Quantitative methods of preoperative evaluation in term of percentage of posterior wall defect and acetabular fracture index using coronal CT scans of the acetabulum are necessary in order to use the normal contralateral acetabulum as a reference [4, 5]. Moreover, measurements assess the posterior wall fracture only. This study showed that measuring the coronal PAAA of the femoral head does not require imaging the normal contralateral acetabulum in order to evaluate the unstable posterior hip fracture. Moreover, measurement included arc coverage of the posterior wall and

posterior half of the medial wall, which obtained total posterior acetabular arc coverage of the femoral head. Therefore, the PAAA was different from the acetabular fracture index. We measured the coronal PAAA of 21 unstable posterior hip-fracture dislocations that were confirmed by intraoperative fluoroscopic stress test. The study showed 54.48° coronal PAAA of the unstable posterior hip fracture–dislocation and 57.43° of 50 % of the posterior wall of the normal contralateral posterior acetabulum, with no statistically significant difference (Table 1). Moreover, coronal PAAA and 50 % of the posterior acetabular wall corresponded to the study by Hamroongroj et al. [6]. Measuring vertical PAAA of the posterior acetabular wall fracture in the vertical plane using 3D CT reconstruction of the lateral pelvis may be another beneficial method for more detailed evaluation of the unstable posterior hip fracture–dislocation. As Table 2 shows, the vertical PAAA of unstable posterior hip fracture–dislocation was 101.67° . The angle was more than half of the intact vertical PAAA of the normal contralateral acetabulum. Moreover, patients 17 and 18 shown in Table 1 displayed 75° and 76° coronal PAAA, respectively, with a 22.42- and 24.60-mm coronal posterior wall, respectively. Both cases had clinical unstable posterior hip fracture–dislocations, which did not show on the images [4, 6]. On the other hand, both cases had outstanding 119° and 112° of vertical PAAAs of the wall fracture compared with 120° and 118° of intact vertical PAAA of normal contralateral acetabulum (Table 2). Using 3D CT reconstruction of the lateral pelvis, the centroacetabulo–greater sciatic notch line is drawn as a reference for dividing the ischium from the ilium. Levels of the posterior acetabular wall fracture in the vertical plane can be quantified to determine whether the fracture involves the superior dome of the acetabulum in terms of high or low posterior acetabular wall fracture using vertical PAAA. Our study found that the 16 cases involved the superior acetabular dome when posterior acetabular wall fracture was classified as high; five cases were classified as low. Treatment of the high fracture should include the superior articular surface congruency, concentric reduction and posterior stability; low fracture should include concentric reduction and posterior stability. The amount of superior acetabular dome involvement depends on the level of posterior wall fracture extending above the centroacetabulo–greater sciatic notch line and can be assessed using the vertical

Table 3 Mean, standard deviation (SD) and 95 % confidence interval (CI) of vertical, coronal posterior acetabular arc angle (PAAA) of the femoral head and coronal posterior acetabular wall depth of high and low posterior acetabular wall fractures

	High wall fracture (<i>n</i> =16)	Low wall fracture (<i>n</i> =5)	<i>P</i> value
Coronal PAAA (°)	54.50 ± 9.66 (45–76) (95 % CI 49.35–59.65)	54.40 ± 7.93 (42–62) (95 % CI 44.56–64.24)	0.984
Vertical PAAA (°)	107.63 ± 16.88 (74–134) (95 % CI 98.63–116.62)	82.60 ± 20.60 (63–113) (95 % CI 57.02–108.18)	0.013
Coronal posterior acetabular wall depth (mm)	15.46 ± 4.57 (9.28–24.60) (95 % CI 13.02–17.89)	13.81 ± 3.91 (8.70–18.59) (95 % CI 8.96–18.66)	0.478

PAAA. Our study showed that the amount of superior acetabular dome involvement ranged from 5° to 63° of vertical PAAA (Table 2). Levels of posterior acetabular wall fracture in the vertical plane may affect the degrees of hip flexion during the intraoperative fluoroscopic stress test. In high wall fractures, the degree of flexion should be less than that in low wall fractures. Table 3 shows that vertical PAAA of the low fracture was $82.60^{\circ} \pm 20.60^{\circ}$, whereas that of the high fracture was $107.63^{\circ} \pm 16.88^{\circ}$, an obviously statistically significant difference. Coronal PAAA and coronal posterior wall of low and high wall fractures displayed minimal differences, with no statistical significance. This confirmed that configuration of the high wall fracture has a more vertical extension than the low wall fracture. We found four avascular necroses of the femoral head, one hip osteoarthritis and three postoperative sciatic nerve injuries in high wall fractures in the three years of follow-up but no complications in low wall fractures. These complications might relate to superior acetabular dome involvement in high wall fractures and the degree of hip flexion during the injury.

In conclusion, the coronal and vertical PAAA of unstable posterior hip fracture–dislocation were 54.48° and 101.67° . The vertical PAAA, referring to centroacetabulo–greater sciatic notch line, quantitatively assessed posterior acetabular wall fracture as either high or low, whether or not the fracture involved the superior acetabular dome. High

fractures were more frequent than low fracture and had many complications.

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