



Radiographic markers of acetabular retroversion : Correlation of the cross-over sign, ischial spine sign and posterior wall sign

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Radiological diagnosis of acetabular retroversion is based on the presence of the cross-over sign (COS), the posterior wall sign (PWS), and prominence of the ischial spine (PRISS). The primary purpose of the study was to correlate the quantitative cross-over sign with the presence or absence of the PRISS and PWS signs.

The hypothesis was that both, PRISS and PWS are associated with a higher cross-over sign ratio or higher amount of acetabular retroversion.

A previous study identified 1417 patients with a positive acetabular cross-over sign. Among these, three radiological parameters were assessed : (1) the amount of acetabular retroversion, quantified as a cross-over sign ratio ; (2) the presence of the PRISS sign ; (3) the presence of the PWS sign. The relation of these three parameters was analysed using Fisher's exact test, ANOVA, and linear regression analysis.

In hips with cross-over sign, the PRISS was present in 61.7%. A direct association between PRISS and the cross-over sign ratio ($p < 0.001$) was seen. The PWS was positive in 31% of the hips and was also significantly related with the cross-over sign ratio ($p < 0.001$). In hips with a PRISS, 39.7% had a PWS sign, which was a significant relation ($p < 0.001$). In patients with positive PWS, 78.8% of the cases also had a PRISS ($p < 0.001$). Both the PRISS and PWS signs were significantly associated with higher grade cross-over values.

Both the PRISS and PWS signs as well as the co-existence of COS, PRISS, and PWS are significantly associated with higher grade of acetabular retrover-

sion. In conjunction with the COS, the PRISS and PWS signs indicate severe acetabular retroversion. Presence and recognition of distinct radiological signs around the hip joint might raise the awareness of possible femoroacetabular impingement (FAI).

Keywords : acetabulum ; retroversion ; cross-over ; dysplasia ; acetabular version.

INTRODUCTION

It is widely assumed that in the normal hip the acetabular opening is anteverted in the axial plane. A retroverted acetabulum has been described as a

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posteriorly oriented acetabular opening (14,15,18). This has been identified as a specific variant of dysplasia of the hip (17). The prominent anterolateral edge of the retroverted acetabulum leads to a decreased clearance between the femoral head and neck junction and the anterior acetabular wall during flexion and internal rotation, predisposing to impingement (13,15) and leading, in time, to anterior labral and adjacent cartilaginous lesions (14). Therefore, acetabular retroversion and in particular cranial retroversion, has been proposed to contribute to the development of osteoarthritis of the hip (4,5,10,12,14,15,18). Apart from its role in femoroacetabular impingement (FAI), retroversion may contribute to several other anatomical abnormalities seen in developmental acetabular dysplasia (10,11).

In a recent study (20) the prevalence of acetabular retroversion was reported to be 48% (unilaterally and bilaterally in 18% and 40%, respectively), whereas 52% of the hips had no cross-over sign (COS). In the group with positive COS, the cross-over sign ratio averaged $26\% \pm 11\%$ (range, 3% to 93%). The presence of acetabular retroversion was more frequent in men.

Others (3) reported acetabular retroversion to be present in 6% in a normal population and 20% in a patient population with radiographic presence of arthritis of the hip.

To quantify acetabular version, computed tomography (CT) with horizontal acetabular cross sections (1,2,6,13,18,19) has been proposed and is commonly used. However, as with conventional radiographs, positional problems may affect reliability of CT measurements. In addition, CT is not often used to make the primary diagnosis, and it exposes patients to a higher and additional dose of radiation. Using conventional radiography, however, the presence of the cross-over sign (COS) and posterior wall (PWS) sign on an anteroposterior pelvic radiograph (15) are widely considered useful in diagnosing acetabular retroversion.

Jamali *et al* (7) first established a method to directly quantify anatomic acetabular version (AV) on anteroposterior (AP) pelvic radiographs. They could demonstrate that the presence of a positive COS was a highly reliable (sensitivity 96%, speci-

ficity 95%, positive and negative predictive values 90% and 98%, respectively) indicator of cranial AV of $< 4^\circ$. Both the radiographic anteversion measurements and the cross-over sign demonstrated substantial inter- and intraobserver reliability.

The posterior wall sign (PWS) as described by Reynolds *et al* (15) characterises the coverage of the femoral head by the posterior wall in relation to the center of the femoral head on anteroposterior pelvic radiographs. In a physiologically anteverted acetabulum, the visible outline of the edge of the posterior wall descends through the centre of the femoral head or lateral to it. If the posterior wall does not laterally extend up to the center of the femoral head the PWS is pathological and therefore categorised as 'positive' and as 'negative' if its lateral extension is beyond the center of the femoral head (fig 1).

Recently, Kalberer *et al* (8) introduced the prominence of the ischial spine sign (PRISS) to detect acetabular retroversion. On an anteroposterior pelvic radiograph the presence of a medial prominence of the ischial spine projected inside the pelvic brim is categorised positive and negative if the ischial spine projects outside of or onto the pelvic brim (fig 2). The positive PRISS sign showed an excellent sensitivity and positive predictive value and proved to be reliable and reproducible among observers. Furthermore, they found a significant correlation between PRISS and COS to demonstrate that these patients actually have a true retroversion of the distal hemipelvis and not only a "hypoplastic posterior wall" and/or a "prominence of the anterior wall". They did not however, take into account the role of the posterior wall sign, nor did they quantify the amount of cross-over.

It remains unknown, if the three signs (COS, PRISS, and PWS) are independent abnormalities identified on AP pelvic radiographs, or whether they are all part of an acetabular malformation and related to each other. If so, the assumption of Kalberer *et al* that acetabular retroversion may be due to malrotation of the whole distal hemipelvis as opposed to a malformation of the acetabular walls may be correct.

The purpose of the current study was to determine the association between the prominence of the ischial spine sign (PRISS) and the posterior wall

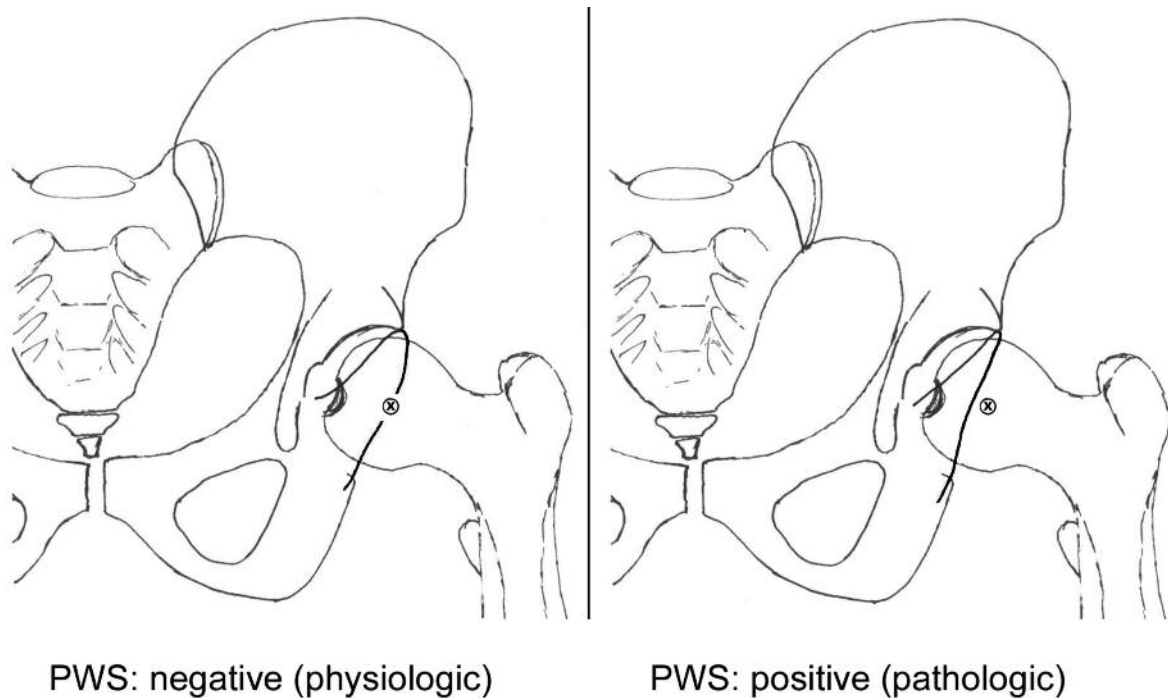


Fig. 1. — In a physiologically anteverted acetabulum, categorized as ‘negative’, the visible outline of the edge of the posterior wall descends through the centre of the femoral head or lateral to it. If the posterior wall does not laterally extend up to the center of the femoral head, the PWS is pathologic and therefore categorized as ‘positive’.

sign (PWS) with the amount of acetabular retroversion (cross-over sign ratio) in a population with positive cross-over sign (COS).

MATERIAL AND METHODS

The investigation was approved by the Institutional Review Board. Based on a patient population of an earlier study on prevalence of acetabular retroversion (20), all patients with positive acetabular cross-over sign (COS) were identified. In this preliminary review, the PRISS was not found in acetabula with no signs of retroversion (negative COS). Therefore, the PRISS sign (and also the PWS) was not further looked for in the population with negative COS sign, but we concentrated on acetabula with positive COS.

To be included in the study, their pelvic radiographs had to be correctly rotated in both the frontal and sagittal plane (16). The radiographic features measured in this study included three parameters : the cross-over sign, the posterior wall sign, the presence of a prominent ischial spine and the amount of acetabular retroversion as assessed with the cross-over sign (5,9,15,16). The cross-

over sign was expressed as an overlap ratio of the anterior rim and the entire length of the lateral acetabular opening (16) (cross-over sign ratio, fig 3).

Statistical analyses were performed with SPSS 13.0 software (SPSS Inc., Chicago, Illinois) using descriptive statistics, ANOVA (two-way, Amount of COS and PRISS / PWS), and Fisher’s exact test (COS and PRISS, COS and PWS, PRISS and PWS).

RESULTS

This study included 1417 hips presenting with an acetabular cross-over sign (cross-over sign ratio $\geq 1\%$). The PRISS could be categorized as either present or not in 1355 (95.6%), while on the remaining radiographs, the PRISS sign was equivocal. The posterior wall sign could be analysed in 1367 (96.5%) of the hips, while in the remaining patients the exact course of the posterior acetabular wall could not be visualized due to artifact. The hips with missing information regarding either the PRISS or PWS were still included in the statistical

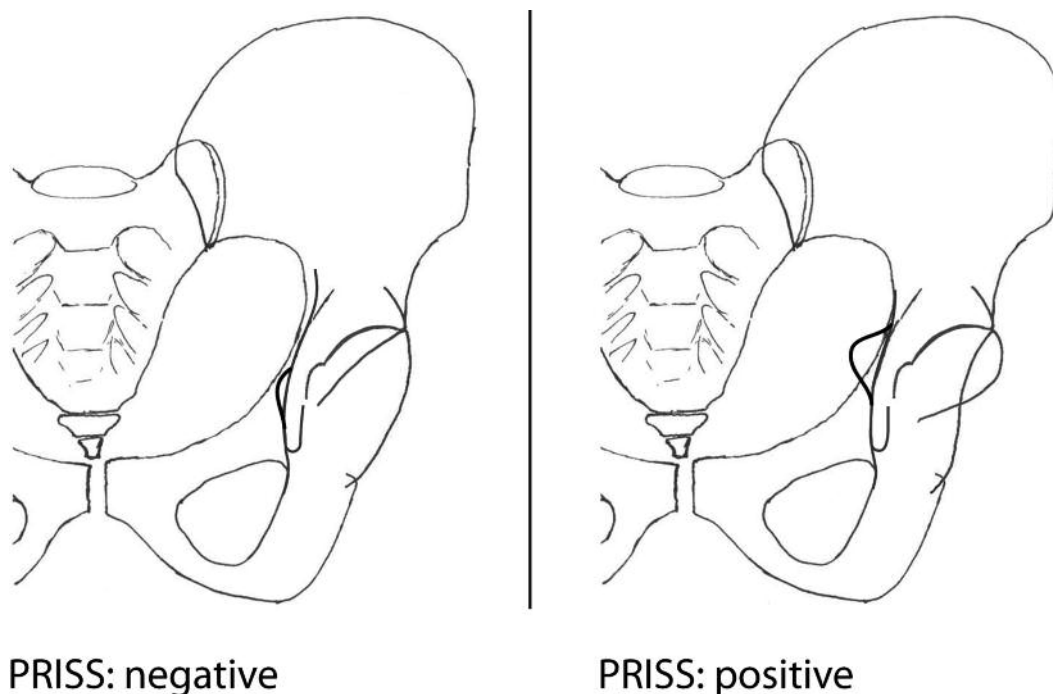


Fig. 2. — On an anteroposterior pelvic radiograph, the presence of a prominent ischial spine projecting into the pelvis is categorized positive. If the ischial spine projects outside of or onto the pelvic brim the PRISS sign is negative.

analysis (with 'missing' data). Only 1350 hips allowed comparison of all three signs (COS, PRISS, and PWS). These 1350 hips represent the 100% in the following specifications :

The PRISS was present in 61.7% (n = 833) of the hips with cross-over and was significantly correlated with the cross-over sign ratio ($p < 0.001$, Fisher's Exact Test). The PWS was positive in 31% (n = 419) of the hips and was also significantly related to the cross-over sign ratio ($p < 0.001$, Fisher's Exact Test). In the hips with PRISS present, 39.7% also had a positive posterior wall sign, which was significant ($p < 0.001$, Fisher's Exact Test). In the patients with positive PWS, 78.9% of the cases also had a PRISS ($p < 0.001$, Fisher's Exact Test) (table I, fig 4).

Both the PRISS and posterior wall signs were significantly associated with higher grade cross-over sign ratio (ANOVA). The presence of one of the signs was associated with a mean increase in the cross-over value of about 5%. The presence of both signs was even associated with an increase of about

12%. Mean and median values are listed in table I and fig 4.

DISCUSSION

Since abnormalities of acetabular version, and in particular retroversion of the acetabulum can be a predisposing factor for pain and degenerative changes of the hip (4,10,12,14,15,18), their recognition and early assessment is important in the patient's management. On conventional radiographs, the cross-over (COS), posterior wall (PWS) and prominence of the ischial spine (PRISS) signs have been previously described to play a role for diagnosis of an acetabular retroversion and are easy to apply even for inexperienced physicians. It should be recognised, however, that the PWS sign can exist independently of any malrotation of the acetabulum. This is the case in hip dysplasia in which the COS is not necessarily present. These three signs, however, have never been evaluated before in terms of their interdependence.

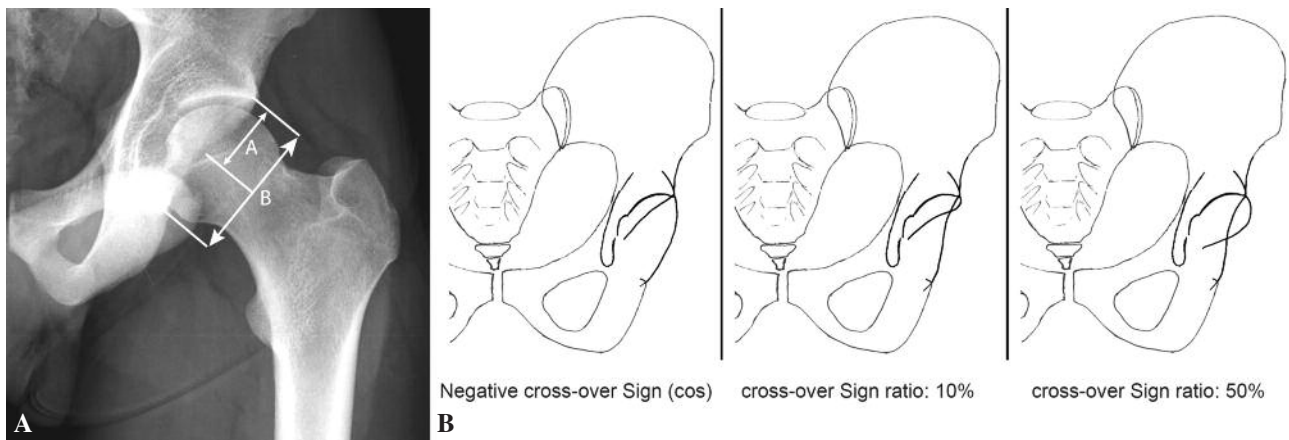


Fig. 3. — In patients with positive cross-over sign (COS), the COS was not simply categorized as being present or not, but rather expressed as a ratio (A/B) of the overlap distance (A) of anterior wall with regard to the length of the posterior wall (B).

Table I. — Mean ratio of overlap of the cross-over sign (COS) measured, with associated presence of posterior wall sign (PWS) and/or prominence of the ischial spine (PRISS)

Group	Example	Sign	n	%	Mean cross-over ratio [%]	SD cross-over ratio [%]
1		COS alone	428	31.7	20.5	9.6
2		COS & PWS	89	6.6	25.1	10.2
3		COS & PRISS	503	37.3	25.9	10.6
4		COS & PRISS & PWS	330	24.4	32.3	11.6

PRISS categorized in n = 1355
 PWS categorized in n = 1367
 PRISS & PWS categorized in n = 1350

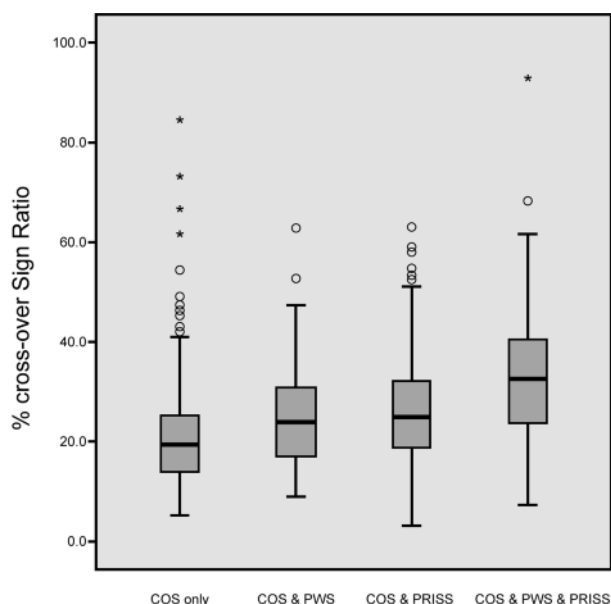


Fig. 4. — Boxplot delineating the values of cross-over overlap ratio. The values increase with presence of one sign, and even more so with presence of both signs.

In this investigation of a population of 1417 hips with varying degree of retroversion, a positive PWS was present in 419 (31%) and a positive PRISS in 833 (61.7%) of the cases. Four different groups (group 1 : positive COS alone ; group 2 : COS and PWS positive ; group 3 : COS and PRISS positive ; group 4 : COS, PWS and PRISS positive) according to the presence of a positive PRISS and PWS sign could be observed. For group 1 to 4 an increasing cross-over sign ratio has been seen (table I, fig 4). Therefore this study shows that, both the PRISS and PWS are significantly associated with higher grade of acetabular retroversion.

An isolated cross-over sign combined with negative PRISS and PWS signs (group 1) has been found to be associated with only low degree of cross-over sign ratio (average 20.5%). This constellation may represent a malformation of the anterior wall together with a normal posterior wall.

A simultaneous occurrence of COS and PWS (group 2 ; fig 5), but negative PRISS, most probably corresponds to a specific malformation of the acetabulum in terms of pathologic prominence of the anterior wall combined with a hypoplastic



Fig. 5. — Pelvic radiograph of patient presenting with positive cross-over sign (COS) and positive posterior wall sign (PWS). The posterior acetabular wall does not extend to the center of the femoral head (especially on the left side). Prominence of the ischial spine (PRISS) is not present.

posterior wall or normal anterior border and deficiency of the posterior aspect, respectively.

In a constellation with positive COS and PRISS (group 3 ; fig 6), but negative PWS sign, a slightly malrotated AP radiograph of the pelvis, in terms of external rotation of the focused hip, may be a possible explanation. But since radiographs lacking correct rotation of the pelvis were excluded, by means of the coccyx not pointing to the symphysis, malrotation is unlikely as a possible reason for group 3 findings. Another possible cause may be an isolated hypertrophy of the ischial spine without direct association with the acetabular retroversion.

As mentioned before the simultaneous presence of COS, PWS and PRISS signs (group 4 ; fig 7) represents the population with the highest degree of overlap ratio of the cross-over sign. Therefore group 4 is characterized by the most pronounced acetabular retroversion. Since both the anterior and posterior walls as well as the ischial spine are part of the distal hemipelvis, the appearance of all three signs may indicate that retroversion is not due to a



Fig. 6. — Pelvic radiograph of patient presenting with positive cross-over sign (COS) of both hips, although the percentual overlap is low. The posterior wall sign (PWS) was categorized as negative, since the posterior wall extends to the center of the femoral head. Prominence of the ischial spine (PRISS) is present of both sides.

deficiency or absence of the posterior wall and/or prominence of the anterior wall, but that it is more likely a developmental external rotation of the distal hemipelvis.

Our results suggest that the simultaneous presence of COS, PWS and PRISS signs (group 4) may represent a developmental malrotated distal hemipelvis with normal configuration of the acetabulum. In contrast, the concomitant occurrence of one or two signs (COS, PWS, PRISS ; group 1 to 3) of retroversion may correspond to a correctly rotated acetabulum with varying degree of developmental malformation of the anterior and/or posterior acetabular wall. Which particular conditions are responsible for the developmental malrotation of the distal hemipelvis and malformation of the acetabulum as well as to what extent congenital or lifetime situations are related, remains unknown.

This study has some limitations. Although radiographs of the pelvis were correctly rotated in both the frontal and sagittal plane (16) and acetabular retroversion was quantified by the cross-over overlap ratio, this method may not be an exact measure-



Fig. 7. — Pelvic radiograph of patient presenting with all three signs (COS, PWS, PRISS).

ment independent of pelvic rotation. Therefore further investigation, including CT scans for objective measurements of the acetabular retroversion should be undertaken to correlate them with radiological findings in terms of COS, PWS and PRISS sign as well as overlap ratio of the COS sign on conventional radiographs. Moreover, in future studies not only the presence of the PRISS and PWS sign should be assessed, but they may also have to be quantified. This would allow determining a cut-off value to differentiate a physiological distribution from a pathological finding. The same applies to the COS sign which has been found to be more common than previously expected (20) ; especially very cranial COS (small ratio) might not represent a pathological condition. Furthermore, the absence of clinical data and long-term follow-up does not allow classifying the radiological findings of the different groups (1-4) regarding “true pathological” or “normal anatomic variations”, neither is it possible to know which variations would give rise to symptoms. A further limitation is that the combination of negative COS and the presence of a PWS was not investigated.

In conclusion the PRISS and posterior wall signs alone as well as the simultaneous occurrence of

COS, PRISS, and PWS are significantly associated with higher grade of acetabular retroversion. The presence of all three signs indicates that retroversion is not due to a deficiency or absence of the posterior wall and/or prominence of the anterior wall, but that it is more likely an external rotation of the distal hemipelvis.

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