RESEARCH ARTICLE

Pelvic Incidence in Patients with Hip Osteoarthritis

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Abstract

Background: Hip osteoarthritis (OA) is a major cause of pain and disability that results in considerable social and medical costs. Mechanics such as posture, alignment and orientation of the hips and the spinal column and the relationship between these factors have been implicated in the development of both hip and spine pathologies. This study aims to test the hypothesis if pelvic incidence varies in patients with and without osteoarthritis. We assessed the relationship between spinopelvic alignment as measured by pelvic incidence (PI) and the presence of hip OA.

Methods: We collected supine pelvis CT scans of 1,012 consecutive patients not known to have hip OA. Our first group consisted of 95 patients with moderate to severe hip OA as per radiology reports. The second group included 87 patients with no evidence of hip OA. Power analysis revealed the need for 77 patients per group to find a mean difference in PI of 5º or less between both groups. Two trained physicians independently measured the PI to account for inter-observer reliability.

Results: Patients with moderate to severe hip OA had a mean PI of 56.5º±12.8º. The mean PI for patients without hip OA was 57.2º±7.5º. An independent samples t-test revealed no significant difference between the PI values of the two groups. Spearman's correlation coefficient of 0.754 demonstrated a high inter-observer reliability.

Conclusion: There was no difference in PI angle of hip OA patients and "healthy" patients. Our measurements of patients without OA were almost identical to the reported normal PI values in the literature. It appears that hip OA is not associated with PI angle, refuting the hypothesis made in previous studies, stating that elevated PI contributes to the future development of hip arthritis. CT scan seems to be a reliable and accurate way of assessing pelvic incidence.

Keyword: Hip osteoarthritis, Hip-Spine syndrome, Pelvic incidence

Introduction

Hip osteoarthritis (OA) is a substantial public health problem (1). It is a major cause of pain and disability that results in considerable social and medical costs (2). The development of hip OA is multifactorial, as genetic predisposition and several local mechanical risk factors contribute to its development (2). Identifying structural abnormalities in the asymptomatic pelvis that may predispose towards early hip OA is a major focus of orthopedic research, leading to concepts of femoroacetabular impingement due to coronal and axial plane pelvic abnormalities (3-5).

Sagittal spinopelvic alignment has been demonstrated to play a significant role in the outcome of spinal reconstruction. However, the potential role of spinopelvic alignment in the development of hip OA has not been fully explored (5). The purposes of this study were to (1) validate a method of measuring pelvic incidence on CT scan and (2) assess the relationship between spinopelvic alignment as measured by pelvic incidence (PI) and the presence of hip OA.

Materials and Methods

An approval from the Institutional Review Board (IRB)

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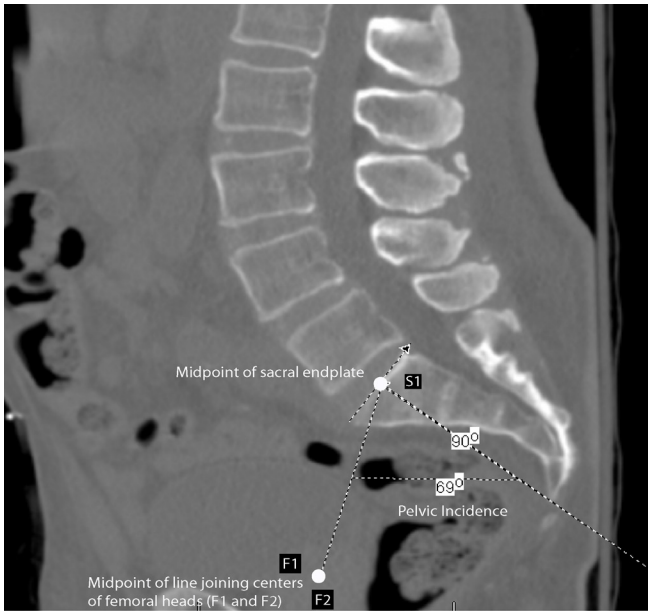

Figure 1. Measurement of pelvic incidence on a sagittal CT scan has been demonstrated.

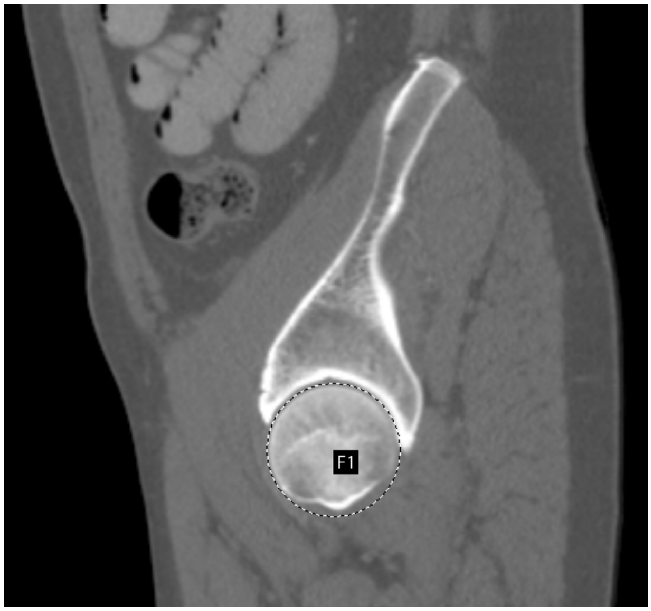

Figure 2. Femoral head center placement (F1) has been shown.

was received for this retrospective study. We obtained a list of 1,012 consecutive patients who had a supine Computer Tomography (CT) scan of their pelvis at our institution from 1998 to 2010. These patients were taken from the general hospital population and received CT scans for a variety of reasons such as evaluation of hip pain, motor vehicle accidents or traumatic episodes. None of the CT scans were taken for pre-operative assessment.

PI was measured by two individuals blinded to the status of the hip OA. A study by Vialle et al. calculated the PI of asymptomatic subjects to be 55 ± 10.6 degrees (6). A Shapiro-Wilk test showed that the raw angle values were not normally distributed but the log values were normal. A t-test done on the log values gave a confidence interval of -0.027 to 0.062. Expecting a mean difference of 5 degrees or less between both groups and assuming a power of 0.8 and a p-value of 0.05, sample size calculation revealed the need for 77 patients in each group. All measurements were made using computer assistance (Philips iSite Enterprise 3.5 software, September 2008).

The pelvic incidence was measured on a CT scan by a new method described below. Pelvic incidence is the angle subtended by a line connecting the femoral heads to a perpendicular bisector of the S1 endplates. Pelvic incidence was measured on CT scan with sagittal reconstructions using specific CT "slices." The sagittal reconstruction bisecting the center of the femoral heads was identified using scout lines on axial and coronal views. On this sagittal slice, a best fit circle was drawn over the femoral heads and the center of the circle was marked. On-screen electronic annotation labels were used to mark the location of the center of the left and right femoral heads in this manner. The midpoint of a line connecting the femoral heads was located using the measurement tool. On the sagittal cut passing through the midline of the sacrum, a perpendicular bisector of the S1 superior endplate was drawn. The PI was determined by measuring the angle between the perpendicular bisector of the S1 endplate and the midpoint of the line joining the centers of the femoral heads (F1 and F2) [Figure 1; 2].

Hip OA was determined by screening radiology reports. We found a total of 95 patients with documented moderate or severe hip OA. We also found 73 patients with documented absence of hip OA. Each image was reviewed to confirm the presence and degree of hip OA by observers blinded to the PI measurements. Radiographic parameters such as the degree of joint space narrowing, subchondral sclerosis, subchondral cysts and osteophytes were used to classify patients as having either absent, mild, or moderate to severe degenerative joint disease. To evaluate potential anatomic differences between patients with and without hip OA, we limited our study to only include two groups of patients: the "absent-hip OA" group included patients with no evidence of OA, and the "hip OA" group which included patients with moderate to severe OA. Moderate and severe were considered as a single group to mitigate between-observer differences due to subjective evaluation of radiographic features. Patients found (either by the observer or the radiologist reading the study) to have at least one prosthetic hip, femoral head avascular necrosis, mild hip OA or no mention of hip OA in the radiology report were excluded. Patient age and gender were retrospectively collected by electronic chart review.

PI was compared between individuals with and without hip OA. To account for inter-observer reliability, two trained physicians independently measured the PI angles in each of the 168 patients. A Welch two-sample t-test and a multivariate regression model were performed to compare both sets of data. All calculations were

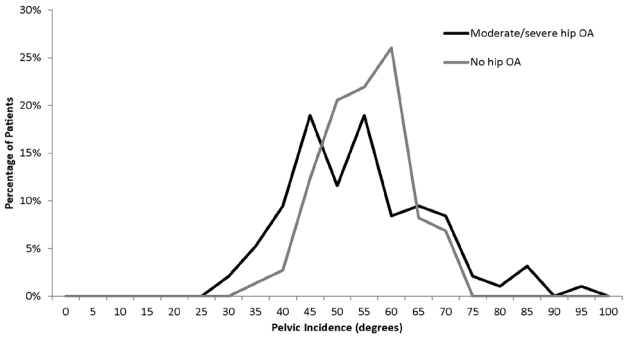

Figure 3. Distribution of pelvic incidence value in patients with and without hip osteoarthritis has been shown.

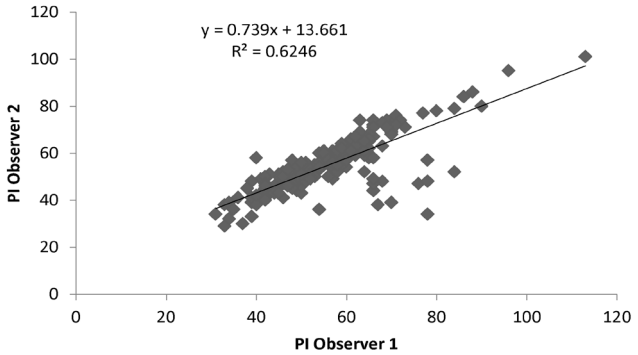

Figure 4. Correlation (Interobserver) reliability for pelvic incidence measurement between two observers has been shown.

performed using the R 2.14.2 software (R Foundation for Statistical Computing, Vienna, Austria).

Results

The hip OA group consisted of 50 males and 45 females, with an average age of 68 years (range: 43 to 93 years). The absent-hip OA group included 17 males and 56 females with an average age of 64 years (range: 44 to 87 years).

By averaging the PI of both observers, the group of patients with hip OA had a mean PI of 56.5 ± 12.8 degrees (range 33-96). The mean PI for the absent-hip OA was 57.2 ± 7.5 degrees (range 36-73). The values for PI in both groups were normally distributed [Figure 3]. The difference in the mean PI between two groups was 0.7 degrees (95% CI: -2.51 to 3.79). An independent samples t-test revealed no significant differences between the PI values of hip OA and absent-hip OA groups (P=0.688).

A multivariate regression model controlling for age, gender and presence/absence of OA only revealed the difference between males and females (54.1±8.9 and 58.6±11.5 respectively) to be significant (CI: 1.4-7.7, P=0.005). However a subgroup analysis by gender showed no difference between PI values of males without hip OA (56.2±8.2) and with moderate-severe hip OA (53.3±9.1) (CI: -2.0-7.7, P=0.242) and females without hip OA (57.5±7.3) and with moderate-severe hip OA (60.0±15.2) (CI: -7.4-2.5, P=0.321).

The PI values for both observers were also plotted against each other. A linear regression trend line showed a coefficient of determination R2=0.625, meaning that there was a good correlation of the values [Figure 4]. A paired t-test showed a mean of the differences between the two observers to be 1.1 degrees (CI: -0.2-2.4, P=0.087).

Discussion

Predicting early hip OA due to structural pelvic morphology has been a major impetus of research in musculoskeletal medicine, leading to exploration of femoral-acetabular impingement. Offierski and MacNab first described the concept of "hip-spine syndrome" in 1983 (7). It suggests that the hip-spine relationship may contribute to the development of both hip and spine disorders (7-9). We sought to determine whether patients there was a difference in PI in patients with or without hip OA to determine whether PI was another structural pelvic risk factor in the pathogenesis of early hip OA. These results indicate that there was no relationship between pelvic incidence and the presence or absence of hip osteoarthritis. Furthermore, we describe a new method of measuring pelvic incidence on CT scan that may be valuable for future studies.

Pelvic incidence (PI) was first proposed in 1998 by Legaye et al. to determine the correlation between sagittal pelvic orientation and the extent of lordosis (10). Pelvic incidence represents the sagittal antero-posterior spatial orientation of the center of the weight bearing axis of the spine and the centers of the femoral heads. Patients with high PI have a more anterior femoral head position relative to the S1 endplate in all positions. PI is the sum of the sacral slope and pelvic tilt and is a pelvic anatomic constant whose value varies between individuals but does not vary with positioning in an individual (10). Higher PI angles are associated with greater lumbar lordosis and lower PI is associated with less lumbar lordosis (11).

We described a method of measurement of PI based on CT scan. The PI of patients in our study without hip OA was around 56.5 degrees based on CT scan evaluation. Our findings were consistent with Vialle's results and support the use of CT scan to evaluate the radiographic parameters describing hip-spine anatomy. All PI angles of our patient population were measured on CT scans of the pelvis. However pelvic incidence has traditionally and repeatedly been measured on plain radiographs (5,6,10). There are several distinct advantages of CT over plan radiographs in the measurement of PI. Non-contrast computed tomography uses successive two-dimensional x-ray sections with adjustable thickness. CT is often considered more accurate because of its higher resolution when compared to x-ray, and unlike the latter, it eliminates the superimposition of unwanted images outside the area of interest. Furthermore, CT eliminates the potential magnification error due to radiographic technique. Inherently, one of the femoral heads is larger on lateral lumbar radiographs. This size difference is an artifact of radiographic technique and may result in shifting of the idealized center of rotation of the femoral

heads and error in PI calculation. Also, the multiple thin sections allows for better annotation of landmarks and calculation of angles. Additionally, some patients undergoing spinal fusion, such as paraplegics or patients with neuromuscular disorders, may not be able to stand for traditional radiographs used to calculate pelvic incidence.

We measured the pelvic incidence on CT scans of the pelvis in 95 patients diagnosed with moderate to severe hip OA (56.5 degrees) and 73 patients without signs of hip OA on imaging (57.2 degrees). We report no significant association between PI angle and hip OA. Even with attaining adequate power and reaching statistical significance the difference would be approximately 4 degrees, thus not clinically relevant and too small to be of radiological importance. In our study, PI measurements from both groups are comparable with an average difference of less than 1 degree. These equivalent average measurements suggest that hip OA is not associated with changes in PI, refuting the hypothesis that elevated PI contributes to the future development of hip OA. These results contrast a previous study by Yoshimoto et al. that retrospectively compared the spinopelvic alignments of 150 patients with hip OA and 150 patients exhibiting symptoms of low back pain. The authors reported a 6.6 degrees larger PI angle in patients with hip OA when compared to low back pain patients. The authors speculated that a higher PI angle in younger patients might predispose them to developing hip OA later (5). Our study differs from this methodology by the use of CT scan to measure PI in both groups. We believe that the high prevalence of low back pain in the general population is a confounder of the previous study since patients may develop back pain due to a variety of reasons. Therefore, we define only hip OA and absent-hip OA groups, based on objective radiographic criteria.

There are several important limitations to our study. One limitation is the retrospective nature of the analysis. Additionally, the mean age of the patients evaluated in the two groups was different. However, we do not consider this to be a significant bias since PI does not change with age. There are several unknown confounders, such as BMI, alcohol use, history of trauma, genetic predisposition, which may also predispose patients to the development of early hip OA. Female patients outnumbered males in both groups. This difference might be considered relevant since female pelvic structure varies from male pelvic anatomy. However, gender subgroup analysis still failed to show any significant association between PI and hip OA. Our measurements were done on CT and PI measurement has been described on the literature as taken on plain radiographs. Plain pelvic radiographs were not readily available to all patients and thus a correlation between PI values obtained on CT and plain radiographs was not possible. However, as we previously mentioned, our measurements of patients without OA were almost identical to the reported normal PI values by Vialle et al (6). Since PI is an intrinsic parameter of the pelvis that is supposedly constant in all positions, we would not expect that position would affect pelvic incidence. We did not validate the PI calculation compared to X-rays as it was not possible in this retrospective trauma database. We followed the same measurement technique using centers of the femoral head and the S1 endplate, so we would expect that the mean measurements would be similar. Finally, whenever a negative result is encountered, type II error must be considered. We performed an a priori sample size calculation power analysis and we estimated that 100 patients in each of the two groups would be sufficient to appropriate power our study. These equivalent average measurements suggest that hip OA is not associated with changes in PI, refuting the hypothesis that elevated PI contributes to the future development of hip OA.

Despite the aforementioned limitations, we believe that we have validated a novel, clinically useful methodology of measuring pelvic incidence based on CT scans. Furthermore, we have determined, based on these data, that pelvic incidence is not significantly different between patients with and without hip OA and therefore may not be a predictor of early hip OA. We believe that these conclusions may be of interest to orthopedic surgeons and other healthcare worker in the field of musculoskeletal medicine.

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References

1. Cooper C, Inskip H, Croft P, Campbell L, Smith G, McLaren M, et al. Individual risk factors for hip osteoarthritis: obesity, hip injury, and physical activity. Am J Epidemiol. 1998; 147(6):516-22.
2. Lanyon P, Muir K, Doherty S, Doherty M. Assessment of a genetic contribution to osteoarthritis of the hip: sibling study. BMJ. 2000; 321(7270):1179-83.
3. Matsuyama Y, Hasegawa Y, Yoshihara H, Tsuji T, Sakai Y, Nakamura H, et al. Hip-spine syndrome: total sagittal alignment of the spine and clinical symptoms

in patients with bilateral congenital hip dislocation. Spine. 2004; 29(21):2432-7.
4. Fogel GR, Esses SI. Hip spine syndrome: management of coexisting radiculopathy and arthritis of the lower extremity. Spine J. 2003; 3(3):238-41.
5. Yoshimoto H, Sato S, Masuda T, Kanno T, Shundo M, Hyakumachi T, et al. Spinopelvic alignment in patients with osteoarthrosis of the hip: a radiographic comparison to patients with low back pain. Spine. 2005; 30(14):1650-7.
6. Vialle R, Levassor N, Rillardon L, Templier A, Skalli W, Guigui P. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. J Bone Joint Surg Am. 2005; 87(2):260–7.
7. Offierski CM, MacNab I. Hip-spine syndrome. Spine. 1983; 8(3):316-21.
8. Parvizi J, Pour AE, Hillibrand A, Goldberg G, Sharkey PF, Rothman RH. Back pain and total hip arthroplasty: a prospective natural history study. Clin Orthop Relat Res. 2010; 468(5):1325-30.
9. Ben-Galim P, Ben-Galim T, Rand N, Haim A, Hipp J, Dekel S, et al . Hip-spine syndrome: the effect of total hip replacement surgery on low back pain in severe osteoarthritis of the hip. Spine. 2007; 32(19):2099-102.
10. Legaye J, Duval-Beaupere G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J. 1998; 7(2):99-103.
11. Lazennec JY, Brusson A, Rousseau MA. Hip-spine relations and sagittal balance clinical consequences. Eur Spine J. 2011; 20(Suppl 5):686–98.