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VALIDATION OF MEASURING PI USING CT AND A COMPARISON WITH WHOLE SPINE AND LUMBOSACRAL X-RAYS

VALIDAÇÃO DA MEDIÇÃO DAIP USANDO TC E COMPARAÇÃO COM RADIOGRAFIAS DA COLUNA TOTAL E LOMBOSSACRAL

VALIDACIÓN DE LA MEDICIÓN DE IP CON TC Y COMPARACIÓN CON RADIOGRAFÍAS DE LA COLUMNA VERTEBRAL TOTAL Y LUMBOSACRA

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ABSTRACT

Objective: The objective of this study is to describe a new, extremely simple method for measuring pelvic incidence (PI) using computed tomography (CT) and to compare those measurements with measurements derived from whole spine and lumbosacral X-rays in a Brazilian population. Methods: Patients who had whole spine and lumbosacral X-rays and whole abdomen, pelvis, or lumbar spine CT performed within a period of less than three months were selected. Image overlay was used to measure PI from the CT. The PI was calculated by two independent examiners, and the PI for each exam was calculated twice, with an interval of two months between the assessments. The intra- and interexaminer reliability and reproducibility were evaluatedusing the intraclass correlation coefficient (ICC) and the repeatability coefficient, considering a 95% confidence interval. Results: Fifty-five patients of both sexes with a mean age of 58.7 years (±19) were analyzed. The mean PI angles in the analyses of both examiners at both evaluations were 54.85° (±13.73) for the whole spine X-ray, 54.06° (±11.67) for the lumbosacral spine X-ray, and 49.96° (±9.85) for the CT. There was good intra- and interexaminer reliability and reproducibility. There was also high concordancewith the whole spine and lumbosacral X-rays. Conclusion: CT is a reliable and reproducible alternative for measuring PI. ***Level of Evidence III; Prospective comparative.***

Keywords: Tomography; Lordosis; Radiography; Spine; Pelvis.

RESUMO

Objetivo: O objetivo deste estudo é descrever um novo método extremamente simples para medir a incidência pélvica (IP) usando tomografia computadorizada (TC) e comparar essas medidas com as medidas derivadas de radiografias de coluna totale lombossacral em uma população brasileira.Métodos: Foram selecionados pacientes que realizaram radiografias de coluna totale lombossacral e tomografia computadorizada de abdome, pelve ou coluna lombar em intervalo inferior a três meses.A sobreposição de imagens foi usada para medir a IP na TC.AIP foi calculada por dois examinadores independentes e aIP de cada exame foi calculada duas vezes, com intervalo de dois meses entre as avaliações. A confiabilidade e a reprodutibilidade intra e interexaminadores foram avaliadas por meio do coeficiente de correlação intraclasse (ICC) e do coeficiente de repetibilidade, considerando um intervalo de confiança de 95%. Resultados: Foram analisados 55 pacientes de ambos os sexos com média de idade de 58,7 anos (±19). Os ângulos IP médios na análise de ambos os examinadores em ambas as avaliações foram de 54,85° (±13,73) na radiografia de coluna *total, 54,06° (±11,67) na radiografia de coluna lombossacral e 49,96° (±9,85) na TC. Houve boa confiabilidade e reprodutibilidade intra e interexaminadores. A concordância também foi alta nasradiografias da coluna total e lombossacral. Conclusões: A TC é uma alternativa confiável e reprodutível para mensuração da IP.* ***Nível de evidência III; Estudo prospectivo comparativo.***

Descritores: *Tomografia; Lordose; Radiografia; Coluna vertebral; Pelve.*

RESUMEN

Objetivo: El objetivo de este estudio es describir un método nuevo y extremadamente simple para medir la incidencia pélvica (IP) mediante tomografía computarizada (TC) y comparar esas medidas con las derivadas de radiografías de columna vertebral total y lumbosacra en una población brasileña. Métodos: Se seleccionaron pacientes a los que se les realizaron radiografías de columna vertebraltotal, lumbosacra y TC de abdomen, pelvis o columna lumbar con un intervalo inferior a tres meses. Se utilizó la superposición de imágenes para medir laIP en la TC. LaIPfue calculada por dos examinadores independientes, y en cada examen se calculó dos veces, con un intervalo de dos meses entre las evaluaciones. La confiabilidad y reproducibilidad intra e interexaminadores fueron evaluadas mediante el coeficiente de correlación intraclase (CCI) y el coeficiente de repetibilidad, considerando un intervalo de confianza del 95%. Resultados: Se analizaron 55 pacientes de ambos sexos con una edad media de 58,7 años (±19). Los ángulos medios deIP en el análisis de ambos examinadores

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en ambas evaluaciones fueron de 54,85° (±13,73) en la radiografía de la columna vertebral total, de 54,06° (±11,67) en la radiografía de columna lumbosacra y de 49,96° (±9,85) en la TC. Hubo buena confiabilidad y reproducibilidad intra e interexaminadores. La concordancia también fue alta enlas radiografías de columna vertebral total y lumbosacra. Conclusiones: La TC es una alternativa confiable y reproducible para medir laIP. ***Nivel de Evidencia III; Estudio prospectivo comparativo.***

Descriptores: *Tomografía; Lordosis; Radiografía; Columna Vertebral; Pelvis.*

INTRODUCTION

The pelvis plays a key role in spinal alignment.[1] Although known for several years,[2] this concept received great attention after the description of pelvic parameters by Legaye and Duval-Beaupere,[3] which allowed a better understanding of the shape and position of the pelvis.

Among pelvic parameters, the most important is pelvic incidence (PI), which is an angular measurement that takes the upper sacral endplate and the femoral heads into account.[3]It is considered a constant morphological parameter that is not influenced by a patient's position or orientation. It is therefore used in surgical planning, serving as the basis for calculating the ideal lumbar lordosis of each individual.[4]

Although considered an anatomical parameter that is not influenced by patient position, the projection of the pelvis a three-dimensional structure in two-dimensional radiographic examinations can be influenced by the position of the pelvis in relation to the X-ray tube during image acquisition.[5] This was demonstrated by Tyrakowski et al.,[5] who showed that pelvic rotation in the axial plane can lead to changes in PI values, and by Chen et al.,[6] who reported variations in these measurements when compared to whole spine and pelvis-centered X-rays.

There are reports of PI measurement methods using computed tomography (CT) in the literature, but these involve sophisticated software that is difficult to apply in clinical practice.[7] New technologies, such as EOS imaging, can minimize measurement variability; however, this technology is still not widespread, especially outside of North America and Europe.[8]

The objective of the present study is to describe a new, extremely simple method of measuring PI using CT and to compare those measurements with measurements obtained using whole spine and lumbosacral X-rays in a Brazilian population.

METHODS

Patients

After approval by the Institutional Review Board (CEP: 90674218.6.0000.0023), patients signed the informed consent formand those who had had whole spine and lumbosacral X-rays and whole abdominal, pelvic, or lumbar spine CT scans performed within a period of less than 3 monthsbetween January 2015 to December 2018 were selected. These CT scan modalities were chosen because they encompass both the lumbosacral junction and the femoral heads, allowing calculation of PI.

Measurement of PI using CT

All CT scans selected for this sample were performed using a six-slice CT scanner (SOMATOM Emotion 6, Siemens Medical System, Inc., NJ, USA) according to the following protocol: 1.25-mm thickness and 1.0-mm collimation, with an increment of 0.8 mm. The helical slices were acquired with 35-cm coverage in 40 seconds (FOV of 25 X 25 cm) and were subsequently subjected to multiplanar reconstruction (MPR) in the axial, sagittal, and coronal planes using a B-60 (moderate bone) filter. The voltage used was 130 kV and 150 mA. The examinations were performed with bone window settings (W1500, C450).

The measurement of PI depends on four specific anatomical points: the two femoral heads, the S1 endplate, and its slope (Figure 1). However, when three-dimensional volumetric reconstruction is performed,there is an overlap of the iliac wing relative to the sacrum, precluding performing the measurement. (Figure 2) To overcome this impediment, an alternative method to measure PI was developed using the image overlay technique, a common method for performing other musculoskeletal exams, such as measuring the tibial tubercle-trochlear groove (TT-TG) distance.[9,10]

Sagittal slices centered on the left femoral head, the S1 endplate, and the right femoral head were selected for multiplanar reconstruction. (Figure 3) By overlapping these images, a new image was created, similar to that obtained by a profile X-ray of the lumbosacral region, but without axial rotation of the femoral heads and without divergence of the X-rays. This phenomenon occurs in a whole spine X-ray because of the non-alignment of the X-ray tube with the pelvic region. The PI was calculated from the newly formed image in the usual way using SURGIMAP software (Nemaris Inc., New York, NY) (Figure 4). The evaluation of the PI from the X-rays was performed according to the traditional technique.[11]

Two examiners analyzed all exams independently and measured the PI angle. After a period of two months, the examiners performed the analyses and calculations a second time. The results of both examiners were compared to assess the inter- and intraexaminer reproducibility and the concordancebetween the methods.

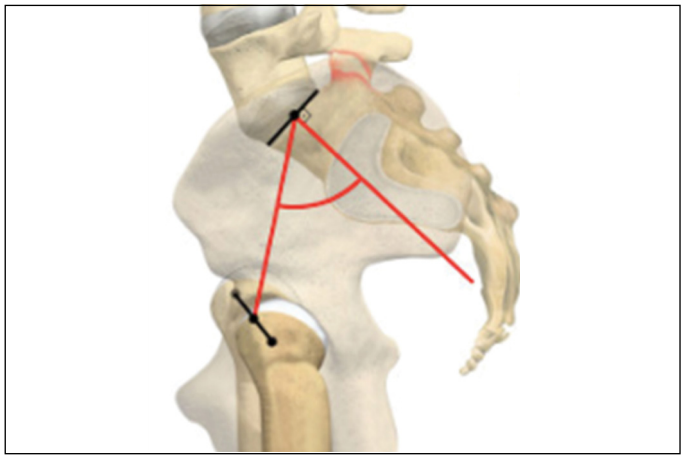

Figure 1. PI angle – measured between a line orthogonal to the S1 endplate and a line connecting the center of the femoral heads to the midpoint of the S1 endplate.

Figure 2. Volumetric reconstruction of CT images showing the overlap of the iliac wing, preventing visualization of the S1 endplate.

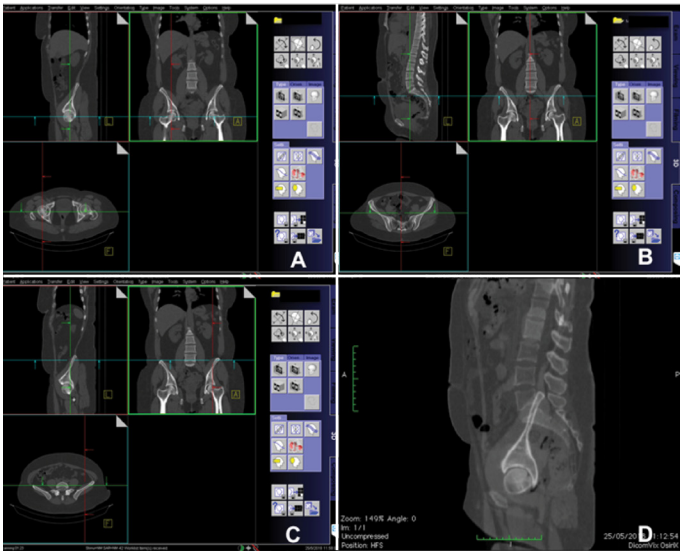

Figure 3. Selection of the images in the sagittal plane from the multiplanar reconstruction. A = sagittal image centered on the right femoral head; B = sagittal image centered on the S1 endplate, C = sagittal image centered on the left femoral head; D = overlap of the three images, creating a new image analogous to a profile X-ray of the lumbosacral region.

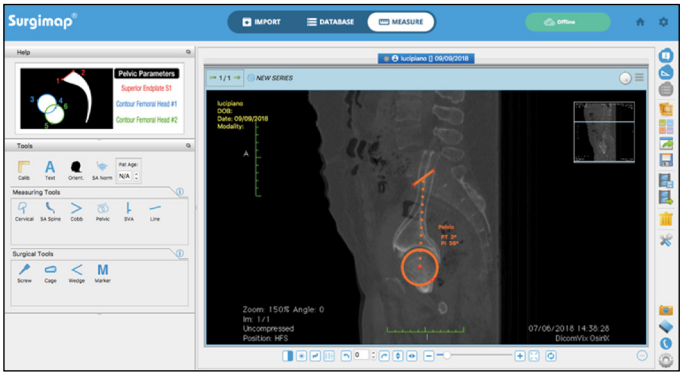

Figure 4. Measurement of the PI angle using software intended for this type of measurement from an image created by overlapping three images, analogous to a profile X-ray of the lumbosacral region.

Statistical analysis

Statistical analysis was performed using IBM-SPSS for Windows version 20.0. Microsoft Excel 2003® was used for data tabulation. The tests were performed with a significance level of 5%. The PI measurements obtained by each examiner at each evaluation and using each method weredescribed using means and standard deviations. The intraclass correlation coefficient (ICC), with a 95% confidence interval (CI), was calculated, as well as the differences between the evaluations using the repeatability measure. The measurements obtained in patients who hadundergonelumbosacral arthrodesis were compared against those of patients who had not.

RESULTS

A total of 55 patients were analyzed: 28 female (51%) and 27 male (49%) patients with a mean age of 58.7 years (±19). Of the 55 patients, 19 had undergone instrumentation surgery in the lumbosacral region, which could hinder performing the measurements. (Table 1) The mean PI angles in the analysis of both examiners at the two different time points were 54.85° (±13.73) for the whole spine X-ray, 54.06° (±11.67) for the lumbosacral X-ray and 49.96° (±9.85) for the CT. (Table 2)

The intraexaminer comparison did not show significant differences between measurements. In addition, good repeatability was observed for all three types of imaging exams, as the ICC values for both examiners for the three analyzed imaging exam types were close to 1. (Table 3)

There was also good interexaminer agreement. The differences between the two examiners were, however, slightly higher than the intraexaminer differences because the interexaminer reproducibilityvalues were generally higher than the intraexaminer values. (Table 4) Nevertheless, the reliability of the method was not compromised because the agreement for both examiners regarding the method was high. Thus, to calculate the PI of the same patient, X-rays or CT can be used, resulting in statistically similar measurements. (Table 5)

When the agreement between methods was compared in patients who hadandthose who had notundergone lumbosacral arthrodesis, there was also no significant difference. (Table 6)

Table 1. Demographic composition of patients whose imaging exams were analyzed.

Variable		Description: (N = 55)
Sex, n (%)	Female	28 (50.9)
	Male	27 (49.1)
Lumbosacral arthrodesis, n (%)	No	36 (65.5)
	Yes	19 (34.5)
Age (years)	Mean ± SD	58.7 ±19
	Median (min/max)	64 (4/85)

Table 2. Results of the examiners' analyses.

Method	Examiner 1		Examiner 2	
	1st evaluation (mean ± SD)	2nd evaluation (mean ± SD)	1st evaluation (mean ± SD)	2nd evaluation (mean ± SD)
Whole spine XR	53.7 ±9.2	53.6 ±9	52.4 ±8.9	51.1 ±9.1
Lumbosacral XR	53.8 ±9.4	53.9 ±9.1	52.7 ±9.5	51 ±9.9
Whole abdomen CT	51 ±8.7	51.3 ±8.4	51.8 ±8.8	49.4 ±9

Table 3. Intraexaminer reproducibility (ICC: intraclass correlation coefficient; CI: confidence interval).

		ICC	95% CI		Repeatability
			Lower	Upper	
Examiner 1	Whole spine XR	0.905	0.842	0.943	2.82
	Lumbosacral XR	0.898	0.830	0.939	2.98
	Whole abdomen CT	0.913	0.856	0.948	2.54
Examiner 2	Whole spine XR	0.883	0.801	0.931	2.99
	Lumbosacral XR	0.899	0.813	0.944	2.89
	Whole abdomen CT	0.871	0.687	0.938	2.79

Table 4. Interexaminer reproducibility (ICC: intraclass correlation coefficient; CI: confidence interval).

		ICC	95% CI		Repeatability
			Lower	Upper	
Evaluation 1	Whole spine XR	0.860	0.768	0.916	3.31
	Lumbosacral XR	0.922	0.865	0.955	2.54
	Whole abdomen CT	0.906	0.843	0.944	2.65
Evaluation 2	Whole spine XR	0.802	0.634	0.890	3.73
	Lumbosacral XR	0.815	0.618	0.903	3.68
	Whole abdomen CT	0.824	0.697	0.898	3.48

Table 5. Comparison between the imaging exam methods for both examiners (ICC: intraclass correlation coefficient; CI: confidence interval).

	ICC	95% CI		Repeatability
		Lower	Upper	
Examiner 1	0.845	0.745	0.907	3.29
Examiner 2	0.960	0.938	0.975	1.79

Table 6. Reproducibility/agreement coefficients for the methods and repeatability measure of pelvic incidence according to history of lumbosacral surgery (ICC: intraclass correlation coefficient; CI: confidence interval).

	ICC	95% CI		Repeatability
		Lower	Upper	
Examiner 1				
No lumbosacral surgery	0.870	0.782	0.927	3.09
With lumbosacral surgery	0.803	0.574	0.918	3.56
Total	0.845	0.745	0.907	3.29
Examiner 2				
No lumbosacral surgery	0.958	0.929	0.977	1.83
With lumbosacral surgery	0.964	0.926	0.985	1.75
Total	0.960	0.938	0.975	1.79

DISCUSSION

Measurement of PI is critical in the surgical planning for patients undergoing spinal surgery.[12,13] Considering that there is no movement in the sacroiliac joint, it can be used as a constant anatomical measurement.[3] However, it is not uncommon in clinical practice to observe variations in PI angles in pre- and postoperative X-rays, or even during follow-up, and this is even more common in cases of vertebral deformities. This observation served as the inspiration for us to find a more accurate way of performing this measurement.

The explanation found for this variability is thatduring two-dimensional radiographic examinations the projection of the pelvis – a three-dimensional structure –is influenced by the patient's position relative to the X-ray tube.[5,6] This was demonstrated in a study by Tyrakowski et al.,[5] which was based on X-rays of an anatomical model to evaluate the influence of pelvic rotation in the axial plane on PI values. That study found that pelvic rotation up to 35° causes changes in PI values of up to 6°. Although 35° is a high rotation value, it can occur in patients with deformities.

The 6° value may be a significant difference, especially for PI, because it serves as a basis for calculating other parameters, including lumbar lordosis. The abovementioned study used X-rays centered on the pelvis, not taking the divergence of the X-rays in the sagittal plane into account, and was based on only one model with a PI value of 45°. These issues can generate a greater margin of error in patients with a greater or lesser PI.

The divergence of X-rays in the sagittal plane was studied by Chen et al.[6] These authors compared pelvic parameter values in whole spine and pelvis-centered X-rays and demonstrated better inter- and intraobserver reliability in the measurements of PI in the pelvis-centered X-rays. In that study, the angular difference between the two methods was small; however, the exams were performed at the same time, with the patient in the same position, which usually does not occur in clinical practice.

Centering the X-ray tube on the pelvis allows overlapping of the femoral heads in the sagittal plane, in addition to improving image clarity given the adequate X-ray intensity for this region. Whole spine X-ray is currently the exam of choice for calculating PI. However, how rotation in the axial plane and divergence of X-rays in the sagittal plane together can affect these results has not yet been evaluated.

CT has the advantage of minimizing the variability resulting from both rotation in the axial plane and divergence of X-rays in the sagittal plane. Even in cases where there are deformities or positioning errors during the exam, it is possible to control the selection of images in all planes, ensuring the absolute profile of the region and the overlap of the femoral heads.

Some studies have used CT to measure PI. One of the first was by Vrtovec et al.,[7] but this study was based on a rather complex method using computerized image processing methods with little clinical applicability. Using that method, the PI value found was 47°, a value close to that found using our image overlapping method (49.96°).

Jentzschet al.[14] used CT to measure PI but did not compare those values to the results obtained with the traditional measurement technique using whole spine or lumbosacral-centered X-rays. In addition, the authors describe a more complex measurement method that must be performed manually in multiple planes, not allowing the use of specialized software. By overlapping the images, it is possible to correct any rotation that may occur in CT acquisition and to use automated measurement methods, such as with conventional X-rays.

When comparing the PI values obtained with CT and X-rays in our case series, values approximately 5° smaller were obtained for the tomographic measurements, showing that radiography mayoverestimate this parameter. The results found for the measurements using CT were close to those of a study that evaluated normal values for the Brazilian population using whole spine X-rays and found a mean value of 49.4° (±8.2).[15]

One of the major disadvantages of CT is the high radiation load inherent in the method; however, this exam is part of the basic diagnostic arsenal for planning lumbar spine surgery, especially in patients with vertebral deformities. In addition, CT allows a more reliable calculation of PI, with greater clarity of the structures, which may be even more important in osteoporotic patients or those with severe arthritis.

CONCLUSION

CT can be used to calculate PI, using the image overlay technique, in a highly reproducible manner.

All authors declare no potential conflict of interest related to this article.

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