Weightbearing Anteroposterior Pelvic Radiographs are Recommended in DDH Assessment

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Abstract Neutral pelvic positioning during recording of anteroposterior pelvic radiographs has been recommended for precise interpretation of acetabular deformities. Because the effect of pelvic positioning is controversial in the literature, we asked whether the weightbearing position would alter radiographic interpretations. We obtained sets of supine and weightbearing anteroposterior pelvic radiographs of 31 patients with developmental dysplasia of the hip and measured pelvic tilt, acetabular version, center edge angle, acetabular index, joint space width and femoral head translation. For both genders the pelvis extended when patients were repositioned from supine to weightbearing but extension was more pronounced in women compared with men. The number of patients with apparent acetabular retroversion was reduced from 11 supine to four

when weightbearing. The center edge angle, acetabular index, joint space width and femoral head translation were similar in both views. We recommend weightbearing anteroposterior pelvic radiographs be obtained to assess DDH given the differences in pelvic flexion-extension and interpretations of acetabular version.

Level of Evidence: Level III, diagnostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Usually, radiographs for the assessment of developmental dysplasia of the hip (DDH) or femoroacetabular impingement are made in the supine position. Several authors suggest positioning (moving from supine to weightbearing) has no effect on pelvic tilt [2, 16], while another reports pelvic tilt differs notably by 5° between the two positions for both genders [11]. Further, several studies report an effect of pelvic tilt on radiographically interpreting acetabular version [9, 20, 23]. These investigators recommended neutral pelvic positioning when interpreting acetabular deformities and one group suggested limits for defining neutral pelvic positioning [20]. The distance from the symphysis to the sacrococcygeal joint correlated with the pelvic tilt in a subsequent study [22]. However, AP radiographic parameters of DDH do not seem affected beyond inherent measuring errors unless the image is severely distorted [3, 8, 18].

The effect of pelvic positioning on apparent translation of the femoral head has not, to our knowledge, been reported although several authors suggest lateral or “shearing” femoroacetabular impingement results from DDH [7, 10, 13]. In this view, increased lateral translation

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or subluxation of the femoral head in the widened and steep dysplastic acetabulum causes repeated microtrauma to the anterolateral portion of the labrum during activity [4, 6, 12, 15, 17, 26]. However, the actual occurrence of lateral hypertranslation of the femoral head in DDH has yet to be documented.

Because of the controversy in the literature regarding the role of supine versus weightbearing films and their role on pelvic tilt, we asked whether (1) a change in pelvic tilt occurred when patients with DDH were repositioned from supine to weightbearing and if the degree of dysplasia had any effect on the change; (2) radiographic parameters of dysplasia (center edge angle and acetabular index), joint space width, and acetabular version varied between supine and weightbearing radiographs; and (3) translation of the femoral head occurs during repositioning and the degree of dysplasia influenced translation.

Materials and Methods

We identified 41 selected adult patients with undiagnosed hip pain having complete sets of supine and weightbearing pelvis radiographs made between November 2005 and June 2006. We excluded patients with normal hips on both radiographs ($n = 1$), Legg-Calvé-Perthes disease ($n = 4$), DDH with subluxated femoral head ($n = 1$), reduced joint space width (≤ 2.0 mm) ($n = 1$), previous surgery (total hip replacement and pelvic osteotomy) ($n = 2$), and failure to identify the sacrococcygeal joint ($n = 1$). This left 31 selected patients with varying degrees of uni- or bilateral DDH (center edge angle less than 25°). There were seven males (mean age, 33.0 years; range, 17–56 years) and 24 females (mean age, 31.4 years; range, 16–45 years). We assessed pelvic tilt, the center edge angle, the acetabular index, joint space width, acetabular version and x- and y-coordinates of femoral head translation. These parameters were compared in supine and weightbearing radiographs for three groups: each gender in a separate group and a group including both genders. Unilateral DDH was present in five patients (four female, one male) and bilateral DDH in 26 patients (20 female; six male).

Supine AP radiographs were made with the lower extremities parallel and with enough internal rotation for the feet to touch each other and obtain 15° – 20° of internal rotation. We provided no instructions to the patients that might specifically influence pelvic tilt. In the weightbearing position, the patients were asked to stand with the lower extremities parallel and with enough internal rotation for the feet to touch each other. They were instructed to bear equal weight on both extremities. We presumed the natural or functional appearance of the pelvic position with

respect to tilt is maintained in both the supine and weightbearing positions. The xray beam was directed to the midpoint between the symphysis and the center between both anterior superior iliac spines. The tube to film distance was 100 cm in 23 sets of radiographs and 110 cm in eight sets of radiographs. We have accounted for differences in degree of magnification.

We measured pelvic tilt as follows: (1) the distance from the upper edge of the symphysis to the sacrococcygeal joint [20, 22, 23] and (2) the distance from the upper edge of the symphysis to the tip of the coccyx (Fig. 1). Adapted from Anda et al. [2] we define inclination as a forward rotation or flexion of the pelvis around a transverse axis through the hips (this will increase the distance from the symphysis to the sacrococcygeal joint) and reclination or extension as a backward rotation around the same axis (this will decrease the distance from the symphysis to the sacrococcygeal joint). Pelvic rotation was assessed by measuring the widths of the obturator foramens and then calculating the foramen obturator index of Tönnis [24] (Fig. 1). We measured the acetabular version by assessment of the acetabular rims and, if present, the crossover sign [9, 14, 19, 20] (Fig. 1). The center edge (CE) angle [27] and the acetabular index (AI) [25] were determined by the degree of DDH (Fig. 2). We measured the translation of the femoral head by (1) the distance from the intersect of the ilioischial line and the teardrop line to the most medial border of the femoral head (x coordinate) [21] and (2) the distance from the teardrop line to the most cranial border of the femoral head (y coordinate) (Fig. 2). The joint space width (JSW) was measured (1) as the shortest distance between the femoral head and the

Fig. 1 Weightbearing anteroposterior pelvic radiograph is shown. S-SC = the distance from the upper edge of the symphysis to the sacrococcygeal joint; S-C = the distance from the upper edge of the symphysis to the tip of the coccyx; FOR and FOL = the width of the right and left obturator foramen, respectively. Dashed line in the left acetabulum = the anterior rim; the solid line = the posterior rim. These are also visible in the right acetabulum but are not marked.

Fig. 2 Weightbearing anteroposterior pelvic radiograph is shown. TL = the teardrop line; CE and AI in the left hip = the center edge angle and acetabular index, respectively; X and Y in the right hip = the distance from the ilioischial line to the medial border of the femoral head and the distance from the teardrop line to the cranial border of the femoral head, respectively. Between the arrowheads, the joint space width is measured. Arrowheads = the points crossed by a vertical line through the center of the femoral head.

acetabulum at any point along the sclerotic roof of the acetabulum [1] and (2) as the distance between the femoral head and the acetabulum at the points crossed by a vertical line through the center of the femoral head (Fig. 2). In cases in which the CE angle was negative, we measured the joint space width at the lateral limit of the sclerotic acetabular roof. The measured distances from the symphysis to the sacrococcygeal joint were classified according to the limits of neutral pelvic positioning developed by Siebenrock et al. [20] (females, 4.0–5.5 cm; males, 2.5–4.0 cm).

The assessment of radiographic parameters in supine and weightbearing radiographs was separated in time by 4 weeks and performed by one blinded observer (AT). In a

randomly selected subset of 10 sets of radiographs (a total of 20 radiographs), the intraobserver variability was assessed in a blinded manner. This assessment was made another 3 weeks after the assessment of the weightbearing radiographs. For the CE angle and AI the standard deviations and 95% prediction intervals of the intraobserver variability were $\pm 2.0^\circ$ (-4.3° – 3.5°) and $\pm 1.6^\circ$ (-2.2° – 4.2°) respectively. For the remaining parameters the intraobserver variability was also relatively low (Table 1).

To compare radiographic parameters between the supine and weightbearing positions, we used paired t-tests, and to compare data between genders, we used two-sample t-tests. Data were normally distributed. We used linear regression analysis to assess the effect of the degree of dysplasia on pelvic tilt and translation of the femoral head. We performed analyses using the Stata software package (Stata 9.2, College Station, TX).

Results

We observed a change in pelvic tilt when patients with DDH were repositioned from supine to weightbearing, but no effect ($p = 0.14$ – 0.70 ; $R^2 = 0.03$ – 0.10) of the degree of dysplasia on alterations in pelvic tilt (Tables 2, 3). The distance from the symphysis to the sacrococcygeal joint was reduced ($p < 0.005$) in females and males and the combined group (1.2 cm–2.2 cm) with an extension of pelvis when repositioning (Table 2). The amount of change in pelvic tilt was larger ($p = 0.005$) in female patients than in male patients as was the distance from the symphysis to the sacrococcygeal joint in both the supine ($p < 0.001$) and the weightbearing positions ($p = 0.02$). In the supine position, 21 of 24 females had a distance from the symphysis to the sacrococcygeal joint greater than 5.5 cm and three of seven males had a distance greater than 4.0 cm. In the weightbearing position, this was reduced to eight of 24 females, whereas the proportion of males is

Table 1. Intraobserver variability

Radiographic parameter	Difference (mean)	Standard deviation	95% Prediction interval
Width of obturator foramen (cm)	−0.03	± 0.17	−0.36–0.30
Distance from symphysis to sacrococcygeal joint (cm)	−0.04	± 0.11	−0.25–0.17
Distance from symphysis to tip of the coccyx (cm)	−0.01	± 0.18	−0.37–0.35
Center edge angle ($^\circ$)	−0.4	± 2.0	−4.3–3.5
Acetabular index angle ($^\circ$)	1.0	± 1.6	−2.2–4.2
Joint space width; minimal (mm)	0.13	± 0.42	−0.69–0.95
Joint space width; central (mm)	0.24	± 0.60	−0.93–1.41
X coordinate (cm)	0.03	± 0.10	−0.16–0.22
Y coordinate (cm)	−0.02	± 0.12	−0.25–0.21

Table 2. Distance from the symphysis to the sacrococcygeal joint

Radiographic parameter	Number of patients	Supine (mean)	95% CI	Weightbearing (mean)	95% CI	Difference (mean)	95% CI	p Value
Distance from symphysis to sacrococcygeal joint (cm)	All (n = 31)	6.3	5.5–7.0	4.3	3.5–5.0	2.0	1.7–2.3	< 0.0001
	Female (n = 24)	6.9	6.2–7.7	4.7	4.0–5.4	2.2	1.9–2.6	< 0.0001
	Male (n = 7)	4.0	2.5–5.5	2.8	0.8–4.8	1.2	0.5–1.8	0.0042

CI = confidence interval.

Table 3. Classification of the distance from the symphysis to the sacrococcygeal joint

Distance from symphysis to the sacrococcygeal joint (cm)	Supine radiographs (number of patients)	Weightbearing radiographs (number of patients)
Females (n = 24)		
Less than 4.0 cm	3	6
4.0 cm to 5.5 cm	0	10
Greater than 5.5 cm	21	8
Males (n = 7)		
Less than 2.5 cm	2	4
2.5 cm to 4.0 cm	2	0
Greater than 4.0 cm	3	3

unchanged (Table 3). The distance from the symphysis to the tip of the coccyx was also reduced ($p < 0.007$) in all three groups when repositioning.

Even though the CE angle was reduced ($p < 0.006$) by 1.3° to 1.6° and the AI increased ($p < 0.003$) by 1.6° to 2.3° in the groups of all patients and females when repositioning, the CE angle and AI did not differ beyond what might be attributed to intraobserver variability (Tables 1,

4). Overall and in females, JSW was not affected by repositioning ($p = 0.16$ – 0.82 and 0.69 – 0.95 , respectively). In males, JSW (when measured centrally on left hips) was reduced ($p = 0.01$) by 0.67 mm when repositioning. Acetabular version was affected when repositioning. In the supine position, the radiographs of 11 patients (nine female; two male) demonstrated a crossover sign. In the weightbearing position, the crossover sign remained in four of these patients (three female; one male). Pelvic rotation, as assessed by the foramen obturator index, was not influenced ($p = 0.57$) by repositioning (1.02 and 1.03 in the supine and weightbearing positions respectively).

We noted slight medialization and caudalization of the femoral head when repositioning from supine to weightbearing position, but these were not related ($p = 0.08$ – 0.95 ; $R^2 = 0.0002$ – 0.35) to the degree of dysplasia (Table 5). Mean differences of the x-direction translation between the supine and weightbearing positions ranged from 0.06 cm to 0.14 cm ($p = 0.01$ – 0.36), ie, medialization of the femoral head (Table 5). Mean differences of the y-direction translation between the supine and weightbearing positions ranged from 0.09 cm to 0.30 cm ($p = 0.0008$ – 0.14), ie, a caudalization of the femoral head (Table 5).

Table 4. Dysplastic parameters in supine and weightbearing radiographs

Radiographic parameter	Number of patients	Supine (mean)	95% CI	Weightbearing (mean)	95% CI	Difference (mean)	95% CI	p Value
Center edge angle ($^\circ$); right	All (n = 31)	18.9	17.0–20.9	17.6	15.6–19.7	1.3	0.5–2.1	0.0017
	Female (n = 24)	19.0	16.6–21.5	17.5	14.9–20.2	1.5	0.7–2.3	0.0013
	Male (n = 7)	18.6	14.8–22.3	18.0	15.0–21.0	0.6	–1.6–2.8	0.5472
Center edge angle ($^\circ$); left	All (n = 31)	17.1	14.4–19.7	15.7	12.9–18.5	1.4	0.4–2.3	0.0051
	Female (n = 24)	16.1	12.9–19.3	14.5	11.2–17.9	1.6	0.5–2.6	0.0045
	Male (n = 7)	20.3	15.3–25.3	19.7	15.1–24.3	0.6	–1.9–3.0	0.5872
Acetabular index angle ($^\circ$); right	All (n = 31)	11.6	9.4–13.8	13.2	11.4–15.0	–1.6	–2.6––0.6	0.0025
	Female (n = 24)	11.2	8.5–13.9	13.5	11.1–15.8	–2.3	–3.1––1.4	<0.0001
	Male (n = 7)	12.9	8.3–17.5	12.3	10.1–14.5	0.6	–3.0–4.1	0.7062
Acetabular index angle ($^\circ$); left	All (n = 31)	12.3	9.8–14.8	14.3	11.6–16.9	–2.0	–2.9––1.0	0.0002
	Female (n = 24)	12.9	9.9–15.9	15.2	12.1–18.3	–2.3	–3.4––1.2	0.0002
	Male (n = 7)	10.3	5.5–15.1	11.0	5.3–16.7	–0.7	–2.6–1.2	0.3940

CI = confidence interval.

Table 5. Translation of the femoral head in supine and weightbearing radiographs

Radiographic parameter	Number of patients	Supine (mean)	95% CI	Weightbearing (mean)	95% CI	Difference (mean)	95% CI	p Value
X coordinate (cm); right	All (n = 31)	1.27	1.08–1.47	1.22	1.02–1.41	0.06	–0.01–0.13	0.1010
	Female (n = 24)	1.08	0.90–1.25	1.02	0.83–1.21	0.06	–0.03–0.14	0.1749
	Male (n = 7)	1.94	1.71–2.17	1.89	1.75–2.02	0.06	–0.08–0.20	0.3559
X coordinate (cm); left	All (n = 31)	1.39	1.18–1.61	1.32	1.10–1.53	0.08	0.02–0.14	0.0117
	Female (n = 24)	1.21	0.99–1.42	1.15	0.92–1.38	0.06	–0.01–0.12	0.0746
	Male (n = 7)	2.03	1.77–2.29	1.89	1.71–2.06	0.14	–0.02–0.31	0.0821
Y coordinate (cm); right	All (n = 31)	4.72	4.58–4.87	4.60	4.46–4.74	0.12	0.01–0.23	0.0299
	Female (n = 24)	4.69	4.50–4.88	4.60	4.44–4.77	0.09	–0.03–0.20	0.1270
	Male (n = 7)	4.83	4.71–4.94	4.60	4.27–4.93	0.23	–0.10–0.56	0.1390
Y coordinate (cm); left	All (n = 31)	4.82	4.65–4.99	4.65	4.49–4.82	0.16	0.07–0.25	0.0008
	Female (n = 24)	4.83	4.61–5.04	4.70	4.49–4.91	0.13	0.03–0.22	0.0092
	Male (n = 7)	4.80	4.53–5.07	4.50	4.21–4.79	0.30	0.01–0.59	0.0433

CI = confidence interval.

Discussion

Recent authors reporting the effect of pelvic tilt on the interpretation of acetabular version have recommended neutral pelvic positioning with the patient supine during recording of AP pelvic radiographs [9, 20, 23]. However, the role of supine versus weightbearing films and their role on pelvic tilt remains controversial, and therefore we asked whether (1) a change in pelvic tilt occurred when patients with DDH were repositioned from supine to weightbearing and if the degree of dysplasia had any effect on the change; (2) radiographic parameters of dysplasia (center edge angle and acetabular index), joint space width, and acetabular version varied between supine and weightbearing radiographs; and (3) translation of the femoral head occurs during repositioning and the degree of dysplasia influenced translation.

The study group of 31 patients is limited in size. In particular, the small subgroup of seven males could limit the value of information on how repositioning changes the assessment of DDH deformities in males. However, when comparing the results of the male group with those of females and all patients, changes of pelvic tilt and acetabular version, though not necessarily of equal magnitude, are seen in all three groups. This suggests the limited size of the male group does not limit the ability to draw conclusions. The study is conducted on DDH patients and because of the special characteristics of DDH deformities the results may not apply to patients with normally configured hips or those with other abnormalities.

We found changes in pelvic tilt in both male and female study subjects when they were repositioned from supine to weightbearing. Overall, the pelvis were extended, and the change in pelvic tilt was greater in females

than in males. A direct measure in degrees of the changes in pelvic tilt was not directly assessed in this study. However, the distance from the symphysis to the sacrococcygeal joint correlates with the tilt angle [22], and the actual changes in the mean distance from the symphysis to the sacrococcygeal joint were 2.2 cm and 1.2 cm in females and males, respectively. Using the linear relationship between the change in pelvic tilt and the distance from the symphysis to the sacrococcygeal joint developed by Tannast et al. [22], the changes correspond to approximately 13° to 14° in females and 6° to 7° in males taking into account the differences in radiographic techniques. These changes are greater than previously reported [2, 11, 16] although previous reports do not suggest differences between genders in the amount of change in pelvic tilt [2, 11]. However, the reports used different methods to assess differences in pelvic tilt when repositioning. Although the degree of dysplasia (CE angle and AI) did not affect the change in pelvic tilt, the general characteristics of dysplasia such as global coverage deficiency might contribute to increased pelvic mobilization when changing position from supine to weightbearing.

When applying the suggested limits for neutral pelvic positioning developed by Siebenrock et al. [20], the number of patients who exceeded the upper limit were reduced from 24 (77%) in the supine position to 11 (35%) in the weightbearing position. However, only 10 patients (32%) were confined within the suggested limits for neutral pelvic positioning in the weightbearing position. The numbers of patients with a crossover sign was reduced from 11 in the supine position to four in the weightbearing position. As young adults with hip deformities, at least initially, often have symptoms during activities such as walking, running or jumping we believe the weightbearing position to be the

most relevant for diagnostic and preoperative surgical assessment. That is, weightbearing films secure the best coherence between symptoms, functional appearance and hip deformities of the patient. If supine films are used there is a risk of overestimating the incidence of cross-over sign in DDH patients. Besides from the risk of misdiagnosing the patient having apparent acetabular retroversion one might overestimate the need for acetabular reorientation in the surgical setting leading to a possible inferior outcome for the patient.

We observed reductions of the CE angle and increases in the AI when repositioning from supine to weightbearing. Considering the 95% prediction intervals of the intraobserver variability assessment, these changes might be attributed to measuring error and not reflect actual changes. This effect can also account for the reduction of JSW found in the males. Other studies report similar variation of the CE angle and AI when the change in pelvic tilt is confined to the interval observed in this study [3, 8, 18]. As in previous reports, we found no overall differences in hip JSW between the supine and weightbearing positions [1, 5].

The assessment of femoral head translation and the corresponding assessment of intraobserver variability of the x and y coordinates suggest no relevant movement of the femoral head can be detected on AP pelvic radiographs. Further we found no relationship between the degree of DDH and femoral head translation. The medialization and caudalization we measured was so small it is not likely clinically important. If “shearing” impingement occurs in the dysplastic hip, it might not be detectable on a simple change to a weightbearing position. It might occur with activities of flexion and rotation or during gait cycles. Although the hypothesis of “shearing” impingement as the cause of labral tearing in the classic dysplastic hip seems likely, from a biomechanical standpoint [7, 10, 13], there has as yet been no direct observation of its actual occurrence reported in the literature.

The recommendation for neutral pelvic positioning developed by Siebenrock et al. [20] is advantageous because it will allow for standardization in anatomic and epidemiologic studies. We found one-third of patients in the weightbearing position would fit within the suggested limits of neutral pelvic positioning. However, the remaining two-thirds of patients will, as a result of posture, have a pelvic position in relative flexion or extension. We believe this point important since otherwise one might misinterpret the radiographic assessment of the pelvic tilt and acetabular version if applying the suggested limits for neutral pelvic positioning on AP pelvic radiographs. In contrast, dysplastic parameters, joint space width, and translation of the femoral head are not, according to our data, subject to

clinical or surgical misinterpretation in either the supine or weightbearing position. We recommend AP pelvic radiographs be obtained in the weightbearing position to best assess hip deformities.

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