Clinical Radiology xxx (2017) e1–e7

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Influence of patient rotational malpositioning on pelvic parameters assessed on lateral radiographs

A. Assi [a,b,*], Z. Bakouny [a], C. Sauret [b], E. Saghbini [a,c], N. Khalil [a], L. Chelala [a], E. Naoum [a,c], F. Yared [a], W. Skalli [b], I. Ghanem [a,c]

[a] Laboratory of Biomechanics and Medical Imaging, Faculty of Medicine, University of Saint-Joseph, Beirut, Lebanon
[b] Institut de Biomécanique Humaine Georges Charpak, Arts et Métiers ParisTech, Paris, France
[c] Hôtel-Dieu de France Hospital, University of Saint-Joseph, Beirut, Lebanon

ARTICLE INFORMATION

Article history:
Received 5 September 2016
Received in revised form
17 March 2017
Accepted 22 March 2017

AIM: To estimate the effect of patients' axial rotation (AR) during pelvic radiograph acquisition, on the reliability and validity of sagittal pelvic parameters.

MATERIALS AND METHODS: Lateral digitally reconstructed radiographs (LDRRs) were obtained from the pelvic computed tomography (CT) scans of eight children and nine adults. Then, the AR of the pelvis was simulated and the corresponding LDRRs were reconstructed at 5°, 10°, 15°, and 20° of the AR. Pelvic parameters were measured digitally on each radiograph. Intra- and interobserver variability were evaluated at each AR position (three operators repeated the measurements three times each). The bias on each clinical parameter, in each AR position, was calculated relatively to the 0° position.

RESULTS: Interobserver variability increased similarly in children and adults with AR. It reached 4.4° for pelvic incidence and 4.7° for the sacral slope at 20° of AR. Biases on radiological parameters increased with AR and exceeded the acceptable threshold of errors when AR reached 10°. A linear regression was established (R^2=0.834, p<0.0001) in order to estimate the AR of a patient on a lateral pelvic radiograph based on the measurement of the bifemoral distance normalized to the sagittal pelvic thickness.

CONCLUSIONS: AR of patients during radiograph acquisition can be estimated in clinical practice, which would allow physicians to discard any radiographs where the calculated AR exceeded 10°.

Introduction

The sagittal curvatures of the spine vary greatly among asymptomatic subjects,[1] and it has been widely demonstrated that sagittal spine curvatures are highly correlated to pelvis morphological and positional parameters.[2–4] Pelvic incidence was proposed as an anatomical parameter[5] that quantifies the relative inclination of the sacrum within the iliac bones and correlates with the sagittal curvatures of the spine.[6] A classification of the normal

* Guarantor and correspondent: A. Assi, Laboratory of Biomechanics and Medical Imaging, Faculty of Medicine, University of Saint-Joseph, PTS, Campus of Innovation and Sport, Damascus Street, PoBox 17-5208, Mar Mikhael, Beirut, Lebanon. Tel.: +961 1 421 676, +961 3 564 557 (mobile); fax: +961 1 421 681.
E-mail addresses: ayman.assi@gmail.com, ayman.assi@usj.edu.lb (A. Assi).

http://dx.doi.org/10.1016/j.crad.2017.03.021
0009-9260/

morphotypes of the sagittal pelvis and spine, mainly based on the sacral slope,[3] ensued in order to guide sagittal correction of spinal curvatures.[7] Thus, for preoperative planning, the desired postoperative sagittal curvatures should be based on the morphology of the pelvis, quantified by pelvic incidence and sagittal pelvic thickness,[8] as well as on other important positional parameters of the pelvis, namely sacral slope, pelvic tilt,[6] and pelvic inclination.[9] These parameters are of paramount importance in the radiographic evaluation of a large range of spinal pathologies such as spondylolisthesis, adolescent idiopathic scoliosis, adult spinal deformity, but also degenerative conditions.[10,11]

Although these parameters are easily accessible on standard full-spine sagittal radiographs, their measurements can be biased by a number of factors including the two-dimensional (2D) nature of the radiograph, as it projects three-dimensional structures onto a bi-dimensional plane, and the potential malpositioning of patients during radiograph acquisition. Therefore, it is crucial to quantify the errors associated with this technique, especially those related to patient malpositioning during radiograph acquisition. Although tilting the pelvis in the sagittal plane would affect the positional parameters, it would not affect the anatomical parameters; however, axial rotation of the pelvis in the horizontal plane could influence the lateral projection of the pelvis, and thus, all of the measured parameters. Moreover, it would be useful for physicians to have a tool to easily estimate the axial rotation of patients during radiograph acquisition solely from the available lateral pelvic radiograph.

The primary aim of the present study was to evaluate the effect of axial malpositioning of the patient during lateral pelvic radiograph acquisition on both the validity and reliability of commonly measured pelvic parameters. The secondary aim of this study was to provide a simple equation to estimate patient axial rotation in order to decide on the eligibility of lateral radiographs.

Materials and methods

Sample

Helical pelvic computed tomography (CT) scans of nine adults and eight children (0.6 mm slice thickness, 512×512 resolution, 0.768 mm pixel spacing) were extracted from the database of the radiology department of University of Saint-Joseph, Beirut, Lebanon. All patients had undergone CT in order to investigate visceral pain. Adult patients (four male, five female) had an average age 55.6 (standard deviation [SD] 24.5) years, ranging from 22–80 years. Paediatric patients (five male, three female) had an average age 12 (SD 2.2) years, ranging from 9–15 years. All patients who undergo tests at the university hospital systematically sign authorization for the use of their anonymous data for research purposes. The design of the present study had been approved by the institutional review board of the institution.

Lateral digitally reconstructed radiographs (DRRs) were simulated from each CT dataset in a DICOM (digital imaging and communications in medicine) format, with squared pixels (pixel spacing = 0.141mm), using specific software developed at Arts et Métiers ParisTech (Paris, France). This technique had been previously used[12–14] and allows the simulation of the axial rotation of X-ray beams in any direction: (1) the generation of a lateral DRR is based on linear scanning by the X-ray beams from the top to the bottom of the CT volume with cylindrical projections: a collimator is simulated to avoid vertical divergence of the X-rays and to allow only horizontal propagation. The horizontal enlargement was corrected by applying a scaling factor on the image, in order to measure exact lengths on the radiographs. (2) Pelvic rotation was mimicked by rotating the CT volume around the vertical axis. Thus, five DRRs were generated from each CT examination, while introducing an axial rotation from 0° to 20° with 5° increments (Fig 1).

Radiological parameters

Radiological parameters were measured digitally on each radiograph using the SterEOS 2D toolbox (version 1.5.1; EOS-Imaging, Paris, France). The following parameters were measured (Fig 2): sagittal pelvic thickness (mm), pelvic incidence (degrees), pelvic tilt (degrees), sacral slope (degrees),[8] pelvic inclination (degrees),[9] and the bi-femoral distance (mm), which was defined as the length of the horizontal line drawn between the centres of the two femoral heads.

Data processing

Three orthopaedic residents were recruited from the university hospital and were repeatedly trained on the methods of measurement. The six parameters were measured on each DRR, in each pelvic axial rotation position (0°, 5°, 10°, 15°, 20°) three times by each of the three independent trained operators. Repeated measurements were separated by 2-week intervals. Nine values were thus obtained for each parameter, at each axial rotation position. The values measured at 0° of axial rotation were considered as the reference. The reproducibility (SR) SD, which includes both intra- and interobserver variability, was calculated for each parameter, at each axial rotation position, according to the guidelines of the ISO 5725-2 standard.[15] The variability was assessed in both children and adults. Moreover, the intraclass correlation coefficient (ICC), (2,k) model, was calculated in order to evaluate the intra- and interobserver agreement for each parameter: ICC>0.80 indicates very high reliability, 0.60–0.79 moderately high reliability, 0.40–0.59 moderate reliability, and <0.40 low reliability.[16]

Furthermore, in order to evaluate the bias at each axial rotation increment, the mean value of the nine measurements (three operators, three measurements each) of each parameter was compared to the mean value measured at 0° position. The threshold value for the acceptable bias was set as the uncertainty of measurement at 0°, defined as the

Please cite this article in press as: Assi A, et al., Influence of patient rotational malpositioning on pelvic parameters assessed on lateral radiographs, Clinical Radiology (2017), http://dx.doi.org/10.1016/j.crad.2017.03.021